A BENTHIC INVERTEBRATE MONITORING
STUDY ON THE ATHABASCA RIVER,
WHITECOURT, ALBERTA
1990

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BEAK ASSOCIATES CONSULTING LTD.
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Maire E. Luoma
Bob M. Shelast

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EXECUTIVE SUMMARY

Alberta Newsprint Company (ANC) was issued a permit by Alberta Environment, under the Clean Water Act, to operate a chemi-thermomechanical pulp (CTMP) newsprint mill near Whitecourt, Alberta. The permit requires that a benthic invertebrate monitoring program be included as part of the environmental program for the mill. A baseline benthic invertebrate monitoring program was conducted in the spring and fall of 1989 to establish pre-operational conditions in the Athabasca River (Beak 1990). The 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. The objectives of the 1990 study were to establish spring pre-operational and fall post-operational (start-up) conditions in the Athabasca River, by determining if there were any differences in benthic invertebrate community structure between sampling sites, by evaluating the general water quality conditions of the Athabasca River as reflected by the benthic invertebrate community structure, and by determining if there were any differences in pre-operational and post-operational conditions in the Athabasca River.

Benthic invertebrate sampling was conducted during the spring between 14 and 17 May, and during the fall between 11 and 15 October 1990, at seven sites, which were established in 1989. Sites 1 and 2 were located upstream of the ANC effluent outfall to provide information on the background benthic community structure of the river. 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 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 riffle/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, depth and substrate composition were documented at each sampling location. A qualitative assessment 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. of Edmonton and Econotech Services Limited of Vancouver, for several parameters associated with the treated effluent discharge.

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

The basic computations of total number of taxa, total number of organisms, standing crop (number/m^2) and Shannon-Weaver species diversity were calculated for each benthic sample. A mean standing crop (number/m^2) was also calculated for each major taxonomic group for each site. Statistical analyses were conducted using Analysis of Variance (ANOVA) to determine whether significant differences existed in the numbers of taxa and numbers of organisms between sites during each sampling period. A benthic community analysis was conducted 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 surveys, to further assess the effects of pulp mill effluent on the benthic invertebrates.

The physical data indicated that there were some variations in substrate composition, water velocity and depth between sites and/or seasons. Substrates at all sites consisted mainly of cobbles and pebbles, with lesser amounts of gravels and sand. In May, pebbles were the dominant substrate at all sites, except Site 7 where cobbles were dominant, while in October, cobbles were the dominant substrate at all sites, except Sites 1 and 5 where pebbles were dominant. Generally, more algae were present on the substrates in October than May. There were some variations in mean water velocity and mean water depth between sites and seasons. Seasonal differences in physical characteristics were the result of changes in the flow regime and water levels between seasons. Water velocity and depth 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. The Millar Western effluent and/or the McLeod River may have been responsible for slight increases in BOD, true color and total suspended solids concentrations at Site 6 in May. In October, there were slight increases in BOD concentrations at sites downstream of the ANC mill, the McLeod River, the Millar Western mill and the Whitecourt sewage treatment plant. However, dissolved oxygen concentrations were not affected by these BOD inputs. Treated effluent discharges did not have any effect on true color or total suspended solids concentrations in the Athabasca River in October. Total phosphorus concentrations were higher at Sites 3 and 4, than at background sites in October, likely as a result of the ANC effluent.

Detailed water quality analyses at Sites 2 and 3 indicated that most parameters were below detection limits and/or did not exceed provincial objectives or federal guidelines. Total phenols were higher at Site 3 than background Site 2 in October, possibly as a result of the ANC effluent, however the value did not exceed provincial objectives. Resin acids were detected at both Site 2 in May and Site 3 in October (no values available for Site 2 in October), but the total resin acid values were below the provincial objective in both cases. In October, the total resin acid value in the ANC effluent was below the detection limit of 10 $\mu g/L$.

A total of 110 taxa of benthic invertebrates has been identified from the 1989 and 1990 samples collected from the Athabasca River. Of these, 60 taxa were identified from the May 1990 samples and 53 taxa from the October samples.

There were significant differences in the mean numbers of taxa and the mean numbers of organisms between sites during both seasons. In May, the mean number of taxa at Site 4 was significantly different and the mean numbers of organisms at Sites 3 and 4 were significantly different from both background sites. In October, the mean numbers of taxa at all downstream sites were similar to at least one of the background sites, whereas the mean numbers of organisms at all downstream sites, except Site 3, were significantly different from both background sites. The higher mean standing crops at downstream sites during May were the result of natural organic enrichment and during October was likely the result of the ANC, Millar Western and Whitecourt sewage treatment effluents. The species diversity indicated that most sites were supporting a complex and diverse benthic community. In October, the lower species diversities at downstream sites indicated that there was a dominance of one or more taxa, while other fauna were low in numbers.

Ephemeroptera (mayflies) and Chironomidae (midges) were the dominant taxonomic groups at all sites during May and October. Oligochaeta (aquatic worms) was also dominant in May, while Plecoptera (stoneflies) was dominant in October. Tolerant taxa, mainly Chironomidae, as well as intolerant taxa (Ephemeroptera and Plecoptera), increased in numbers at downstream sites, as a response to natural organic enrichment in May and to organic enrichment from the pulp mills and sewage treatment plant in October.

The RA analysis of the May benthic data indicated that there were three sample clusters. Cluster I consisted of samples from Site 5, Cluster II of samples from Sites 1, 2, 3, 4 and 6 and one sample from Site 7 (7-5), and Cluster III of the other four samples from Site 7. 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. Most of the dominant taxa characteristic of each cluster of sites identified by RA, have been found to respond to organic enrichment. In May, the benthic community structure of all sites on the Athabasca River indicated the presence of some mild organic enrichment. Since pre-operational conditions existed in the river for ANC in May, this represented natural background organic enrichment at Sites 1 to 5. However, the Millar Western and/or the Whitecourt sewage treatment effluents were likely having an enrichment effect on the benthic community structure at Site 7.

The RA analysis of the October benthic data indicated that there were three sample clusters. Cluster I consisted of samples from Site 1, Cluster II of samples from Site 2, and Cluster III of samples from Sites 3, 4, 5, 6 and 7. A higher degree of faunal homogeneity existed between samples within a cluster in October than in May. In October, the dominant benthic community structure of the background sites indicated the presence of some mild natural organic enrichment, similar to May. The ANC effluent appeared to contribute some additional organic enrichment at downstream sites. The Millar Western and/or Whitecourt sewage treatment effluents also appeared to contribute additional organic enrichment at Sites 6 and 7, since no recovery of the benthic community structure, back to background conditions, was apparent at these downstream sites.

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. The third and fourth dominant groups were the carnivores and omnivores in May, and the herbivores and carnivores in October. All other feeding groups formed less than 1% of the total benthic fauna during both surveys. The trophic analysis indicated that similar trends were apparent in the benthic data, as was found by the RA analysis. In general, sites within a cluster had similar percent compositions of the dominant feeding groups. In May, increases in the numbers of certain organisms and shifts in the feeding group structure occurred at Site 7, probably due to the change in the nature of the food supply caused by the Millar Western and Whitecourt sewage treatment effluents. In October, the sites downstream of the ANC effluent, as well as the Millar Western and the Whitecourt sewage treatment effluents, exhibited shifts in the feeding group structure due to organic enrichment.

The mean number of taxa, mean standing crop and mean species diversity at most sites in the spring of 1990 were lower than during the spring of 1989. Natural factors appeared to be responsible for these decreases. In the fall of 1990, the mean numbers of taxa at all sites were similar to the pre-operational values. The mean standing crop was higher and the mean species diversity was lower at all downstream sites in the fall of 1990, compared to the pre-operational values. A low species diversity is typically the result of organic enrichment, where a few tolerant taxa, which are more suited to organic enrichment increase in numbers, thus causing an uneven distribution. Therefore, this decrease in species diversity was likely the result of organic enrichment from the ANC and Millar Western pulp mills and the Whitecourt sewage treatment plant. In general, the benthic community strucutre of all downstream sites during the fall of 1990 was similar to the pre-operational surveys, except that some taxa increased in numbers as a response to the organic loading from the pulp mill and sewage effluents, causing a change in the order of the dominant taxa.

The benthic invertebrates of the Athabasca River at downstream sites responded to mild organic enrichment from the pulp mill and sewage effluents by an increase in the populations of certain tolerant, as well as intolerant taxa. The benthic community structure also shifted from a balanced association at background sites to one of increasing proportions of tolerant taxa at downstream sites. This is a typical response to mild organic enrichment.

1.0 INTRODUCTION

Alberta Newsprint Company (ANC) was issued a permit by Alberta Environment, under the Clean Water Act, to operate a chemi-thermomechanical pulp (CTMP) newsprint mill near Whitecourt, Alberta. The permit requires that a benthic invertebrate monitoring program be included as part of the environmental program for the mill. A baseline benthic invertebrate monitoring program was conducted during the spring and fall of 1989 to establish pre-operational conditions in the Athabasca River (Beak 1990). The 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. Beak Associates Consulting Ltd. (Beak) was retained by ANC in 1990 to continue this monitoring program.

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 objectives of the 1990 benthic invertebrate monitoring program were to establish spring pre-operational and fall post-operational (start-up) conditions in the Athabasca River, specifically:

- to determine if there were any differences in benthic invertebrate community structure between sampling 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 in pre-operational and post-operational conditions in the Athabasca River.

2.0 METHODOLOGY

2.1 SITE LOCATIONS

Seven sites were established in 1989 on the Athabasca River for benthic invertebrate sampling (Figure 1). The site locations were based on an effluent mixing study conducted in August 1988, which indicated that in the vertical plane, initial dilutions of 100 to 1 could be achieved in the first 20 to 30 m downstream of the effluent diffuser (Beak 1988). Under a high flow regime, lateral mixing should be complete just upstream of the McLeod River confluence, approximately 8 km downstream of the effluent diffuser. However, under low flow conditions complete mixing could require 33 to 45 km. Sites 1 and 2 were located upstream of the effluent outfall to provide information on the background benthic community structure of the river. 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. 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 14 and 17 May, and during the fall between 11 and 15 October 1990. 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, Crowther 1979).

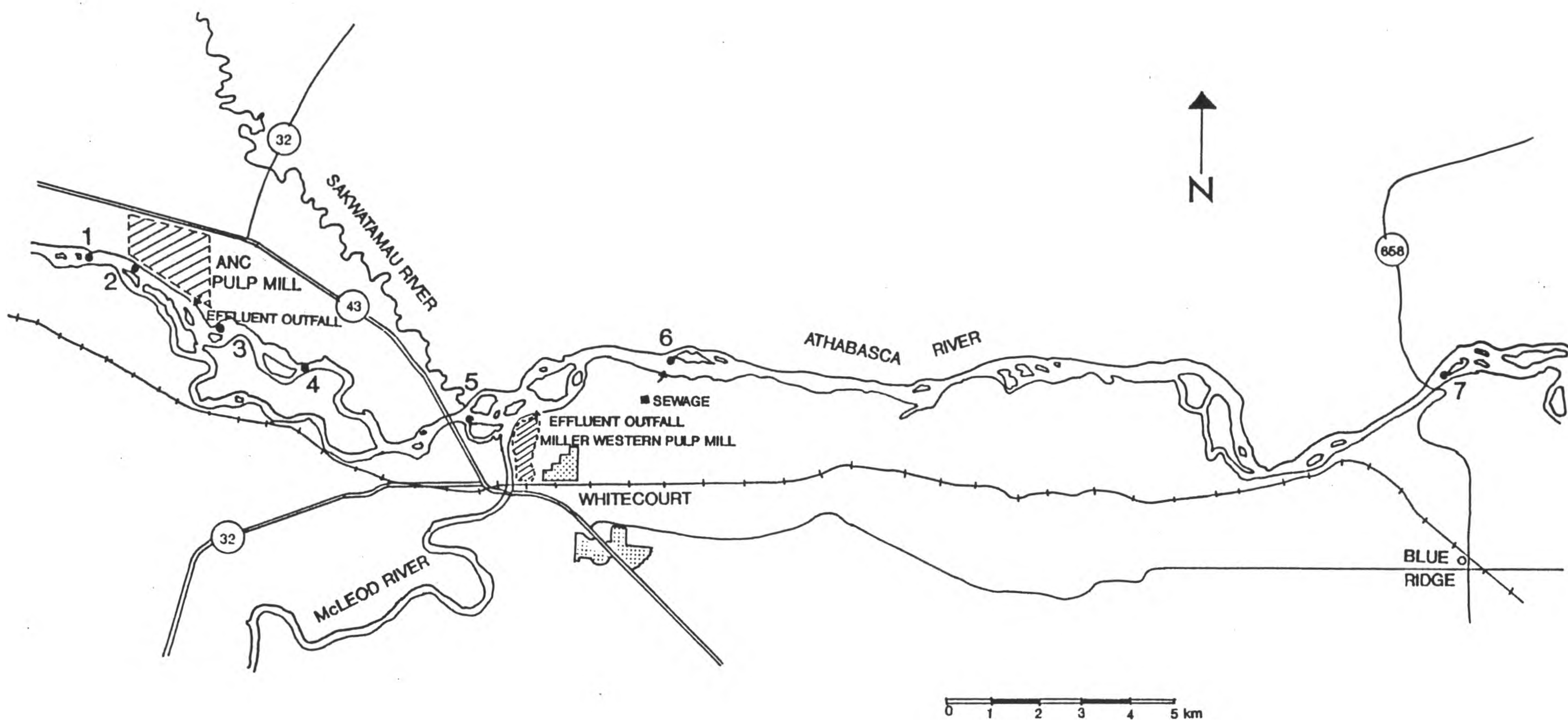

Figure 1. Benthic invertebrate sampling sites on the Athabasca River.

2.3 PHYSICAL AND CHEMICAL SAMPLING

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

A qualitative visual estimate of the amount of algal growth, based on the thickness on the substrate and areal extent, was made at each site. The algal growth was classified into three categories: light (<1 mm thickness), light to moderate (1 to 5 mm) and moderate to heavy (5 to 10 mm).

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, preserved by standard methods, and analyzed by Alpha Laboratory Services Ltd. of Edmonton for true color, total phosphorus, total Kjeldahl nitrogen, total suspended solids, and biochemical oxygen demand using standard methods (APHA-AWWA-WPCF 1985) and approved Alberta Environment methods (Alberta Environment 1987). A more detailed water chemistry analysis was conducted in both May and October for Site 2 (just upstream of the effluent outfall) and in October for Site 3 (just downstream of the effluent outfall). Parameters analyzed for at these sites included total phenols, total organic carbon, total metals and resin acids. These parameters were analyzed using standard methods by Alpha

Laboratories Services Ltd., except for resin acids which were analyzed by Econotech Services Limited of Vancouver.

2.4 BENTHIC SAMPLE ANALYSIS

In the laboratory, each benthic sample was sorted either by a whole sort method or the subsampling method of Wrona et al. (1982). Subsampling was used when 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 sub-samples were removed from the agitated solution and organisms were sorted and counted using a dissecting microscope. The size of the subsamples varied (50 or 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.

All organisms were identified to the lowest practical taxonomic level (genus where possible). These organisms were then stored in vials with 70% isopropyl alcohol. Samples of chironomid larvae (midges) were cleared, mounted on microscope slides 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:	Merritt and Cummins (1984), Pennak (1978), 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)
Others:	Brooks and Kelton (1967)

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 (May and October).

All new taxa identified from the 1990 samples were added to the 1989 species list (Beak 1990). The basic computations of total number of taxa, total number of organisms, standing crop (number/m^2) and Shannon-Weaver species diversity were calculated for each benthic sample and means were calculated for each site. Confidence limits for all means were calculated at the 95% level. 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. A mean standing crop (number/m^2) of each major taxonomic group was also calculated for each site.

The initial basic computations were conducted on an IBM-PC compatible personal computer. The percent contribution of each taxon of the total numbers per sample was also calculated and these data set up in the Fortran format for input into RA (described below). All data were then transferred to the University of Calgary Honeywell Multics system for all other computer analyses. All input data were archived on a floppy disk.

Statistical analyses were conducted using one-way analysis of variance (ANOVA) to determine whether numbers of taxa and numbers of organisms were significantly different between sites during May and October. A posteriori testing, using the Student-Newman-Keuls (SNK) procedure was then conducted for each ANOVA to determine which site means differed significantly (Sokal and Rohlf 1969).

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). A robust statistical test preserves the validity of the probability statements applied to it, even though the assumptions upon which it is based are violated. Therefore, ANOVA will generally be valid, even on extremely non-normal populations, especially when there is equal and large sample sizes (Glass et al. 1972, Harris, 1975, Green 1979).

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. RA will make use of the natural variability of benthic data, rather than try to impose uniformity on them. 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). The technique of RA ranks species on a scale of 0 to 100 (ordination units) to approximate their positions along a species gradient. These initial rankings are the species scores. 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. These species scores are then re-scaled between 0 and 100. 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 in conjunction with RA 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 surveys, to further assess the effects of pulp mill effluent on the benthic invertebrates of the Athabasca River. The mean number of taxa, mean standing crop, mean species diversity and the dominant taxa present at each site were compared to determine general trends between years.

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

3.0 RESULTS AND DISCUSSION

The benthic monitoring data collected in May represented pre-operational conditions in the Athabasca River. Downstream discharges in May from other operations included the Millar Western treated effluent (released between Sites 5 and 6) and the Whitecourt sewage treatment effluent (released between Sites 6 and 7). The ANC mill became operational in August 1990 and therefore, the October data represented start-up conditions at all downstream sites (Sites 3 to 7).

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. The mean daily discharge recorded for the Athabasca River near Windfall (Station No. 07AE001) during the sampling program indicated that flows in the spring were higher than in the fall, ranging from 175 to 180 m^3/s in May and 139 to 155 m^3/s in October (Water Survey of Canada unpublished data). Recent historical (1980 - 1988) mean daily discharge for the same time period ranged from 223 to 270 m^3/s in May and 179 to 201 m^3/s in October (Environment Canada 1981 - 1989). During the 1989 benthic monitoring program, flows in the river ranged from 367 to 429 m^3/s in June and 234 to 258 m^3/s in October (Beak 1990). The differences in mean daily discharge between the 1989 and 1990 surveys were primarily due to differences in the sampling schedule, particularly during the spring. In 1989, samples were collected in late June when peak flows in the river generally occur, due to mountain runoff. In 1990, the survey was conducted in mid-May when increased flows are typically the result of local snowmelt and are usually less pronounced than during mountain runoff events. In October, flows were variable between years and the differences were the result of climatic conditions in the watershed.

The physical characteristics of substrate composition, water velocity and water depth were kept as similar as field conditions allowed, between sample locations within a site, as well as between sites (Appendix A). Substrates at all sites consisted mainly of cobbles and pebbles, with few gravels and sand (Table 2). In May, pebbles were the dominant substrate at all sites, except Site 7 and comprised between 54.5 and 80.4% of the substrate composition. Cobbles ranged between 19.6 and 45.5% of the substrate composition. At Site 7, the cobbles comprised 63.0% and the pebbles of 29.1% of the substrate composition in May. In October, cobbles were the dominant substrate at all sites, except

Table 2. Mean percent of substrate size distribution (by weight) with 95% confidence limits for sites, May and October 1990.

Site	Cobble (64-256 mm)		Pebble (16-64 mm)		Large Gravel (4-16 mm)		Small Gravel (2-4 mm)		Coarse Sand (0.5-2 mm)	
	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct
1	19.6 ± 6.3	40.4 ± 4.2	80.4 ± 6.3	59.3 ± 4.2	0.1 ± 0.1	-	-	-	-	-
2	41.0 ± 10.2	62.5 ± 10.9	59.0 ± 10.2	37.5 ± 10.9	-	-	-	-	-	-
3	41.8 ± 17.5	55.9 ± 16.8	58.2 ± 17.5	44.1 ± 16.8	-	-	-	-	-	-
4	43.7 ± 11.0	51.2 ± 7.0	56.1 ± 10.8	48.5 ± 6.9	0.2 ± 0.2	0.4 ± 0.3	-	-	-	-
5	27.2 ± 4.3	43.1 ± 10.9	72.8 ± 4.3	56.8 ± 11.0	-	0.2 ± 0.3	-	-	-	-
6	45.5 ± 20.7	67.1 ± 4.3	54.5 ± 20.7	31.0 ± 5.0	-	1.8 ± 1.8	-	0.1 ± 0.1	-	0.1 ± 0.1
7	63.0 ± 8.1	66.4 ± 5.4	29.1 ± 9.3	31.2 ± 5.3	3.4 ± 1.3	2.3 ± 1.4	4.4 ± 3.7	0.1 ± 0.1	0.1 ± 0.1	-

Sites 1 and 5 where pebbles were dominant. Cobbles comprised between 51.2 and 67.1% of the substrate at sites where they were dominant, while pebbles accounted for 31.0 to 48.5% of the substrate composition. At Sites 1 and 5, pebbles consisted of 59.6 and 56.8% and cobbles of 40.4 and 43.1% of the substrate composition, respectively. Small amounts of gravel were found at all sites, except Sites 2 and 3.

The seasonal difference in substrate was due to differences in sampling locations within a site during each season. In spring, when water levels were higher, samples were taken nearshore where the predominant substrate was pebbles. In the fall, when water levels had receded, samples were taken closer to mid-channel. This area of the river is subject to greater velocities during peak flows than nearshore areas. The resulting scour would tend to reduce the amount of smaller substrate found in mid-channel areas.

A qualitative assessment of the amount of algae found growing on the substrates indicated that generally more algae were present in October than May. In May, a light growth of algae was observed on the substrates at Sites 1 to 5 and a moderate to heavy growth of algae at Sites 6 and 7. In October, a light growth of algae was observed on the substrates at Sites 1 and 2 and a moderate to heavy growth at Sites 3 to 7.

There was variation in mean water velocity between sites and seasons (Table 3). In May, mean water velocity at the substrate surface between sites ranged from 28 to 73 cm/s, while in October, mean water velocity was less ranging from 31 to 52 cm/s. There were only slight variations in mean water depth between sites and seasons (Table 3). In May, mean water depth between sites ranged from 33 to 38 cm, while in October, mean water depth was less ranging from 28 to 32 cm. Seasonal differences in both water velocity and depth were the result of changes in the flow regime and water levels between spring and fall. Water velocity and depth 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 invertebrate community structure between sites within a season. Habitat differences were, however, considered in the interpretation of the benthic invertebrate results.

Table 3. **Mean water velocity and depth with 95% confidence limits for sites, May and October 1990.**

Site	Water Velocity (cm/s)		Water Depth Site (cm)	
	May	October	May	October
1	38 ± 7	48 ± 5	36 ± 2	32 ± 2
2	37 ± 5	31 ± 2	35 ± 2	32 ± 2
3	73 ± 8	52 ± 4	33 ± 2	31 ± 1
4	49 ± 10	51 ± 3	33 ± 2	30 ± 2
5	54 ± 5	39 ± 6	38 ± 1	31 ± 1
6	46 ± 4	40 ± 4	33 ± 2	29 ± 1
7	28 ± 4	31 ± 5	34 ± 3	28 ± 2

3.2 WATER QUALITY

The results of the field and laboratory water quality analyses for the May and October 1990 surveys for all sites are presented in Table 4. 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. It should be noted that treated effluent from the ANC mill was released to the Athabasca River beginning in August. Mean daily discharge to the river for August, September and October were 10,035, 12,010 and 11,610 m^3/d, respectively. ANC final treated effluent quality data for August to October are shown in Table 5. This data represents treated effluent quality during start-up and reflects the effluent quality when operation of the effluent treatment system was being fine-tuned. Therefore, the October water quality analyses are representative of start-up conditions only. A summary of Millar Western effluent quality data is presented in Appendix B.

The pH values recorded during the surveys ranged from 8.5 to 9.1 in May and 8.5 to 8.7 in October. The difference in pH values between seasons was probably a reflection of differences in primary productivity. During periods of increased primary productivity and photosynthetic activity, pH values in natural waters tend to increase (Cole 1975, Wetzel 1975). Maximum primary productivity generally occurs in early spring. However, with the advent of the spring freshet, scour and decreased light penetration due to increased suspended sediment concentrations, reduce the algal population, hence primary productivity. Water samples were collected during the May survey prior to the onset of the spring freshet. The pH values recorded at both background and downstream sites during the May and October survey exceeded the Alberta Surface Water Quality Objective (ASWQO) of 6.5 to 8.5 at all but two sites (Site 3 in October and Site 7 in May) but were within the Canadian Water Quality Guideline (CWQG) of 6.5 to 9.0 at all sites, except at Site 5 in May (Alberta Environment 1977, CCREM 1987). From August to October, the average monthly pH of the ANC treated effluent ranged between 7.0 and 7.5. However, ANC effluent discharge did not affect pH values at downstream sites.

Conductivity values were similar at each site during both seasons and ranged from 275 to 305 μmhos/cm and 290 to 300 μmhos/cm during May and October, respectively. Conductivity values recorded in October were not affected by discharge of treated effluent from ANC.

Table 4. Water quality results of samples collected from the Athabasca River, May and October 1990.

	SITE															
	1		2		3		4		5		6		7			
Parameter	15 May	13 Oct	15 May	13 Oct	15 May	13 Oct	16 May	13 Oct	16 May[a]	14 Oct	16 May	14 Oct	14 May	15 Oct	ASWQO	CWQG
pH (units)*	8.6	8.6	8.8	8.6	9.0	8.5	9.0	8.6	9.1	8.7	9.0	8.6	8.5	8.6	6.5 - 8.5	6.5 - 9.0
Conductivity (μmhos/cm)*	290	290	290	290	290	290	295	290	305	290	275	300	280	300	-	-
Dissolved Oxygen(ppm)*	10.7	12.4	10.6	12.5	10.5	12.5	10.3	12.4	10.4	12.9	10.2	13.1	10.1	12.8	5.0	5.0 - 9.5
DO (percent saturation)*	98	101	97	102	96	102	93	101	97	105	94	103	93	101	-	-
Temperature (^{o}C)*	9.0	4.0	9.0	4.0	9.0	4.5	8.0	4.0	10.0	4.0	9.0	3.0	9.0	3.0	Increase of 3^{o}C	-
True Color (units)	10.0	7.0	5.0	7.0	10.0	7.0	12.5	5.0	10.0	2.0	20.0	2.0	10.0	2.0	Increase of 30 units	-
Total Phosphorus (mg/L as P)	0.08	0.02	0.04	0.02	0.03	0.08	0.02	0.06	0.04	0.02	0.03	0.02	0.04	0.03	0.05	-
Total Kjeldahl Nitrogen (mg/L as N)	0.4	0.2	0.4	0.2	< 0.1	0.3	< 0.1	0.2	< 0.1	0.2	< 0.1	0.2	< 0.1	0.2	1.0	-
Total Suspended Solids (mg/L)	6	10	6	8	6	3	8	7	5	4	10	4	8	5	Increase of 10 mg/L	Increase of 10 mg/L
Biochemical Oxygen Demand (mg/L)	< 1	1	< 1	1	< 1	1	< 1	1	< 1	2	1	2	< 1	2	-	-

* Measured in the field.

a. Millar Western Pulp Ltd. was not discharging effluent to the Athabasca River on this date.

ASWQO Alberta Surface Water Quality Objectives (Alberta Environment 1977)

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

Table 5. **Average monthly concentrations of selected parameters for ANC final treated effluent, August to October 1990.**

Parameter*	Month August	September	October
Discharge (m^3/d)	10,035	12,010	11,610
pH (units)	7.4	7.0	7.5
Dissolved Oxygen (mg/L)	7.4	7.7	7.6
DO (percent saturation)	97	105	99
Biochemical Oxygen Demand (mg/L)	8.5	13.0	9.0
Temperataure (^{o}C)	27.5	29.0	26.5
True Color (units)	127	224	225
Total Suspended Solids (mg/L)	17	30	38
Total Phosphorus (as P) (mg/L)	22.05	16.59	18.85
Total Kjeldahl Nitrogen (mg/L)	2.48	3.65	3.11
Total Phenols (mg/L)	0.049	0.030	0.048
Total Resin and Fatty Acids (μg/L)	< 1	80	< 10

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.

Dissolved oxygen concentrations during May ranged from 10.1 to 10.7 ppm, which represents 93 to 98% saturation. A general trend was evident, where dissolved oxygen concentrations and saturation levels in May decreased progressively from upstream sites to downstream sites. Since treated effluent was not discharged from ANC to the river during the spring, ANC did not contribute to this dissolved oxygen sag. There are no effluent discharges or inputs from major tributaries to the river between the four upstream sites, therefore the decrease in dissolved oxygen concentrations and saturation levels would be considered natural. Below Site 4, discharges from the McLeod River, the Millar Western mill and the Whitecourt sewage treatment plant may have affected dissolved oxygen levels. However, saturation levels remained high and dissolved oxygen concentrations were above the ASWQO and CWQG. In October, dissolved oxygen concentrations ranged from 12.4 to 13.1 ppm, which represents 101 to 105% saturation. Both dissolved oxygen concentrations and saturation levels at sites downstream of ANC were similar to or exceeded the values recorded at the background sites. ANC treated effluent quality data indicated that from August to October, monthly average dissolved oxygen concentrations ranged from 7.0 to 7.6 mg/L, which represents 96 to 99% saturation.

Biochemical oxygen demand (BOD), a measure of the amount of oxygen required to oxidize organic matter in water, ranged from <1 to 1 mg/L in May and 1 to 2 mg/L in October. In May, BOD loading from the Millar Western mill and the McLeod River may have been responsible for the slight increase in the BOD concentration at Site 6. In October, there were also slight increases in BOD concentrations at sites downstream of the ANC mill, the McLeod River, the Millar Western mill and the Whitecourt sewage treatment plant. From August to October, the average monthly BOD concentration in the ANC treated effluent ranged from 8.5 to 13 mg/L. However, dissolved oxygen concentrations, as discussed previously, were not affected by these BOD inputs.

True color values recorded during the May survey ranged from 5 to 20 units with the maximum value recorded at Site 6, which was situated 4 km below the Millar Western effluent outfall. In October, true color ranged from 2 to 7 units, with the maximum values recorded at background Sites 1 and 2 and at Site 3, just below the ANC effluent outfall. From August to October, the monthly average color value recorded for the ANC treated effluent ranged from 127 to 225 units.

Total suspended solids concentrations were similar during both seasons ranging from 5 to 10 mg/L in May and 3 to 10 mg/L in October. In May, the maximum value was recorded at Site 6 and was probably the result of inputs from both the McLeod River and the Millar Western mill. In October, the maximum total suspended solids concentrations were recorded at background Sites 1 and 2. Treated effluent discharge from ANC and Millar Western or inputs from the McLeod River did not have any effect on total suspended solids concentrations. From August to October, the monthly average total suspended solids concentrations in the ANC treated effluent ranged from 17 to 38 mg/L.

Total phosphorus (as P) concentrations ranged from 0.02 to 0.08 mg/L in both May and October and did not vary seasonally, but did vary spatially. In May, the maximum total phosphorus concentration of 0.08 mg/L was recorded at background Site 1 which exceeded the ASWQO of 0.05 mg/L total phosphorus. Total phosphorus concentrations decreased steadily downstream until Site 5, when values increased and fluctuated slightly. In October, maximum total phosphorus concentrations were recorded at Sites 3 and 4 located below the ANC effluent outfall, with concentrations of 0.08 and 0.06 mg/L, respectively, which exceed the ASWQO of 0.05 mg/L. The average total phosphorus concentration in the ANC treated effluent during October was 18.85 mg/L. As noted in Section 3.1, the amount of algae at sites downstream of the outfall had increased probably due to phosphorus inputs from the ANC effluent discharge, as well as inputs from the Millar Western mill and the Whitecourt sewage treatment plant. Phosphorus is generally regarded as the nutrient that limits productivity in freshwater ecosystems (Wetzel 1975). Total phosphorus concentrations were at background levels by the lowermost downstream sites. Since the October survey, mass loading of total phosphorus in the ANC treated effluent has been reduced by 50 to 75% (B. Steinback pers. comm.).

Total Kjeldahl nitrogen (TKN) concentrations in May were below the detection limit of 0.1 mg/L at all sites, except background Sites 1 and 2, where a value of 0.4 mg/L was recorded. In October, a concentration of 0.2 mg/L was recorded at all sites, except at Site 3, where a concentration of 0.3 mg/L was recorded. The average monthly concentration of TKN in the ANC treated effluent from August to October ranged from 2.48 to 3.65 mg/L. However, it did not appear that effluent discharge had any significant affect on TKN concentrations in the Athabasca River. All TKN values recorded during both surveys were below the ASWQO of 1.0 mg/L.

The detailed water quality results for Site 2 in May and October and for Site 3 in October are presented in Table 6. Total phenol concentrations in May were <0.001 mg/L, while in October, concentrations at Sites 2 and 3 were 0.002 and 0.005 mg/L, respectively. The

Table 6. **Water quality results for selected parameters of samples collected at Sites 2 and 3 on the Athabasca River, May and October 1990. All values in mg/L unless otherwise stated.**

Parameter	Site 2 May	Site 2 October	Site 3 October	ASWQO	CWQG
Total Phenols	<0.001	0.002	0.005	0.005	0.001
Total Organic Carbon	2.0	2.2	2.2	-	-
Total Cadmium	<0.001	< 0.001	<0.001	0.01	0.0018*
Total Copper	0.001	0.003	<0.001	0.02	0.006 *
Total Nickel	0.014	0.011	0.003	-	0.15 *
Total Lead	<0.001	< 0.001	<0.001	0.005	0.007 *
Total Arsenic	<0.001	< 0.001	<0.001	0.01	0.05
Total Mercury	< 0.0001	< 0.0005	< 0.0005	0.0001	0.0001
Total Manganese	<0.05	< 0.05	<0.05	0.05	-
Total Cobalt	0.001	0.002	<0.001	-	-
Total Chromium	<0.001	0.008	0.002	0.05	0.002
Total Iron	0.21	0.08	0.13	0.30	0.30
Total Selenium	<0.001	< 0.001	<0.001	0.01	0.001
Total Silver	<0.001	< 0.001	<0.001	0.05	0.0001
Total Vanadium	0.010	< 0.001	<0.001	-	-
Total Molybdenum	0.004	< 0.001	0.002	-	-
Total Resin Acids (μg/L)	5	-**	13	100	-
Pimaric Acid	<5	-	7	-	-
Sandaracopimaric Acid	<5	-	<2	-	-
Isopimaric Acid	<5	-	2	-	-
Levopimaric Acid	<5	-	<2	-	-
Dehydroabietic Acid	5	-	4	-	-
Abietic Acid	<5	-	<2	-	-
Neoabietic Acid	<5	-	<2		-
Chlorodehydroabietic Acid	<5	-	-	-	-
Dichlorodehydroabietic Acid	<5	-	-	-	-

* At hardness > 180 mg/L ($CaCO_3$)
** Water sample broken in transit to the analytical laboratory.
ASWQO Alberta Surface Water Quality Objectives (Alberta Environment 1977)
CWQG Canadian Water Quality Guidelines for Freshwater Aquatic Life (CCREM 1987)

increase in total phenol concentrations at Site 3, compared to background levels was possibly due to effluent discharge from ANC. From August to October, phenol concentrations in treated effluent ranged from 0.030 to 0.049 mg/L. Phenolic compounds can also occur naturally in the aquatic environment as decomposition products of aquatic plants and decaying vegetation (CCREM 1987). The total phenol values recorded during October at both sites were similar to or below the ASWQO of 0.005 mg/L, but exceeded the CWQG of 0.001 mg/L.

Total organic carbon concentrations did not vary between sites and seasons. Total organic carbon values of 2.0 mg/L were recorded at Site 2 in May and 2.2 mg/L at Sites 2 and 3 in October.

Metal concentrations during both surveys were low, and in many cases, below detection limits. Total chromium was the only metal that exceeded the CWQG. The total chromium concentration recorded at Site 2 in October was 0.008 mg/L, which was higher than the CWQG of 0.002 mg/L, but not the ASWQO of 0.05 mg/L. Metals are not generally considered to be a major component of pulp mill effluent. The concentrations recorded during this study were probably the result of natural processes.

Resin acids were detected at both Site 2 in May and Site 3 in October. Resin acid data for Site 2 in October is not available since the water sample was broken in transit to the analytical laboratory. In May, a concentration of 5 μg/L total resin acids was recorded at Site 2 with dehydroabietic acid identified as the only component of the total value. In October, a concentration of 13 μg/L total resin acids was recorded at Site 3. Pimaric acid, isopimaric acid and dehydroabietic acid were identified as the component resin acids. The concentration of resin and fatty acids in the ANC treated effluent in October was below detection limits (<10 μg/L). All resin acid values were below the ASWQO of 100 μg/L.

3.3 BENTHIC INVERTEBRATES

3.3.1 Basic Computations

A total of 110 taxa of benthic invertebrates has been identified (most to the generic level) from the 1989 and 1990 samples collected from the Athabasca River (Table 7). Of these, 60 taxa were identified from the May 1990 samples and 53 taxa from the October samples. A total of 15 new taxa was identified from the 1990 samples.

Table 7. **Benthic invertebrate species list with codes and functional feeding groups for the spring (S) and fall (F). Abbreviations for functional feeding groups as in Table 1.**

Species Code	Taxa	Functional Feeding Group	Season
	ARTHROPODA		
	INSECTA		
	Ephemeroptera (mayflies)		
	Ametropodidae		
001	*Ametropus* sp.	D	SF
	Baetidae		
002	*Baetis* spp.	DH	SF
003	*Pseudocloeon* sp.	DH	F
	Ephemerellidae		
096	*Drunella coloradensis*	H	S
004	*Drunella doddsi*	H	S
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		
012	*Paraleptophlebia* sp.	DH	SF
	Metretopodidae		
013	*Metretopus borealis*	C	S
	Siphlonuridae		
014	*Ameletus* sp.	DH	SF
	Tricorythidae		
015	*Tricorythodes* sp.	D	SF
	Trichoptera (caddisflies)		
	Brachycentridae		
016	*Brachycentrus* sp.	O	SF
	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

(continued)

Table 7. (continued)

Species Code	Taxa	Functional Feeding Group	Season
	Lepidostomatidae		
022	*Lepidostoma* sp.	D	F
	Leptoceridae		
023	*Oecetis* sp.	HC	F
097	Limnephilidae (early instar)*	DH	F
	Psychomyiidae		
024	*Psychomyia* sp.	DH	S
	Plecoptera (stoneflies)		
025	Capniidae**	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
027	*Zapada* sp.	D	S
	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	F
	Pteronarcyidae		
033	*Pteronarcella* sp.	DH	S
034	*Pteronarcys* sp.	DH	SF
	Taeniopterygidae		
035	*Taenionema* sp.	H	SF
	Diptera (flies, midges)		
	Athericidae		
036	*Atherix* sp.	C	S
	Ceratopogonidae		
037	*Bezzia/Palpomyia gp.***	C	SF
	Empididae		
038	*Chelifera* sp.	CD	SF
039	*Hemerodromia* sp.	CD	SF
	Simuliidae		
040	*Simulium* sp.	O	S

(continued)

Table 7. (continued)

Species Code	Taxa	Functional Feeding Group	Season
	Tipulidae		
041	*Hexatoma* sp.	C	SF
042	*Limnophila* sp.	C	F
043	Eriopterini Tribe	D	SF
	Chironomidae		
	Chironominae		
	Chironomini Tribe		
044	*Cryptochironomus* sp.	C	S
045	*Microtendipes* sp.	D	S
046	*Cyphomella* sp.***	D	SF
047	*Paralauterborniella nigrohalteralis*	D	S
048	*Polypedilum* spp.	DH	SF
049	*Robackia demeijerei*	D	SF
050	*Saetheria* sp.	D	S
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	S
057	*Sublettea* sp.	D	SF
058	*Tanytarsus* sp.	D	SF
059	Tanytarsini (early instar)*	D	S
	Diamesinae		
	Diamesini Tribe		
102	*Diamesa* sp.	D	SF
060	*Pagastia* sp.	D	F
061	*Potthastia gaedii* gp.	DH	SF
	Orthocladiinae		
103	*Brillia* sp.	D	F
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	F
107	*Krenosmittia* sp.	D	S
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

(continued)

Table 7. (continued)

Species Code	Taxa	Functional Feeding Group	Season
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		
	Pentaneurini Tribe		
075	*Larsia* sp.	C	SF
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
	Hemiptera		
	Corixidae (water boatmen)		
081	*Callicorixa audeni*	C	SF
082	*Sigara decoratella*	DH	F
083	*Sigara solensis*	DH	F
	Odonata (dragonflies)		
	Gomphidae		
084	*Ophiogomphus* sp.	C	S
	Megaloptera (alderflies)		
	Sialidae		
110	*Sialis* sp.	C	S
	ARACHNIDA		
085	Hydracarina (water mites)	C	SF

(continued)

Table 7. (continued)

Species Code	Taxa	Functional Feeding Group	Season
	CRUSTACEA		
	Podocopa (seed shrimps)		
	Cypridae		
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
	HIRUDINEA (leeches)		
	Rhynchobdellida		
	Glossiphoniidae		
091	*Helobdella stagnalis*	C	F
092	**NEMATODA** (roundworms)	D	SF
	MOLLUSCA		
	GASTROPODA (snails)		
	Basommatophora		
	Lymnaeidae		
093	*Lymnaea* sp.	O	SF

(continued)

Table 7. (concluded)

Species Code	Taxa	Functional Feeding Group	Season
	PELECYPODA (clams)		
	Heterodonta		
	Sphaeriidae		
094	*Pisidium* sp.	O	S
	PLATYHELMINTHES		
	TURBELLARIA (flatworms)		
	Tricladida		
	Planariidae		
095	*Polycelis coronata*	CD	F

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

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

*** *Cyphomella* sp. was previously (1989) identified as *Paracladopelma* sp.

The raw benthic data showing taxa identified and numbers of organisms per sample for all sites are presented in Appendix C. Summary tables of the basic computations for each sample are presented in Appendix D.

May

The mean number of taxa at each site during May ranged between 11 and 31 taxa (Figure 2). The highest mean number of taxa occurred at Site 4 and the lowest at Sites 5, 6 and 7, with intermediate values at Sites 1, 2 and 3.

The mean standing crop at each site during May ranged between 596 and 5,184 organisms/m^2 (Figure 3). The mean standing crop increased downstream from Sites 1 to 4 and then decreased at Sites 5, 6 and 7, to values similar to Sites 1 and 2. The higher mean standing crops at Sites 3 and 4, compared to other sites, was mainly the result of an increase in the numbers of one chironomid taxon, *Cricotopus/Orthocladius* spp. Since the ANC mill was not yet operational in May, these hgher mean standing crops were the result of pre-operational conditions in the Athabasca River.

The results of the one-way ANOVA's to determine whether numbers of taxa and numbers of organisms varied between sites are presented in Appendix E. There were significant differences during May in the mean numbers of taxa between sites ($p < 0.01$) and in the mean numbers of organisms between sites ($p < 0.01$). A posteriori testing was conducted using the SNK procedure (Appendix E). The groups of sites which did not have significantly different mean numbers of taxa ($p > 0.05$) and mean numbers of organisms ($p > 0.05$) were as follows:

Mean Numbers of Taxa	Mean Numbers of Organisms
Sites 1, 2, 3	Sites 1, 2, 5, 6, 7
Sites 1, 3, 7	
Sites 1, 5, 6, 7	

Any two sites not within a group are considered significantly different. Often there are no clear boundaries between sets of means not significantly different from each other and therefore, sets overlap. The mean number of taxa at Site 1 was significantly different from Site 4, at Site 2 from Sites 4, 5, 6 and 7, at Site 3 from Sites 4, 5 and 6, and at Site 4 from

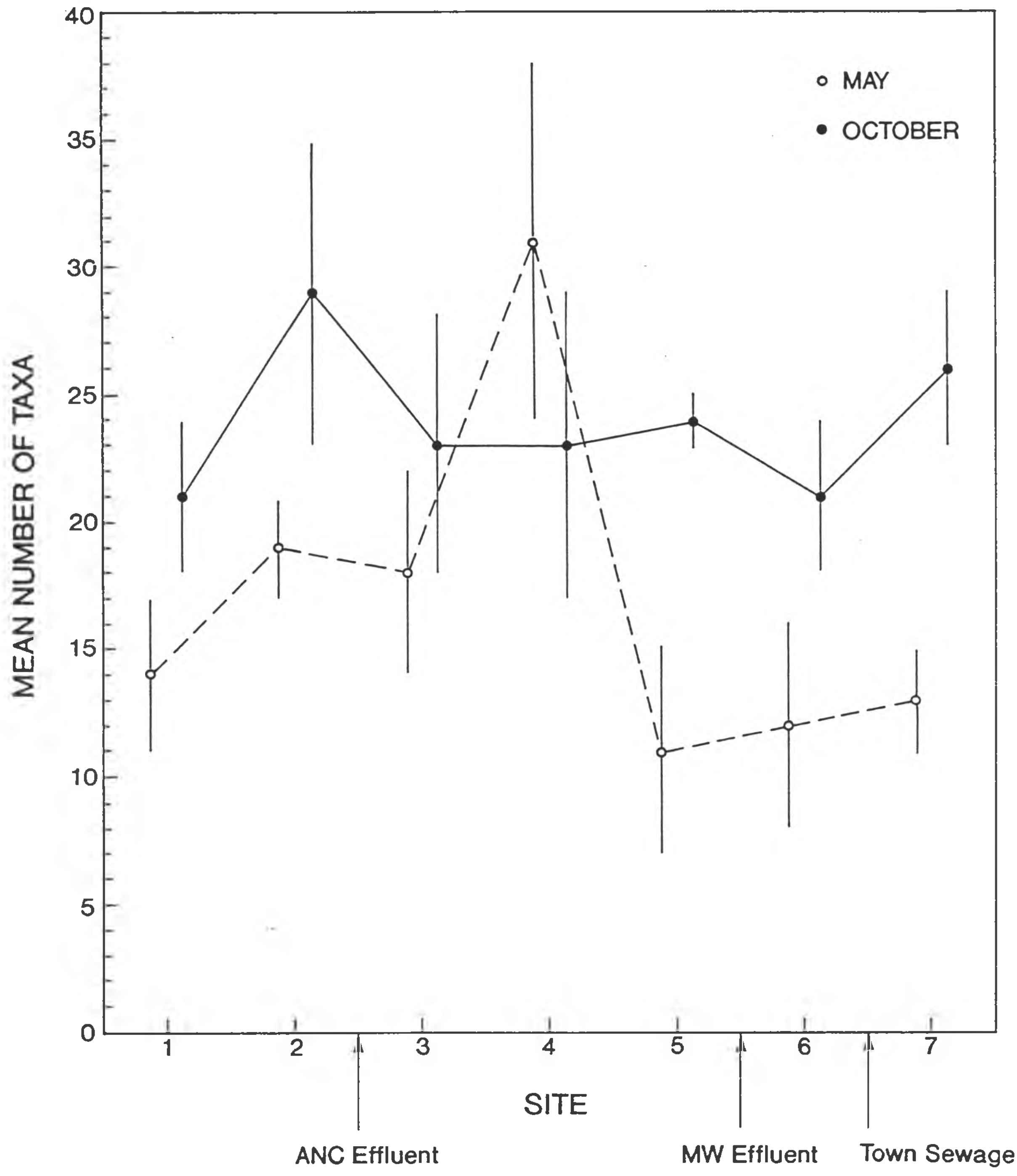

Figure 2. **Mean number of taxa with 95% confidence limits for sites on the Athabasca River, May and October 1990.**

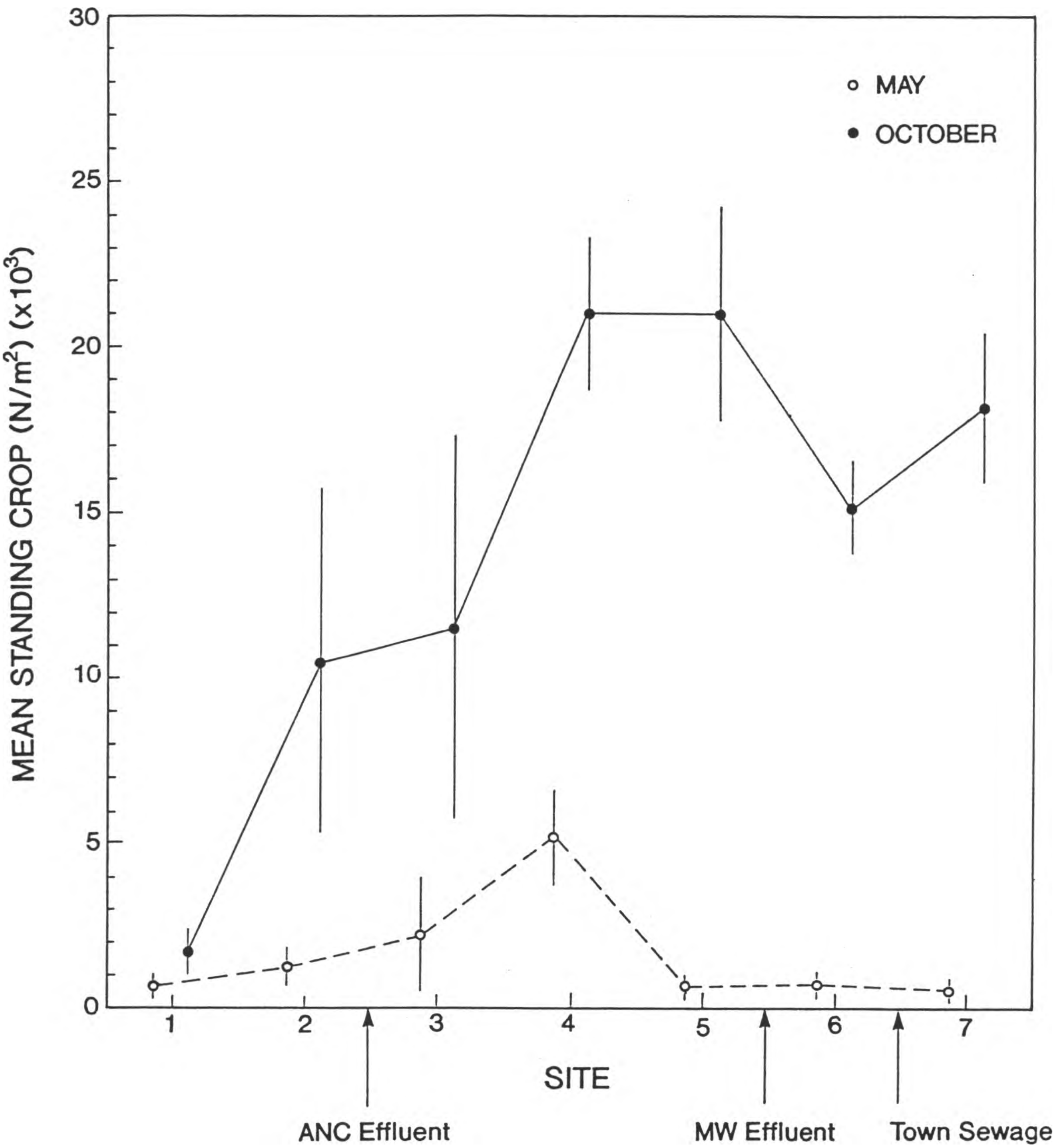

Figure 3. Mean standing crop (number/m^2) with 95% confidence limits for sites on the Athabasca River, May and October 1990.

Sites 5, 6 and 7. The mean number of organisms at Site 1 was significantly different from Sites 3 and 4, at Site 2 from Sites 3 and 4, at Site 3 from Sites 4, 5, 6 and 7, and at Site 4 from Sites 5, 6 and 7. Only the mean number of taxa at Site 4 was significantly different from both background sites. The mean numbers of organisms at Sites 3 and 4 were significantly different from both background sites.

Species diversity reflects both the number of taxa and evenness of distribution of the organisms among the taxa. The mean species diversity at each site during May ranged between 1.18 and 2.09 (Figure 4). The mean species diversity decreased at Site 3 from background values, increased at Site 4, decreased again to the lowest value at Site 6, and then increased at Site 7. 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 species diversities indicated that most sites were supporting a complex and diverse benthic invertebrate community. Since the ANC mill was not yet operational in May, these species diversities were representative of pre-operational conditions in the Athabasca River.

Ephemeroptera (mayflies), Chironomidae (midges) and Oligochaeta (aquatic worms) were the dominant taxonomic groups at all sites during May (Figure 5). Trichoptera (caddisflies), Plecoptera (stoneflies) and the remaining groups were also present but in small numbers. The mean standing crop of Chironomidae increased at Sites 3 and 4, as well as Ephemeroptera and Oligochaeta at Site 4. At Sites 5, 6 and 7, the mean standing crops of Chironomidae, Ephemeroptera and Oligochaeta decreased to values similar to those at Sites 1 and 2.

October

The mean number of taxa at each site during October ranged between 21 and 29 taxa (Figure 2). The highest mean number of taxa occurred at Site 2 and the lowest at Sites 1 and 6, with intermediate values at Sites 3, 4, 5 and 7. The mean numbers of taxa during October were higher than during May at all sites, except Site 4.

The mean standing crop at each site during October ranged between 1,760 and 20,989 organisms/m^2 (Figure 3). The mean standing crop at Site 3 was similar to background Site 2 and then increased to the highest values at Sites 4 and 5. There was a slight decrease at Site 6 and then a slight increase again at Site 7 in mean standing crop. The higher mean

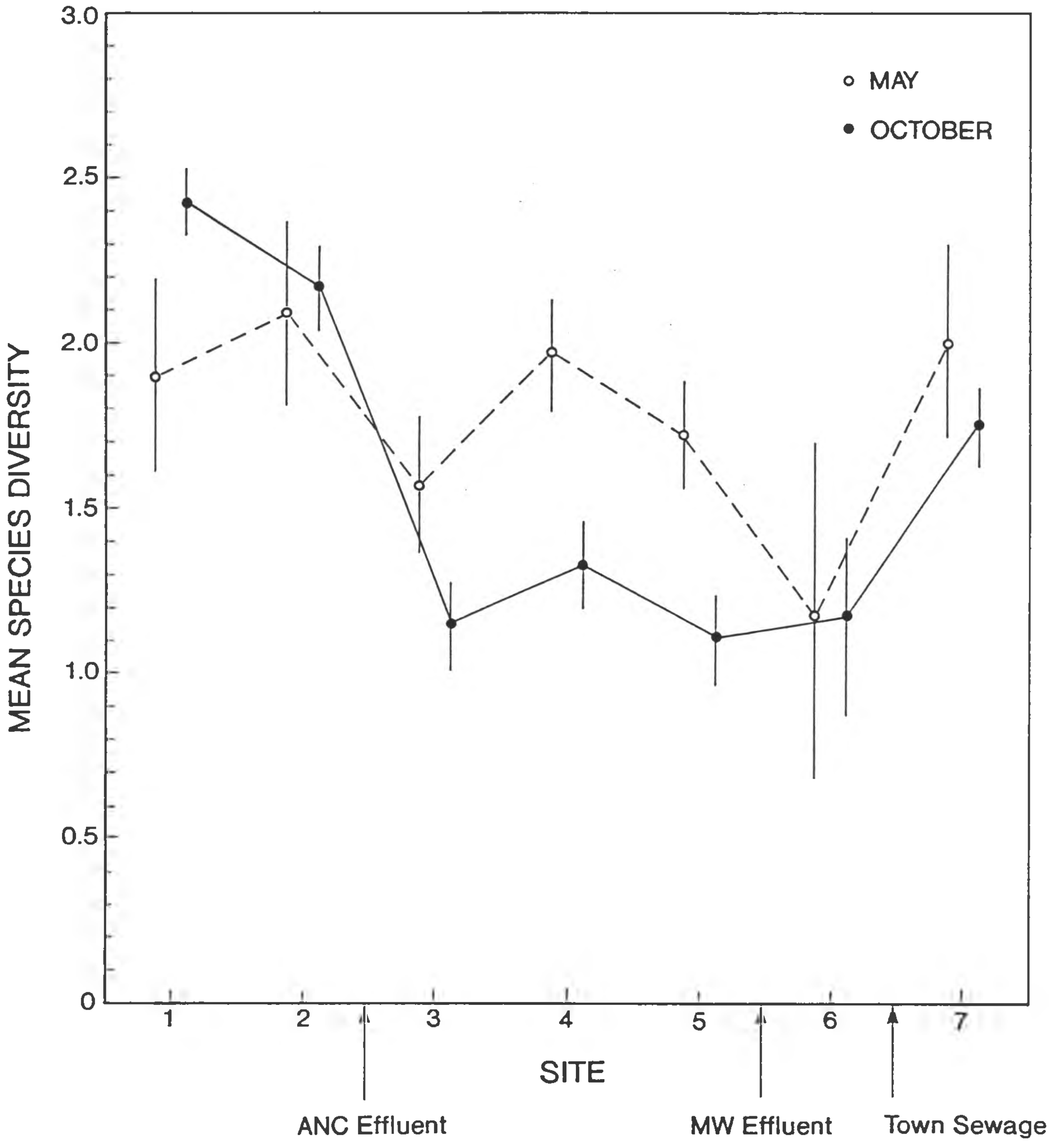

Figure 4. **Mean Shannon-Weaver species diversity with 95% confidence limits for sites on the Athabasca River, May and October 1990.**

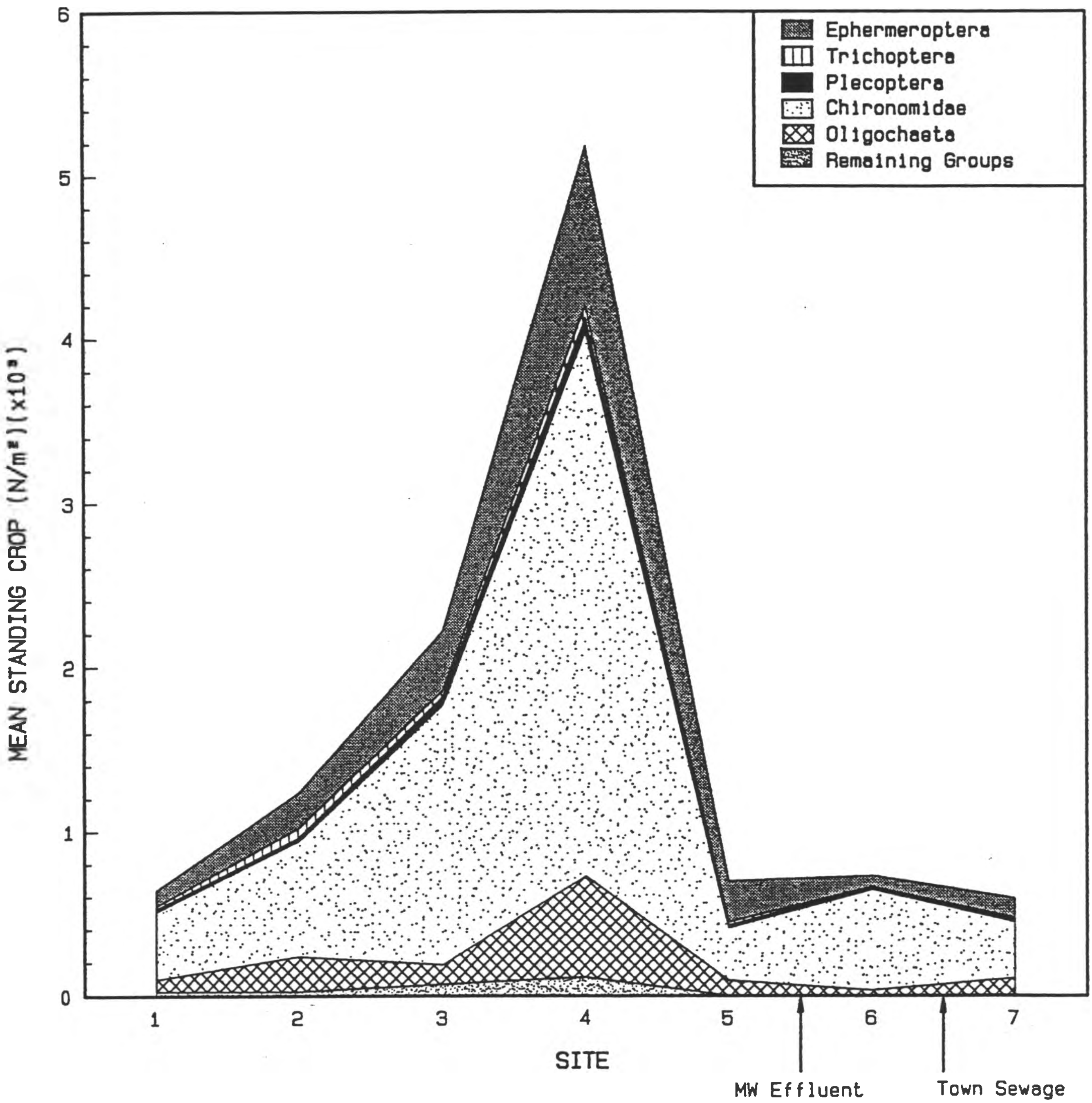

Figure 5. **Mean standing crop (number/m^2) of the major taxonomic groups for sites on the Athabasca River, May 1990.**

standing crops at downstream sites were the result of an increase in the numbers of one chironomid taxon, *Cricotopus/Orthocladius* spp., which made up approximately 70% of the standing crop at Site 4, 78% at Site 5, 72% at Site 6 and 56% at Site 7. The mean standing crops during October were higher than during May at all sites.

The results of the one-way ANOVA's showed that there were significant differences during October in the mean numbers of taxa between sites ($p < 0.05$) and in the mean numbers of organisms between sites ($p < 0.01$) (Appendix E). The SNK procedure showed that the groups of sites which did not have significantly different mean numbers of taxa ($p > 0.05$) and mean numbers of organisms ($p > 0.05$) (Appendix E) were as follows:

Mean Numbers of Taxa	Mean Numbers of Organisms
Sites 1, 3, 4, 5, 6, 7	Sites 2, 3
Sites 2, 5, 7	Sites 4, 5, 7
	Sites 6, 7

The mean number of taxa at Site 1 was significantly different from Site 2 and at Site 2 from Sites 3, 4 and 6. The mean number of organisms at Site 1 was significantly different from all other sites, at Site 2 from Sites 4, 5, 6 and 7, at Site 3 from Sites 4, 5, 6 and 7, at Site 4 from Site 6, and at Site 5 from Site 6. The mean numbers of taxa at all downstream sites were similar to at least one of the background sites, whereas the mean numbers of organisms at all downstream sites, except Site 3, were significantly different from both background sites.

The mean species diversity at each site during October ranged between 1.11 and 2.42 (Figure 4). The mean species diversity decreased at Site 3 and remained lower than background values at all downstream sites, with a slight increase at Site 7. Since the ANC mill became operational in August, the October species diversity values reflected post-operational (start-up) conditions at Sites 3 to 7 in the Athabasca River. The mean species diversities during October were lower than during May at all downstream sites.

Ephemeroptera, Plecoptera and Chironomidae were the dominant taxonomic groups at all sites during October (Figure 6). Trichoptera, Oligochaeta and the remaining groups were present in small numbers. The mean standing crop of Chironomidae increased at Sites 3, 4 and 5 and then decreased slightly at Sites 6 and 7. The mean standing crops of Ephemeroptera and Plecoptera increased slightly at Site 4, decreased at Sites 5 and 6 and

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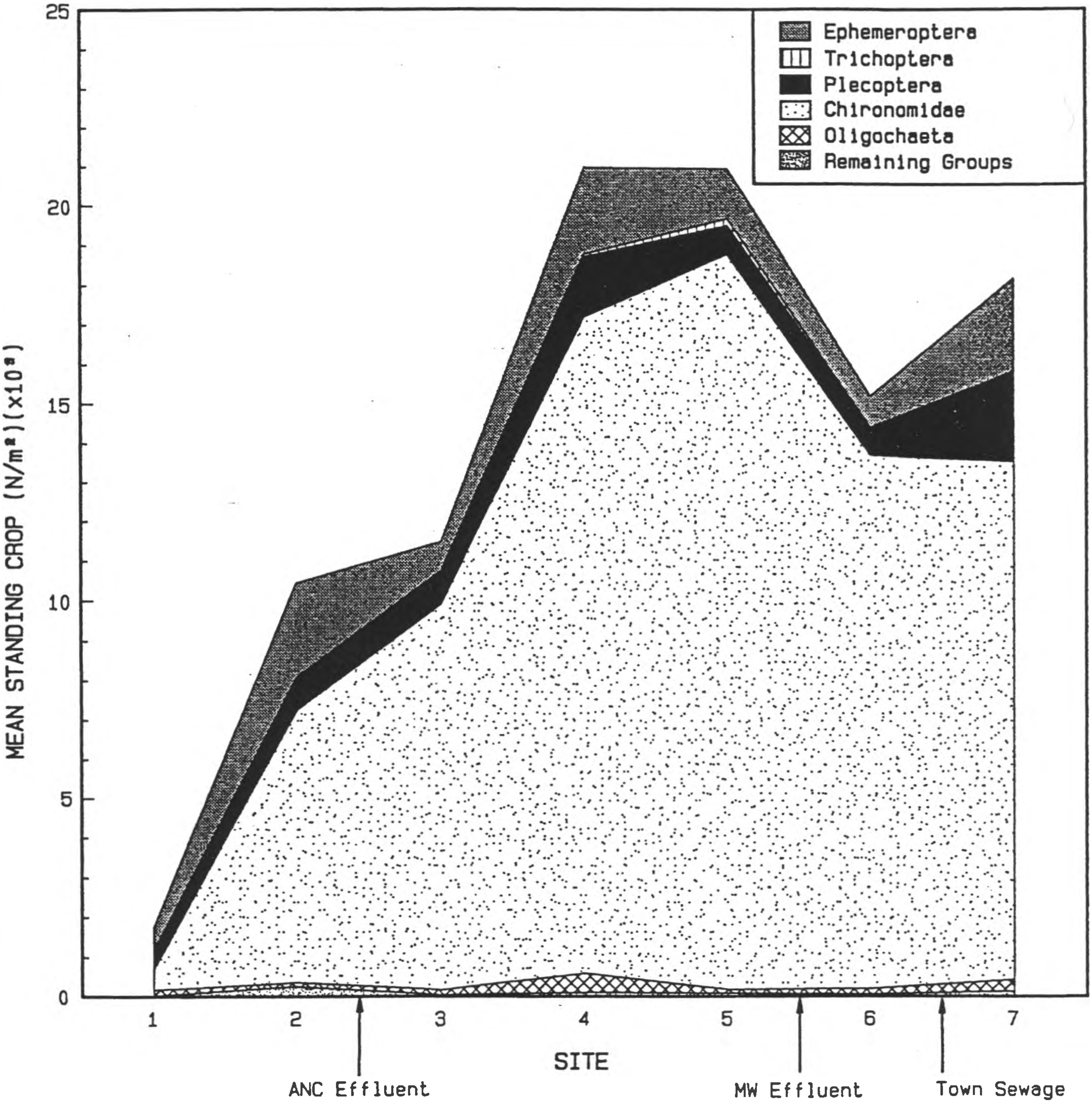

Figure 6. Mean standing crop (number/m^2) of the major taxonomic groups for sites on the Athabasca River, October 1990.

then increased again at Site 7. There was also a slight increase in the mean standing crop of Oligochaeta at Site 4.

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 Oligochaeta and Chironomidae, 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. Although, the individual taxa from the same major group tend to respond relatively uniformly, exceptions are not uncommon and the intensity of respones can vary considerably among taxa (Anderson 1989). Therefore, a community analysis including individual taxa is provided in Section 3.3.2.

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). The increases in mean standing crops at downstream sites (Sites 3 to 7) during October, in comparison to background sites were 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 and Plecoptera), increased in numbers at downstream sites, as a response to the organic enrichment.

3.3.2 Community Analysis

Reciprocal Averaging Ordination (RA) was conducted to analyze the data in terms of benthic invertebrate community structure. The results of the RA analysis are shown as a species dominance distribution matrix for each sample site for both May and October (Appendix F). These results were plotted as two-axes (X and Y) ordinations for both site and species scores on a scale of 0 to 100 (ordination units) on each axis. The species ordinations are shown in Appendix F. The taxa represented by the species codes in the matrices and species ordinations are listed in Table 7.

May

There were three sample clusters in May (Figure 7). Cluster I consisted of samples from Site 5. Cluster II consisted of all samples from Sites 1, 2, 3, 4 and 6 and one sample from Site 7 (7-5). Cluster III consisted of four samples from Site 7 (7-1, 7-2, 7-3, 7-4). Each cluster is representing samples 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 site ordination indicated that sample clusters during May, especially Clusters I and III, were loosely grouped and had a low degree of faunal homogeneity. The separation of Clusters I and III from Cluster II indicated that the benthic community structure of Sites 5 and 7 differed from all other sites.

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

Cluster I: *Cricotopus/Orthocladius* spp., *Rhithrogena* sp., Tubificidae, *Baetis* spp.

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

Cluster III: *Cricotopus/Orthocladius* spp., Enchytraeidae, *Ephemerella inermis*, *Micropsectra* sp., Naididae

The mean standing crops (number/m^2) of the dominant taxa identified by RA for each site for May are shown in Figure 8.

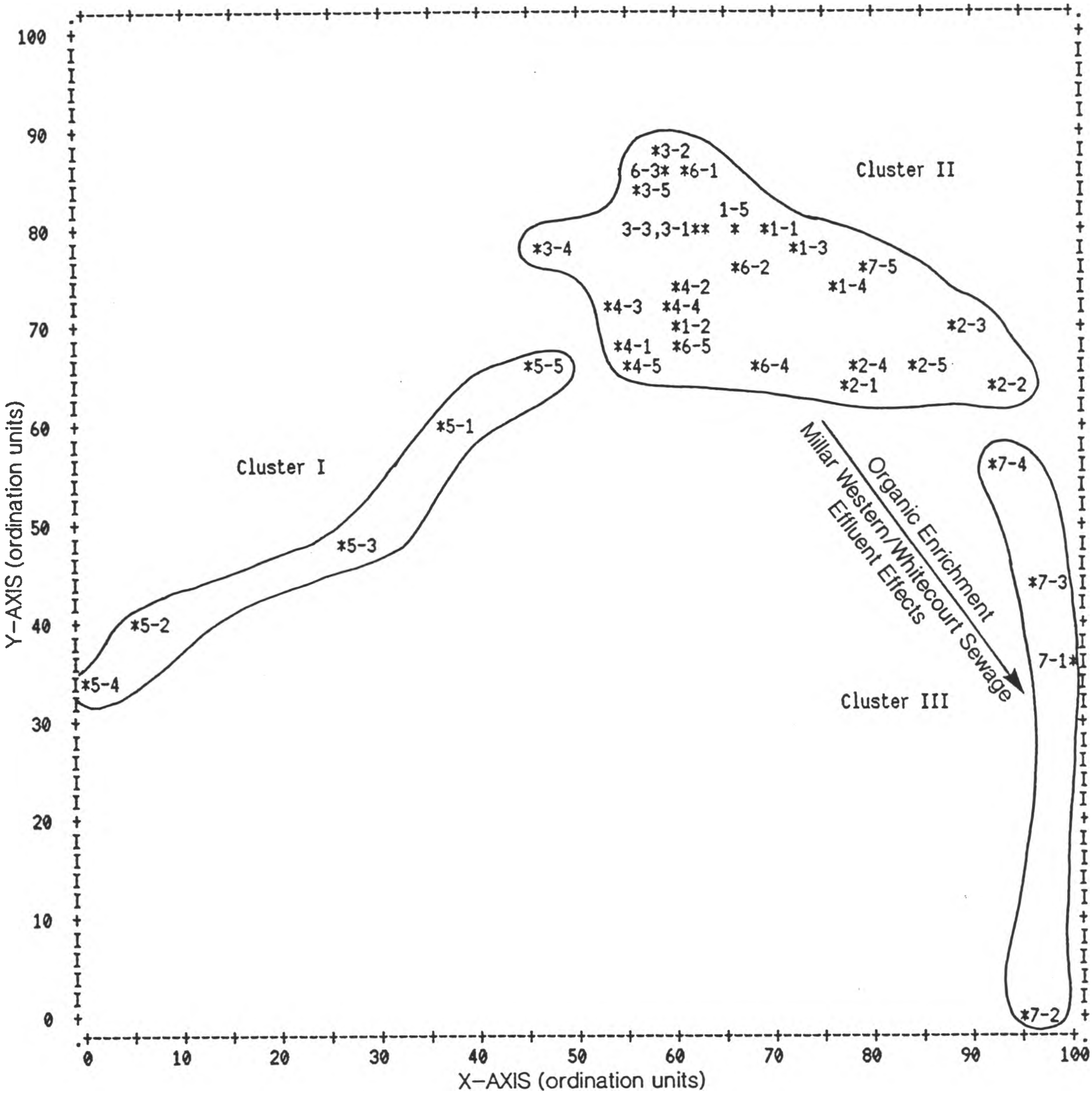

Figure 7. Reciprocal averaging ordination of site scores, May 1990.

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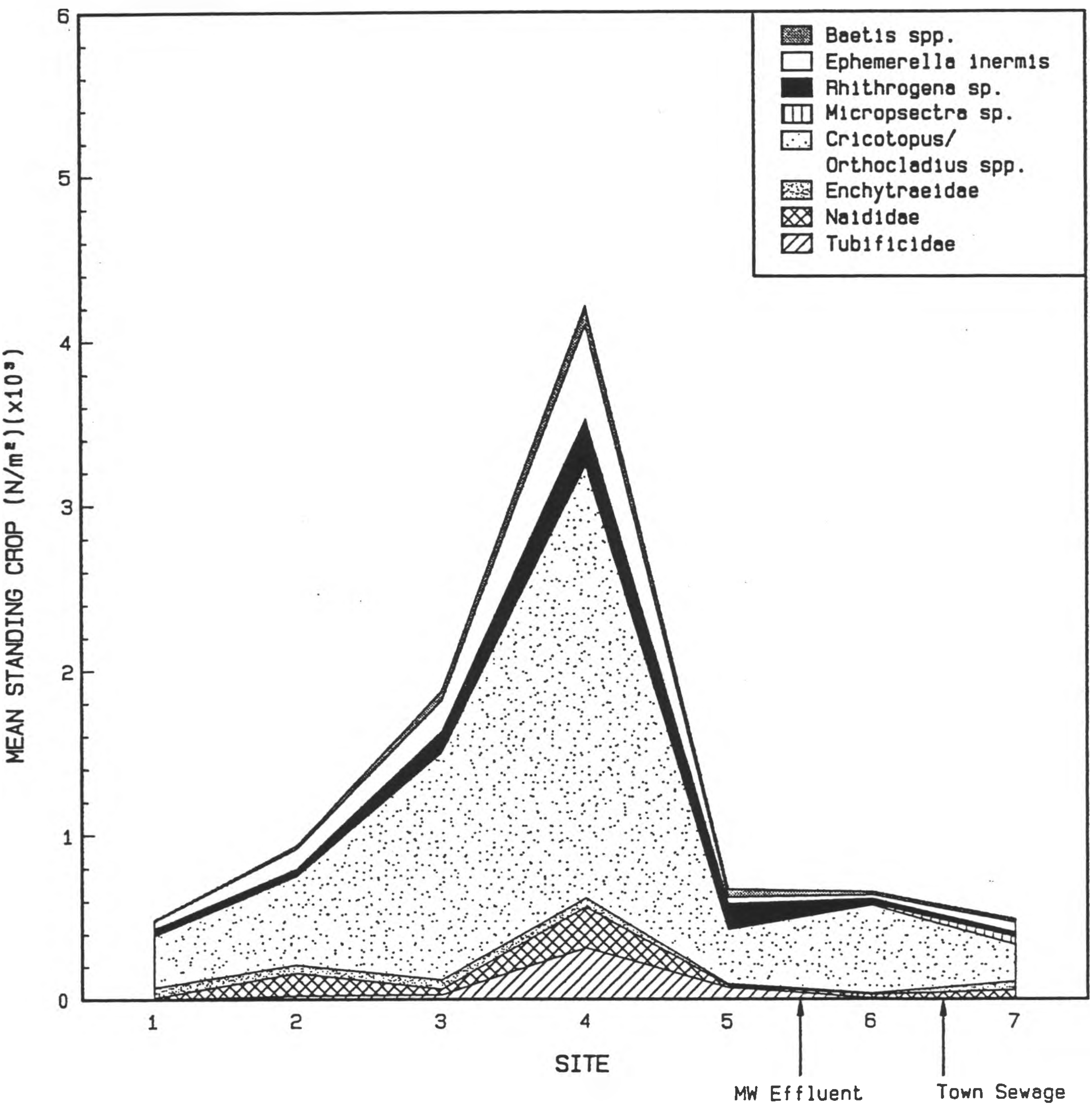

Figure 8. Mean standing crop (number/m^2) of the dominant taxa identified by RA for sites on the Athabasca River, May 1990.

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, 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 samples in Clusters I, II and III. This was shown by one chironomid taxon, *Cricotopus/Orthocladius* spp. (Orthocladiinae), which was dominant in all three clusters. There were lower numbers of *Cricotopus/Orthocladius* spp. in samples of Cluster I, increasing numbers in samples of Cluster II and then decreasing numbers again in samples of Cluster III (Appendix E-1). Orthocladiinae, such as *Cricotopus/Orthocladius* spp., have been found to respond to mild organic enrichment, where oxygen levels are not seriously depressed (Hynes 1960).

The other dominant taxa of the main cluster (Cluster II) included two mayflies, *Ephemerella inermis* and *Rhithrogena* sp. (Ephemeroptera). Most Ephemeroptera are grazers, feeding principally on algae and detrital materials (Merritt and Cummins 1984) and thus some species, such as *Ephemerella inermis* and *Rhithrogena* sp., are suited to mild organic enrichment (Hynes 1960, Roback 1974).

Two aquatic worms, Naididae and Enchytraeidae (Oligochaeta), were also dominant taxa within Cluster II. The Oligochaeta have been found to be a reliable indicator 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). 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).

The dominant taxa of *Ephemerella inermis*, Enchytraeidae and Naididae in Cluster II were replaced in Cluster I by another Ephemeroptera, *Baetis* spp. and another Oligochaeta, Tubificidae. *Baetis* spp. which also feeds on algae and detrital materials, similar to most Ephemeroptera, are suited to mild organic enrichment (Roback 1974). The Tubificidae are very tolerant of pollution and are found in large numbers in severely organically polluted water (Brinkhurst and Cook 1974). The Tubificidae was one of the dominant taxon in samples of Cluster I, but their numbers were low.

The dominant taxon of *Rhithrogena* sp. in Cluster II was replaced in Cluster III by a chironomid, *Micropsectra* sp. of the Tanytarsini Tribe. Tanytarsini (Chironominae) like Orthocladiinae, have been found to respond to mild organic enrichment, where oxygen levels are not seriously depressed (Hynes 1960).

The benthic community structure of all sites on the Athabasca River indicated the presence of some mild organic enrichment. Since pre-operational conditions existed in the Athabasca River for ANC in May, this represented natural background organic enrichment at Sites 1 to 5, probably from agricultural sources and/or from the leaching of soils. The benthic community structure of Site 6, downstream of the Millar Western mill, was similar to the upstream sites, indicating that the Millar Western effluent was having little effect on this site in May. The benthic community structure of Site 7, downstream of both the Millar Western mill and the Whitecourt sewage treatment plant, showed the presence of mild organic enrichment, similar to upstream sites, except that the benthic community was dominated by *Micropsectra* sp., instead of *Rhithrogena* sp. The Millar Western mill and/or the Whitecourt sewage treatment effluents were likely having an enrichment effect on the benthic community structure of Site 7 (Beak 1991), by providing conditions more suitable to *Micropsectra* sp.

October

The site ordination indicated three sample clusters in October (Figure 9). Cluster I consisted of samples from Site 1 and Cluster II of samples from Site 2. Cluster III consisted of samples from Sites 3, 4, 5, 6 and 7. During October, a higher degree of faunal homogeneity existed between samples within a cluster, than during May.

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

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

Cluster II: *Cricotopus/Orthocladius* spp., *Rheotanytarsus* spp., *Ephemerella inermis*

Cluster III: *Cricotopus/Orthocladius* spp., *Rheotanytarsus* spp., *Ephemerella inermis*, *Taenionema* sp.

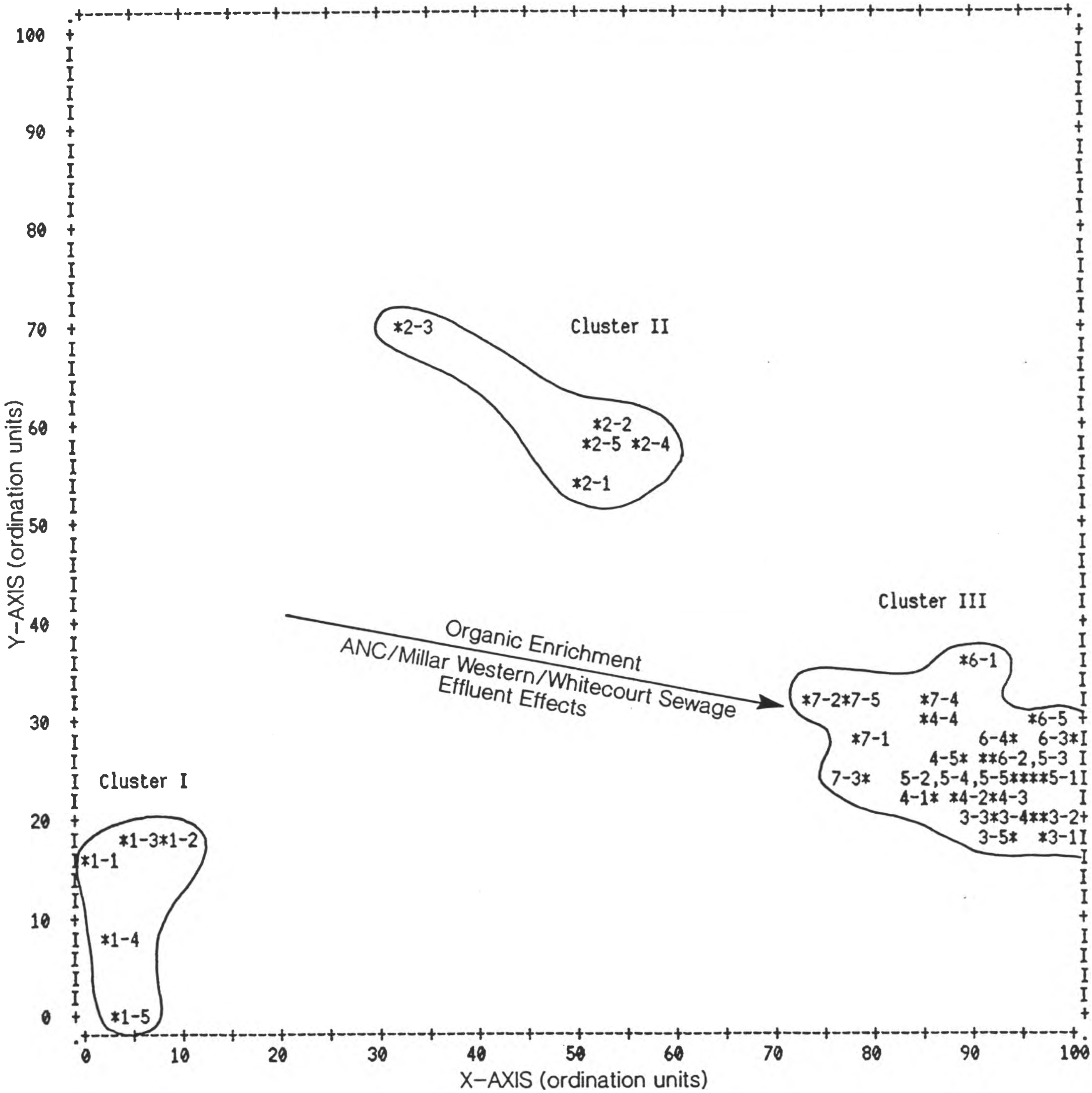

Figure 9. **Reciprocal averaging ordination of site scores, October 1990.**

The mean standing crops (number/m^2) of the dominant taxa identified by RA for each site for October are shown in Figure 10.

A gradient of organic enrichment existed between clusters across the X-axis. This was shown by *Cricotopus/Orthocladius* spp., which was dominant in all three clusters. There were lower numbers of this taxon in samples of Cluster I and increasing numbers in samples of Clusters II and III (Appendix E-2).

The separation of Clusters I and II indicated that there were differences in the benthic community structure of the two background sites. Site 1 (Cluster I) was dominated by *Cricotopus/Orthocladius* spp., two Ephemeroptera (*Rhithrogena* sp. and *Ephemerella inermis*), two Plecoptera (Capniidae and *Taenionema* sp.) and one Oligochaeta (Enchytraeidae), while Site 2 (Cluster II) was dominated by *Cricotopus/Orthocladius* spp., one Ephemeroptera (*Ephemerella inermis*) and one Chironomidae (*Rheotanytarsus* spp.). These dominant taxa have been found to respond to mild organic enrichment, where oxygen levels are not seriously depressed (Hynes 1960, Roback 1974).

The benthic community structure of Sites 3 to 7 (Cluster III), downstream of the ANC mill differed from background Sites 1 and 2 in October, when the ANC mill was operational. The benthic community structure of Cluster III was dominated by *Cricotopus/Orthocladius* spp. and *Ephemerella inermis*, which were also dominant in both Clusters I and II, *Rheotanytarsus* spp., which was also dominant in Cluster II, and *Taenionema* sp. which was also dominant in Cluster I.

The dominant benthic community structures of Clusters I and II indicated the presence of some mild natural organic enrichment at the background sites. The ANC effluent appeared to contribute some additional organic enrichment at downstream sites. This was indicated by the increase in the amount of algae on the substrates (Section 3.1), the increase in total phosphorus concentrations (Section 3.2), the increase in standing crop (Section 3.3.1) and the increase in the numbers of *Cricotopus/Orthocladius* spp. at downstream sites, in comparison to background sites. The Millar Western mill and/or the Whitecourt sewage treatment effluents also appeared to contribute additional organic enrichment at Sites 6 and 7 (Beak 1991), since no recovery of the benthic community structure was apparent at these downstream sites.

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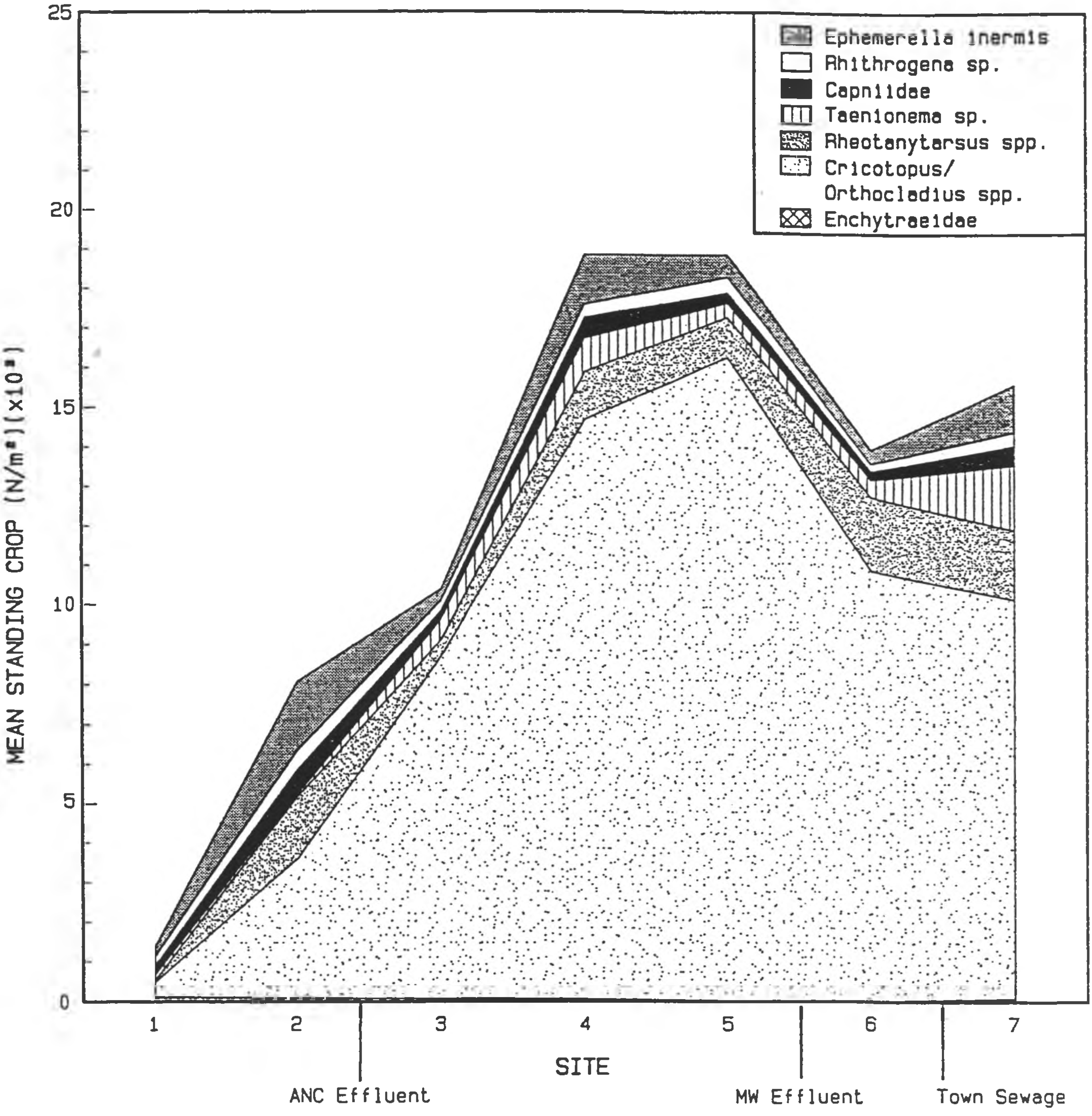

Figure 10. Mean standing crop (number/m^2) of the dominant taxa identified by RA for sites on the Athabasca River, October 1990.

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 May and October. The availability of food is a factor which controls the occurrence and abundance of benthic invertebrate species (Hynes 1972). The percent contribution of each functional group for all samples sites for May and October are presented in Appendix G.

May

The trophic analysis showed that all sites were dominated by detritivore/herbivores, followed by detritivores, in May (Figure 11). The detritivore/herbivores formed 60.9 to 84.5% and the detritivores formed 12.5 to 35.0% 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 third and fourth dominant groups were the carnivores and omnivores, which formed 1.8 to 4.2% and 0.4 to 5.1%, respectively, of the total benthic fauna. All other feeding groups formed less than 1% of the total benthic fauna.

The trophic analysis indicated that, in general, samples sites within a cluster identified by RA had similar percent compositions of the dominant feeding groups. The percent contribution ranges of the four dominant feeding groups for each cluster of sample sites for the May data was as follows:

		DH	D	C	O
Cluster I	(Site 5)	73.6 - 80.4	9.8 - 26.4	0 - 4.8	0 - 7.6
Cluster II	(Sites 1, 2, 3, 4, 6)	54.1 - 89.3	6.7 - 37.9	0 - 9.7	0 - 9.4
Cluster III	(Site 7)	45.7 - 69.2	26.9 - 50.0	0 - 4.4	0 - 1.6

Cluster II (the main group of sites) had a high percentage of detritivore/herbivores, followed by detritivores and then similar percentages of carnivores and omnivores. Cluster I also had a high percentage of detritivores/herbivores, followed by detritivores, omnivores and then carnivores. However, the range of values were smaller for feeding groups in Cluster I than in Cluster II. The similar ranges of most dominant feeding groups, especially between Clusters I and II, was reflected in the loosely grouped sample clusters of RA. Cluster III had a high percentage of detritivore/herbivores, followed by only a slightly lower

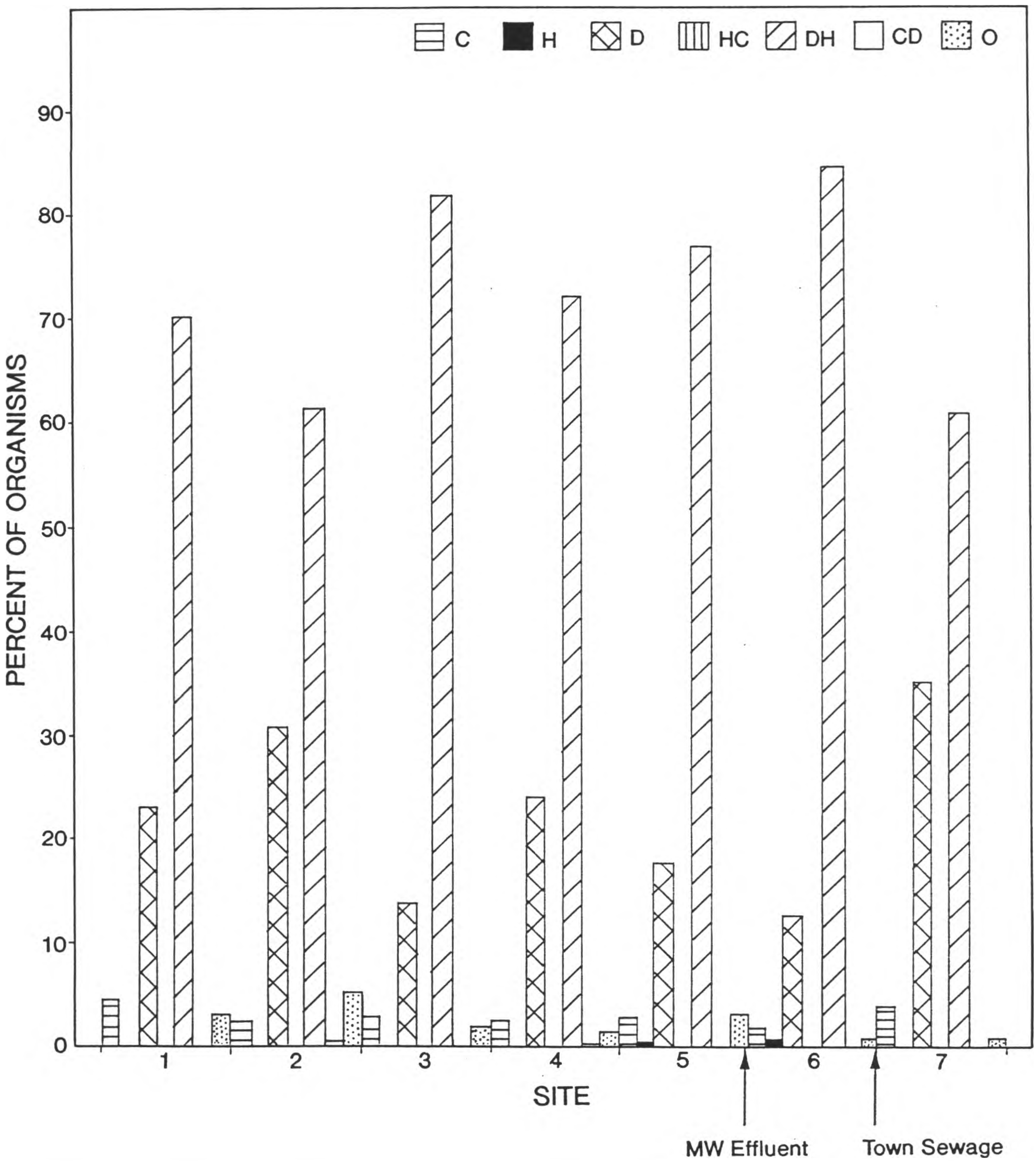

Figure 11. **Percent composition of benthic invertebrate functional feeding groups for sites on the Athabasca River, May 1990.**

percentage of detritivores, then carnivores and omnivores. There was a lower percentage of detritivore/herbivores and a higher percentage of detritivores in Cluster III, compared to Cluster II. This was the result of a shift in the dominant community assemblage from *Rhithrogena* sp. (a detritivore/herbivore) in Cluster II to *Micropsectra* sp.(a detritivore) in Cluster III. There was also a lower percentage of omnivores in Cluster III, compared to Cluster II, which was the result of a decrease in the numbers of *Brachycentrus* sp. and *Hydropsyche* spp. (Trichoptera). Increases in the numbers of certain organisms and shifts in the feeding group structure occurred at Site 7, probably due to the change in the nature of the food supply caused by the Millar Western and Whitecourt sewage treatment effluents.

October

The trophic analysis showed that all sites were dominated by detritivore/herbivores, followed by detritivores in October (Figure 12). The detritivore/herbivores formed 56.9 to 86.6% and the detritivores formed 8.6 to 32.0% of the total benthic fauna. The third and fourth dominant groups were the herbivores and carnivores, which formed 0.6 to 9.1% and 0.6 to 6.8%, respectively, of the total benthic fauna. All other feeding groups formed less than 1% of the total benthic fauna.

The percent contribution of the four dominant feeding groups for each cluster of sample sites identified by RA for the October data was as follows:

		DH	D	H	C
Cluster I	(Site 1)	47.2 - 68.8	19.7 - 33.8	4.3 - 9.7	3.2 - 8.8
Cluster II	(Site 2)	60.2 - 66.3	27.7 - 36.1	0.2 - 1.3	1.4 - 5.0
Cluster III	(Sites 3, 4, 5, 6, 7)	66.4 - 88.4	6.1 - 22.6	0.8 - 14.2	0.3 - 3.4

Cluster I had a high percentage of detritivore/herbivores, followed by detritivores and then similar percentages of herbivores and carnivores. Cluster II also had a high percentage of detritivore/herbivores, followed by detritivores and then carnivores and herbivores. There was a lower percentage of herbivores in Cluster II, compared to Cluster I, which was the result of a decrease in the numbers of *Taenionema* sp. Cluster III had a high percentage of detritivores, followed by detritivores and then herbivores and carnivores. There was a higher percentage of detritivore/herbivores and a slightly lower percentage of detritivores in Cluster III, compared to Clusters I and II. This was the result of an increase in the

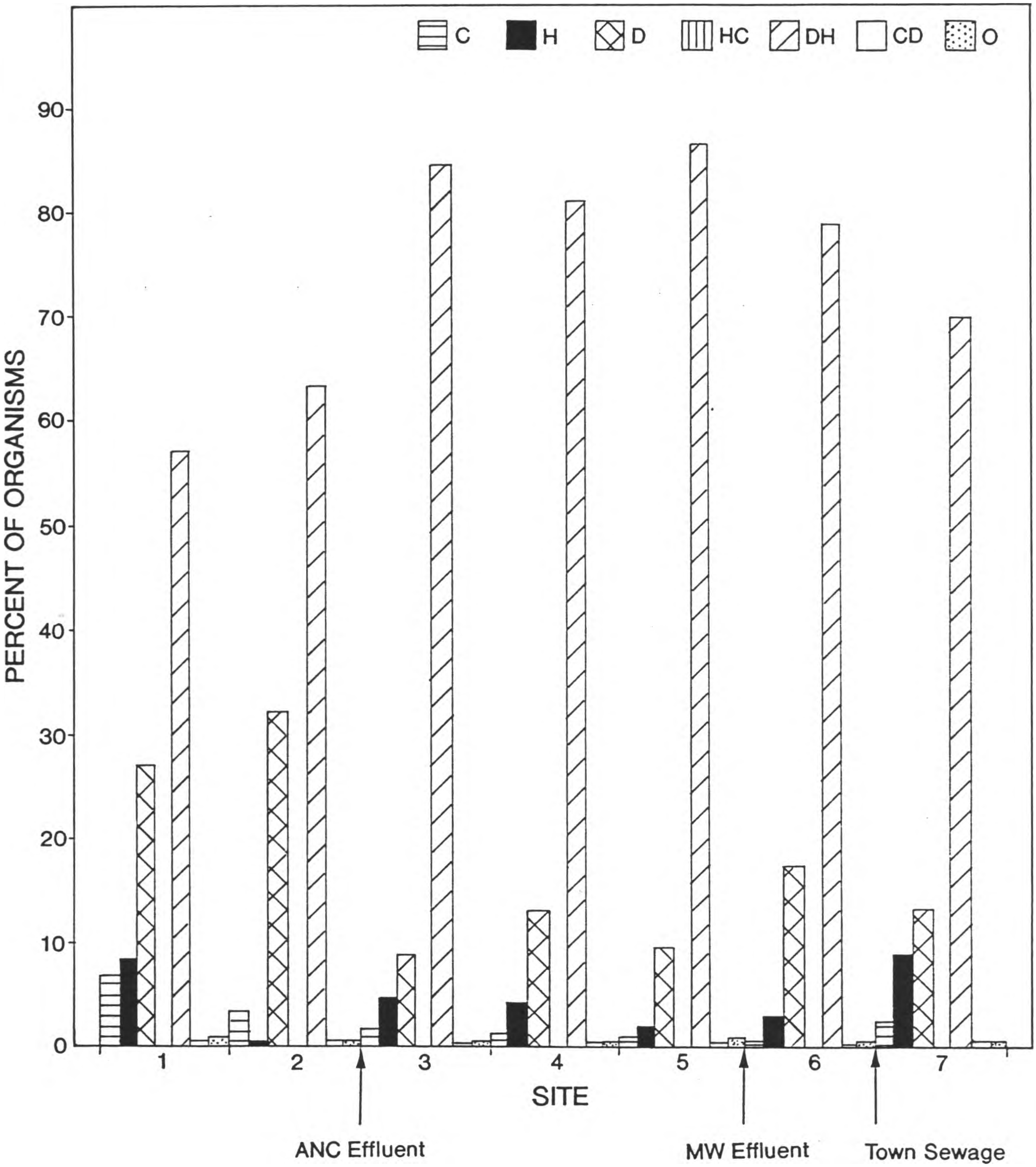

Figure 12. **Percent composition of benthic invertebrate functional feeding groups for sites on the Athabasca River, October 1990.**

numbers of *Cricotopus/Orthocladius* spp. (a detritivore/herbivore) in Cluster III. There was also a higher percentage of herbivores in Cluster III, compared to Clusters I and II, as a result of the increase in the numbers of *Taenionema* sp. A slight decrease in the percentage of carnivores in Cluster III, compared to Clusters I and II, was caused by a decrease in the numbers of several Plecoptera species (*Isogeniodes sp. and Isoperla* sp.).

The trophic analysis indicated that similar trends were apparent in the October benthic data, as was found by the RA analysis. Although all sites appeared to be influenced by mild organic enrichment, it was more evident at sites downstream of the ANC mill, as well as the Millar Western mill and the Whitecourt sewage treatment plant. Increases in the numbers of certain organisms and shifts in the feeding group structure occurred as expected, to 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 to Pre-Operational Surveys

To further 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 post-operational (start-up) conditions existed in the fall of 1990.

Benthic 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). 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. It can therefore be difficult to make direct comparisons of benthic data between years. However, a comparison between pre-operational and post-operational data can be of importance in determining general trends in the benthic community structure.

In the spring of 1990, the mean numbers of taxa at all sites, except Site 4, and the mean standing crops at all sites, except Sites 3 and 4, were lower than during the spring of 1989 (Tables 8 and 9). The mean species diversities at all sites, except Site 7, in the spring of 1990 were lower than during the spring of 1989 (Table 10). Natural factors appeared to have been responsible for these decreases, since they occurred at most sites during a pre-operational year.

Table 8. **Comparison of mean number of taxa between fall 1990 and pre-operational surveys (1989 - 1990)*.**

Site	Spring 1989	Spring 1990	Fall 1989	Fall 1990
1	21	14	24	21
2	25	19	26	29
3	23	18	25	23
4	22	31	23	23
5	20	11	21	24
6	32	12	24	21
7	32	13	27	26

* Pre-operational surveys included the spring and fall of 1989 and the spring of 1990.

Table 9. **Comparison of mean standing crop (number/m^2) between fall 1990 and pre-operational surveys (1989 - 1990)*.**

Site	Spring 1989	Spring 1990	Fall 1989	Fall 1990
1	2,018	643	3,803	1,760
2	3,161	1,242	5,226	10,428
3	1,661	2,224	5,096	11,480
4	1,303	5,184	3,309	20,989
5	5,211	702	3,507	20,955
6	7,128	735	7,482	15,195
7	23,359	596	9,670	18,191

* Pre-operational surveys included the spring and fall of 1989 and the spring of 1990.

Table 10. **Comparison of mean species diversity (Shannon-Weaver Index) between fall 1990 and pre-operational surveys (1989 - 1990)*.**

	Spring		Fall	
Site	**1989**	**1990**	**1989**	**1990**
1	2.46	1.90	2.54	2.42
2	2.70	2.09	2.17	2.17
3	2.67	1.57	2.29	1.15
4	2.68	1.97	2.37	1.33
5	1.95	1.72	2.29	1.11
6	2.57	1.18	2.15	1.18
7	1.83	2.00	2.37	1.75

* Pre-operational surveys included the spring and fall of 1989 and the spring of 1990.

In the fall of 1990, the mean numbers of taxa at all sites were similar to the values found during the pre-operational survey (fall of 1989) (Table 8). The mean standing crops at all sites, except background Site 1, in the fall of 1990 were higher than during the pre-operational survey (Table 9). The mean species diversities at all sites, except background Sites 1 and 2, in the fall of 1990 were lower than during the pre-operational survey (Table 10). 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. This is typically the result of organic enrichment, where a few tolerant taxa, which are more suited to the organic enrichment, increase in numbers. Therefore, the decrease in species diversity at all downstream sites during the fall of 1990 was likely the result of organic enrichment from the ANC and Millar Western pulp mills and the Whitecourt sewage treatment plant.

During the pre-operational surveys, the benthic community structure of Sites 1 to 5, upstream of the Millar Western pulp mill and Whitecourt sewage treatment plant indicated the presence of mild natural organic enrichment (Beak 1990). Effluents from the Millar Western pulp mill and Whitecourt sewage treatment plant appeared to contribute additional mild organic enrichment to downstream sites, especially at Site 7. This was indicated by several taxa which have been found to increase in numbers as a response to a mild increase in organic loading, as long as oxygen is not limiting (Tables 11 and 12).

In the fall of 1990, the dominant benthic community structure of background Sites 1 and 2 indicated the presence of mild natural organic enrichment, similar to the spring. The downstream sites (Sites 3 to 7) were affected by the cumulative organic enrichment of the ANC, Millar Western and Whitecourt sewage treatment effluents. In general, the benthic community structure of sites on the Athabasca River during the fall of 1990 was similar to the pre-operational survey, except that some taxa increased in numbers as a response to organic loading from pulp mill and sewage effluents, causing a change in the order of the dominant taxa (Tables 11 and 12).

Table 11. **Comparison of dominant taxa in the spring during pre-operational surveys (1989-1990).**

Site	Year	Dominant Taxa
1	1989	*Isoperla* sp., *Cricotopus/Orthocladius* spp., *Rhithrogena* sp., *Eukiefferiella* spp., Naididae
	1990	*Cricotopus/Orthocladius* spp., Enchytraeidae, *Ephemerella inermis*
2	1989	*Cricotopus/Orthocladius* spp., *Eukiefferiella* spp., *Lymnaea* sp., *Rhithrogena* sp., Naididae, *Isoperla* sp.
	1990	*Cricotopus/Orthocladius* spp., *Ephemerella inermis*, Naididae
3	1989	*Cricotopus/Orthocladius* spp., *Brachycentrus* sp., Naididae, Tubificidae, *Baetis* spp., *Rhithrogena* sp., *Eukiefferiella* spp., *Hydropsyche* spp.
	1990	*Cricotopus/Orthocladius* spp., *Ephemerella inermis*, *Rhithrogena* sp.
4	1989	*Isoperla* sp., *Rhithrogena* sp., Heptageniidae, Naididae, Tubificidae, *Baetis* spp., *Brachycentrus* sp.
	1990	*Cricotopus/Orthocladius* spp., *Ephemerella inermis*
5	1989	*Cricotopus/Orthocladius* spp., *Eukiefferiella* spp., *Baetis* spp.
	1990	*Cricotopus/Orthocladius* spp., *Rhithrogena* sp., Tubificidae, *Baetis* spp.
6	1989	*Cricotopus/Orthocladius* spp., *Eukiefferiella* spp., *Hydropsyche* spp., *Baetis* spp., Naididae
	1990	*Cricotopus/Orthocladius* spp.
7	1989	*Cricotopus/Orthocladius* spp., *Eukiefferiella* spp., *Hydropsyche* spp.
	1990	*Cricotopus/Orthocladius* spp., Enchytraeidae, *Ephemerella inermis*, *Micropsectra* sp., Naididae

Table 12. **Comparison of dominant taxa in the fall between 1990 and the pre-operational survey in 1989.**

Site	Year	Dominant Taxa
1	1989	*Ephemerella inermis*, *Rhithrogena* sp., *Cricotopus/Orthocladius* spp., *Taenionema* sp., *Tvetenia* spp., *Baetis* spp., Hydracarina
	1990	*Cricotopus/Orthocladius* spp., *Rhithrogena* sp., *Ephemerella inermis*, Capniidae, *Taenionema* sp., Enchytraeidae
2	1989	*Ephemerella inermis*, *Micropsectra* sp., *Cricotopus/Orthocladius* spp., Hydracarina, *Rheotanytarsus* spp., *Tvetenia* spp.
	1990	*Cricotopus/Orthocladius* spp., *Rheotanytarsus* spp., *Ephemerella inermis*
3	1989	*Ephemerella inermis*, *Micropsectra* sp., *Rhithrogena* sp., *Cricotopus/Orthocladius* spp., Hydracarina, *Tvetenia* spp.
	1990	*Cricotopus/Orthocladius* spp.
4	1989	*Ephemerella inermis*, *Cricotopus/Orthocladius* spp., *Micropsectra* sp., *Taenionema* sp, Hydracarina, *Rhithrogena* sp., *Tvetenia* spp.
	1990	*Cricotopus/Orthocladius* spp., *Rheotanytarsus* spp., *Ephemerella inermis*
5	1989	*Rhithrogena* sp., *Ephemerella inermis*, Hydracarina, *Baetis* spp., *Taenionema* sp., *Tvetenia* spp., *Cricotopus/Orthocladius* spp., *Rheotanytarsus* spp.
	1990	*Cricotopus/Orthocladius* spp.
6	1989	*Micropsectra* sp., *Ephemerella inermis*, *Cricotopus/Orthocladius* spp., *Baetis* spp., *Taenionema* sp.
	1990	*Cricotopus/Orthocladius* spp., *Rheotanytarsus* spp.
7	1989	*Micropsectra* sp., *Ephemerella inermis*, *Cricotopus/Orthocladius* spp., Hydracarina, Naididae
	1990	*Cricotopus/Orthocladius* spp., *Rheotanytarsus* spp., *Ephemerella inermis*, *Taenionema* sp.

4.0 SUMMARY AND CONCLUSIONS

There were some variations in the physical characteristics of substrate composition, water velocity and water depth between sites and seasons, which 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. The Millar Western effluent and/or the McLeod River may have been responsible for slight increases in BOD, true color and total suspended solids concentrations at Site 6 in May. In October, there were slight increases in BOD concentrations at sites downstream of the ANC mill, the McLeod River, the Millar Western mill and the Whitecourt sewage treatment plant. However, dissolved oxygen concentrations were not affected by these BOD inputs. Total phosphorus concentrations were higher at Sites 3 and 4, than at background sites in October, likely as a result of the ANC effluent. Detailed water quality analyses at Sites 2 and 3 indicated that most parameters were below detection limits and/or did not exceed provincial objectives or federal guidelines. Total phenols were higher at Site 3 than at background Site 2 in October, possibly as a result of the ANC effluent, however the value did not exceed provincial objectives. Resin acids were detected at both Site 2 in May and Site 3 in October (no values available for Site 2 in October), but the total resin acid values were below the provincial objective in both cases and was below the detection limit in the ANC effluent in October.

There were significant differences in the mean numbers of taxa and the mean numbers of organisms between sites during both seasons. In May, the mean number of taxa at Site 4 was significantly different and the mean numbers of organisms at Sites 3 and 4 were significantly different from both background sites. In October, the mean numbers of taxa at all downstream sites were similar to at least one of the background sites, whereas the mean numbers of organisms at all downstream sites, except Site 3, were significantly different from both background sites. The higher mean standing crops at downstream sites during May were the result of natural organic enrichment and during October were likely the result of the ANC, Millar Western and Whitecourt sewage treatment effluents. The species diversity indicated that most sites were supporting a complex and diverse benthic community. In October, the lower species diversities at downstream sites indicated that there was a dominance of one or more taxa, while other fauna were low in numbers.

Ephemeroptera (mayflies) and Chironomidae (midges) were the dominant taxonomic groups at all sites during May and October. Oligochaeta (aquatic worms) was also dominant in May, while Plecoptera (stoneflies) was dominant in October. Tolerant taxa, as well as intolerant taxa (Ephemeroptera and Plecoptera), increased in numbers at downstream sites, as a response to natural organic enrichment in May and to organic enrichment from the pulp mills and sewage treatment plant in October.

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. Most of the dominant taxa characteristic of each cluster of sites identified by RA, have been found to respond to organic enrichment. In May, the benthic community structure of all sites on the Athabasca River indicated the presence of some mild organic enrichment. Since pre-operational conditions existed in the river for ANC in May, this represented natural background organic enrichment at Sites 1 to 5. However, the Millar Western and/or the Whitecourt sewage treatment effluents were likely having an enrichment effect on the benthic community structure of Site 7. In October, the dominant benthic community structure of the background sites indicated the presence of some mild natural organic enrichment, similar to May. The ANC effluent appeared to contribute some additional organic enrichment at downstream sites. The Millar Western and/or Whitecourt sewage treatment effluents also appeared to contribute additional organic enrichment at Sites 6 and 7, since no recovery of the benthic community structure, back to background conditions, was apparent at these downstream sites.

The trophic analysis showed that all sites during both the spring and fall surveys were dominated by detritivore/herbivores and detritivores which is common natural trait of most streams in North America. The third and fourth dominant groups were the carnivores and omnivores in May, and the herbivores and carnivores in October. The trophic analysis indicated that similar trends were apparent in the benthic data, as was found by the RA analysis. In May, increases in the numbers of certain organisms and shifts in the feeding group structure occurred at Site 7, probably due to the change in the nature of the food supply caused by the Millar Western and Whitecourt sewage treatment effluents. In October, the sites downstream of the ANC effluent, as well as the Millar Western and the

Whitecourt sewage treatment effluents, showed shifts in the feeding group structure due to organic enrichment.

A general comparison was made of the pre-operational and post-operational surveys. The mean number of taxa, mean standing crop and mean species diversity at most sites in the spring of 1990 were lower than during the spring of 1989. Natural factors appeared to be responsible for these decreases. In the fall of 1990, the mean numbers of taxa at all sites were similar to the pre-operational values. The mean standing crop was higher and the mean species diversity was lower at all downstream sites in the fall of 1990, compared to the pre-operational values. A low species diversity is typically the result of organic enrichment, where a few tolerant taxa, which are more suited to organic enrichment increase in numbers, thus causing an uneven distribution. Therefore, this decrease in species diversity was likely the result of organic enrichment from the ANC and Millar Western pulp mills and the Whitecourt sewage treatment plant. In general, the benthic community strucutre of all downstream sites during the fall of 1990 was similar to the pre-operational surveys, except that some taxa increased in numbers as a response to the organic loading from the pulp mill and sewage effluents, causing a change in the order of the dominant taxa.

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 from a balanced association at background sites to one of increasing proportions of tolerant taxa at downstream sites. This is a typical response to mild organic enrichment.

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PERSONAL COMMUNICATION

B. Steinback, Superintendent, Environmental Services, Alberta Newsprint Company, Whitecourt, Alberta.

APPENDICES

APPENDIX A

PHYSICAL CHARACTERISTICS
(SUBSTRATE COMPOSITION, WATER VELOCITY AND DEPTH)
OF SAMPLE LOCATIONS
MAY AND OCTOBER 1990

Appendix A-1. **Substrate size distribution (percentage by weight) for each sample location with means and 95% confidence limits (CL) per site, May 1990.**

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	20.8	79.2	-	-	-
1-2	16.0	84.0	-	-	-
1-3	27.6	72.4	-	-	-
1-4	14.6	85.4	-	-	-
1-5	19.1	80.8	0.1	-	-
Mean ± 95% CL	19.6 ± 6.3	80.4 ± 6.3	0.1 ± 0.1	-	-
2-1	45.4	54.6	-	-	-
2-2	45.2	54.8	-	-	-
2-3	39.4	60.6	-	-	-
2-4	27.4	72.6	-	-	-
2-5	47.8	52.2	-	-	-
Mean ± 95% CL	41.0 ± 10.2	59.0 ± 10.2	-	-	-
3-1	23.0	77.0	-	-	-
3-2	51.7	48.3	-	-	-
3-3	39.9	60.1	-	-	-
3-4	35.3	64.7	-	-	-
3-5	59.1	40.9	-	-	-
Mean ± 95% CL	41.8 ± 17.5	58.2 ± 17.5	-	-	-
4-1	47.5	52.5	-	-	-
4-2	41.1	58.7	0.2	-	-
4-3	57.0	42.9	0.1	-	-
4-4	38.7	60.9	0.5	-	-
4-5	34.3	65.4	0.3	-	-
Mean ± 95% CL	43.7 ± 11.0	56.1 ± 10.8	0.2 ± 0.2	-	-
5-1	26.7	73.3	-	-	-
5-2	25.4	74.6	-	-	-
5-3	25.3	74.7	-	-	-
5-4	33.3	66.7	-	-	-
5-5	25.4	74.6	-	-	-
Mean ± 95% CL	27.2 ± 4.3	72.8 ± 4.3	-	-	-
6-1	54.5	45.5	-	-	-
6-2	50.3	49.7	-	-	-
6-3	44.1	55.9	-	-	-
6-4	17.7	82.3	-	-	-
6-5	60.7	29.3	-	-	-
Mean ± 95% CL	45.5 ± 20.7	54.5 ± 20.7	-	-	-
7-1	63.7	32.3	2.4	1.6	-
7-2	72.0	16.1	3.4	8.5	0.1
7-3	58.9	34.3	2.6	4.0	0.3
7-4	55.0	33.6	5.0	6.3	0.2
7-5	65.5	29.1	3.6	1.8	0.1
Mean ± 95% CL	63.0 ± 8.1	29.1 ± 9.3	3.4 ± 1.3	4.4 ± 3.7	0.1 ± 0.1

Appendix A-2. Substrate size distribution (percentage by weight) for each sample location with means and 95% confidence limits (CL) per site, October 1990.

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	40.0	60.0	-	-	-
1-2	39.1	60.9	-	-	-
1-3	38.1	61.9	-	-	-
1-4	46.3	53.7	-	-	-
1-5	38.6	61.4	-	-	-
Mean ± 95% CL	40.4 ± 4.2	59.6 ± 4.2	-	-	-
2-1	64.1	35.9	-	-	-
2-2	67.4	32.6	-	-	-
2-3	71.8	28.2	-	-	-
2-4	60.7	39.3	-	-	-
2-5	48.7	51.3	-	-	-
Mean ± 95% CL	62.5 ± 10.9	37.5 ± 10.9	-	-	-
3-1	70.6	29.4	-	-	-
3-2	37.4	62.6	-	-	-
3-3	61.7	38.3	-	-	-
3-4	46.5	53.5	-	-	-
3-5	63.2	36.8	-	-	-
Mean ± 95% CL	55.9 ± 16.8	44.1 ± 16.8	-	-	-
4-1	51.1	48.5	0.5	-	-
4-2	47.4	52.1	0.5	-	-
4-3	59.1	40.5	0.4	-	-
4-4	53.8	46.2	-	-	-
4-5	44.6	55.0	0.4	-	-
Mean ± 95% CL	51.2 ± 7.0	48.5 ± 6.9	0.4 ± 0.3	-	-
5-1	53.4	46.5	0.1	-	-
5-2	47.8	51.7	0.5	-	-
5-3	46.4	53.6	-	-	-
5-4	33.8	65.8	0.4	-	-
5-5	33.9	66.2	-	-	-
Mean ± 95% CL	43.1 ± 10.9	56.8 ± 11.0	0.2 ± 0.3	-	-
6-1	66.2	29.6	4.0	0.2	0.1
6-2	64.6	33.5	1.8	0.1	0.1
6-3	70.5	27.4	1.9	0.2	-
6-4	63.3	36.7	0.1	-	-
6-5	71.0	27.8	1.1	0.1	-
Mean ± 95% CL	67.1 ± 4.3	31.0 ± 5.0	1.8 ± 1.8	0.1 ± 0.1	0.1 ± 0.1
7-1	60.0	36.3	3.7	0.1	-
7-2	68.8	29.6	1.5	-	-
7-3	70.1	27.5	2.4	0.1	-
7-4	69.4	27.4	3.1	0.1-	-
7-5	63.7	35.3	0.9	0.1	-
Mean ± 95% CL	66.4 ± 5.4	31.2 ± 5.3	2.3 ± 1.4	0.1 ± 0.1	-

Appendix A-3. **Water velocity and depth for each sample location with means and 95% confidence limits (CL) per site, May 1990.**

Site-Sample	Water Velocity* cm/s	Water Depth cm
1-1	42	37
1-2	45	36
1-3	31	35
1-4	37	39
1-5	33	34
Mean ± 95% CL	38 ± 7	36 ± 2
2-1	37	33
2-2	31	37
2-3	38	36
2-4	35	36
2-5	42	34
Mean ± 95% CL	37 ± 5	35 ± 2
3-1	74	34
3-2	78	35
3-3	68	32
3-4	79	31
3-5	65	34
Mean ± 95% CL	73 ± 8	33 ± 2
4-1	45	32
4-2	62	31
4-3	47	33
4-4	47	34
4-5	42	35
Mean ± 95% CL	49 ± 10	33 ± 2
5-1	52	38
5-2	50	36
5-3	54	39
5-4	60	38
5-5	55	37
Mean ± 95% CL	54 ± 5	38 ± 1
6-1	41	32
6-2	45	34
6-3	47	33
6-4	50	31
6-5	47	35
Mean ± 95% CL	46 ± 4	33 ± 2
7-1	30	33
7-2	24	35
7-3	31	34
7-4	24	31
7-5	30	37
Mean ± 95% CL	28 ± 4	34 ± 3

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

Appendix A-4. Water velocity and depth for each sample location with means and 95% confidence limits (CL) per site, October 1990.

Site-Sample	Water Velocity* cm/s	Water Depth cm
1-1	41	30
1-2	49	30
1-3	48	33
1-4	51	33
1-5	50	32
Mean ± 95% CL	48 ± 5	32 ± 2
2-1	29	30
2-2	32	33
2-3	33	33
2-4	30	33
2-5	32	33
Mean ± 95% CL	31 ± 2	32 ± 2
3-1	51	32
3-2	51	32
3-3	56	30
3-4	49	30
3-5	55	32
Mean ± 95% CL	52 ± 4	31 ± 1
4-1	49	28
4-2	50	28
4-3	54	31
4-4	51	31
4-5	53	31
Mean ± 95% CL	51 ± 3	30 ± 2
5-1	34	31
5-2	45	32
5-3	40	30
5-4	42	31
5-5	36	31
Mean ± 95% CL	39 ± 6	31 ± 1
6-1	35	28
6-2	42	29
6-3	40	31
6-4	41	29
6-5	43	30
Mean ± 95% CL	40 ± 4	29 ± 1
7-1	36	27
7-2	33	28
7-3	30	27
7-4	26	30
7-5	30	30
Mean ± 95% CL	31 ± 5	28 ± 2

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

APPENDIX B

AVERAGE MONTHLY CONCENTRATIONS OF SELECTED PARAMETERS FOR MILLAR WESTERN FINAL EFFLUENT

Appendix B. Average monthly concentrations of selected parameters for Millar Western final effluent, spring (March - May) and fall (August - October) 1990.

	Spring			Fall		
Parameter*	March	April	May	August	September	October
Discharge (m^3/d)	11,908	13,090	12,573	14,052	13,191	13,535
pH (units)	8.3	8.4	8.4	8.4	8.5	8.4
Dissolved Oxygen (mg/L)	3.6	4.9	4.4	4.7	4.3	5.1
Dissolved Oxygen (percent saturation)	53	71	67	72	63	70
Biochemical Oxygen Demand (mg/L)	111	62	34	51	79	80
Temperature (°C)	31.8	31.0	33.5	35.0	32.2	27.8
True Color (units)	845	822	686	625	626	605
Total Suspended Solids (mg/L)	199	218	91	175	266	266
Total Phosphorus (as P) (mg/L)	8.7	5.5	3.0	3.4	5.2	1.2
Total Kjeldahl Nitrogen (mg/L)	18.7	16.1	11.1	7.7	7.4	7.6

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.

APPENDIX C

SPECIES IDENTIFICATIONS AND NUMBERS PER SAMPLE
MAY AND OCTOBER 1990

Site 1 - May 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	2	0	1	0	0
Ephemerellidae					
Ephemerella inermis	3	4	2	2	10
Heptageniidae					
Rhithrogena sp.	4	4	2	2	6
Trichoptera					
Brachycentridae					
Brachycentrus sp.	3	3	0	2	0
Plecoptera					
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	0	0	0	0	1
Perlodidae					
Isogenoides sp.	1	0	1	1	0
Isoperla sp.	0	0	1	1	2
Diptera					
Tipulidae					
Hexatoma sp.	0	0	0	1	0
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	0	0	0	0	1
Polypedilum spp.	2	4	2	1	6
Robackia demeijerei	0	1	0	0	0
Tanytarsini Tribe					
Cladotanytarsus sp.	3	0	3	0	0
Micropsectra sp.	0	0	1	0	0
Rheotanytarsus sp.	1	0	2	1	1
Orthocladiinae					
Cricotopus/Orthocladius spp.	24	19	30	12	57
Eukiefferiella sp.	0	1	1	0	0
Parametriocnemus sp.	0	1	0	0	0
Synorthocladius sp.	2	0	0	0	0
Tvetenia spp.	0	1	1	0	0
Orthocladiinae (early instar)	1	0	0	0	0
Prodiamesinae					
Monodiamesa sp.	1	0	0	0	1
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	1	0	0	0	1

(continued)

Site 1 - May 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Megaloptera					
Sialidae					
Sialis sp.	0	0	1	0	0
Haplotaxida					
Enchytraeidae	5	5	7	6	4
Naididae	2	1	0	0	1
Tubificidae	0	0	1	0	0
Nematoda	2	2	2	2	4

Site 2 - May 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	3	1	1	0	3
Ephemerellidae					
Ephemerella inermis	5	10	9	11	19
Heptageniidae					
Heptagenia sp.	3	5	4	0	5
Rhithrogena sp.	6	4	2	1	4
Trichoptera					
Brachycentridae					
Brachycentrus sp.	1	4	0	0	2
Hydropsychidae					
Arctopsyche sp.	0	0	0	0	1
Hydropsyche sp.	2	4	5	0	7
Plecoptera					
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	0	0	3	2	0
Perlidae					
Claassenia sabulosa	0	0	0	1	0
Perlodidae					
Cultus sp.	0	1	0	1	0
Isogenoides sp.	0	2	0	0	0
Diptera					
Empididae					
Chelifera sp.	1	0	0	0	0
Tipulidae					
Hexatoma sp.	1	0	0	0	0
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	2	2	1	2	1
Polypedilum sp.	0	1	0	1	0
Tanytarsini Tribe					
Cladotanytarsus sp.	2	0	0	1	3
Micropsectra sp.	0	1	2	0	1
Rheotanytarsus sp.	4	8	7	6	7
Sublettea sp.	1	1	1	1	0
Diamesinae					
Diamesini Tribe					
Diamesa sp.	0	1	0	0	1
Potthastia gaedii sp.	0	0	0	0	1

(continued)

Site 2 - May 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Orthocladiinae					
Cricotopus/Orthocladius spp.	36	25	47	58	75
Eukiefferiella sp.	0	0	0	0	2
Nanocladius sp.	0	0	0	0	1
Synorthocladius sp.	0	0	0	0	1
Thienemanniella sp.	0	0	1	0	0
Tvetenia sp.	1	1	1	3	2
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	0	1	0	0	0
Hydracarina	0	0	0	1	0
Haplotaxida					
Enchytraeidae	1	3	3	6	9
Naididae	10	8	2	20	22
Tubificidae	1	0	0	5	4
Nematoda	1	2	1	3	2
Basommatophora					
Lymnaeidae					
Lymnaea sp.	0	0	1	1	0

Site 3 - May 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	9	2	2	2	1
Ephemerellidae					
Ephemerella inermis	54	3	10	12	6
Heptageniidae					
Epeorus sp.	0	0	0	1	0
Heptagenia sp.	0	0	1	0	0
Rhithrogena sp.	15	6	9	20	7
Leptophlebiidae					
Paraleptophlebia sp.	0	0	0	0	1
Trichoptera					
Brachycentridae					
Brachycentrus sp.	0	3	2	0	6
Hydropsychidae					
Hydropsyche sp.	0	0	4	1	0
Plecoptera					
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	0	0	1	1	3
Chloroperlinae (early instar)	0	0	0	1	0
Perlidae					
Claassenia sabulosa	0	0	1	0	0
Perlodidae					
Cultus sp.	1	0	0	0	0
Isogenoides sp.	3	0	4	3	2
Isoperla sp.	2	0	0	1	0
Diptera					
Simuliidae					
Simulium sp.	0	0	0	2	0
Chironomidae					
Chironominae					
Chironomini Tribe					
Polypedilum sp.	2	3	1	2	1
Tanytarsini Tribe					
Rheotanytarsus sp.	6	3	4	2	3
Sublettea sp.	2	2	0	1	0
Orthocladiinae					
Cricotopus/Orthocladius spp.	245	89	102	110	69
Eukiefferiella spp.	6	5	3	9	2
Nanocladius sp.	1	0	0	0	2
Parakiefferiella sp.	1	0	0	0	0

(continued)

Site 3 - May 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Parametriocnemus sp.	1	0	0	1	0
Psectrocladius sp.	0	0	0	0	1
Rheocricotopus sp.	1	0	0	0	0
Thienemanniella sp.	0	0	0	1	0
Tvetenia spp.	16	2	1	4	1
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	0	0	2	0	0
Hydracarina	1	0	0	0	0
Haplotaxida					
Enchytraeidae	16	3	7	0	0
Naididae	7	1	3	2	2
Tubificidae	2	0	2	5	3
Nematoda	13	3	1	5	7

Site 4 - May 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	7	11	13	10	10
Ephemerellidae					
Ephemerella inermis	52	39	44	49	72
Heptageniidae					
Epeorus sp.	1	0	0	0	0
Heptagenia sp.	0	0	0	2	0
Rhithrogena sp.	26	23	20	17	36
Siphlonuridae					
Ameletus sp.	3	0	0	2	2
Trichoptera					
Brachycentridae					
Brachycentrus sp.	1	3	2	15	1
Hydropsychidae					
Hydropsyche sp.	1	0	1	1	4
Hydroptilidae					
Stactobiella sp.	0	0	0	0	2
Plecoptera					
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	3	1	5	1	1
Chloroperlinae (early instar)	0	1	0	0	1
Nemouridae					
Nemoura sp.	2	0	0	0	0
Perlidae					
Claassenia sabulosa	1	0	0	1	1
Perlodidae					
Cultus sp.	0	0	0	0	2
Isogenoides sp.	1	3	3	1	1
Isoperla sp.	0	3	2	4	2
Pteronarcyidae					
Pteronarcys sp.	0	0	0	0	1
Diptera					
Empididae					
Chelifera sp.	0	0	1	0	1
Hemerodromia sp.	1	0	0	1	1
Tipulidae					
Hexatoma sp.	0	0	0	1	0

(continued)

Site 4 - May 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	1	2	0	2	2
Polypedilum spp.	6	3	1	8	6
Tanytarsini Tribe					
Cladotanytarsus sp.	0	0	0	2	2
Micropsectra sp.	0	1	1	1	2
Rheotanytarsus sp.	11	20	20	41	33
Sublettea sp.	0	1	2	3	0
Tanytarsus sp.	0	0	1	0	0
Diamesinae					
Diamesini Tribe					
Diamesa sp.	0	0	0	1	0
Potthastia gaedii gp.	1	0	1	0	1
Orthocladiinae					
Corynoneura sp.	0	0	0	1	1
Cricotopus/Orthocladius spp.	146	256	232	265	270
Eukiefferiella sp.	3	13	3	5	7
Nanocladius sp.	0	2	0	1	2
Parakiefferiella spp.	2	1	4	6	1
Parametriocnemus sp.	0	0	2	0	3
Rheocricotopus sp.	0	0	0	1	0
Synorthocladius sp.	0	0	1	1	1
Thienemanniella sp.	2	3	1	1	4
Tvetenia sp.	8	18	2	6	12
Prodiamesinae					
Monodiamesa sp.	2	1	1	0	1
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	1	0	1	3	1
Hydracarina	2	1	0	4	1
Haplotaxida					
Enchytraeidae	4	6	3	9	2
Naididae	9	25	16	34	26
Tubificidae	18	12	29	43	39
Nematoda	1	8	10	11	8

Site 5 - May 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	4	5	4	4	4
Ephemerellidae					
Drunella doddsi	0	0	0	1	0
Ephemerella inermis	7	2	0	4	5
Heptageniidae					
Rhithrogena sp.	22	17	7	19	5
Leptophlebiidae					
Paraleptophlebia sp.	0	0	0	0	1
Trichoptera					
Brachycentridae					
Brachycentrus sp.	6	0	0	0	2
Hydropsychidae					
Hydropsyche sp.	1	0	0	0	0
Plecoptera					
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	1	0	0	0	0
Perlodidae					
Cultus sp.	0	0	0	1	1
Isogenoides sp.	1	0	0	1	0
Isoperla sp.	1	0	0	1	0
Diptera					
Chironomidae					
Chironominae					
Chironomini Tribe					
Polypedilum sp.	1	0	0	0	0
Robackia demeijerei	0	2	0	0	0
Tanytarsini Tribe					
Rheotanytarsus sp.	0	1	1	0	1
Orthocladiinae					
Cricotopus/Orthocladius spp.	38	28	17	20	26
Eukiefferiella sp.	0	1	0	0	0
Parametriocnemus sp.	0	1	0	0	0
Thienemanniella sp.	0	1	0	0	0
Tvetenia sp.	2	0	0	0	1
Prodiamesinae					
Monodiamesa sp.	1	0	0	0	0
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	1	0	0	0	0

(continued)

Site 5 - May 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Haplotaxida					
Enchytraeidae	0	2	1	1	0
Naididae	2	0	2	0	2
Tubificidae	3	12	4	10	2
Nematoda	1	0	0	0	1

Site 6 - May 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	1	2	0	4	1
Ephemerellidae					
Drunella coloradensis	0	0	0	1	0
Ephemerella inermis	1	1	0	7	1
Heptageniidae					
Rhithrogena sp.	3	2	1	3	3
Trichoptera					
Brachycentridae					
Brachycentrus sp.	0	1	1	0	0
Plecoptera					
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	0	1	0	1	0
Chloroperlinae (early instar)	0	0	0	1	0
Perlodidae					
Isogenoides sp.	1	0	1	0	0
Taeniopterygidae					
Taenionema sp.	0	0	1	0	0
Diptera					
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	2	0	0	0	0
Polypedilum spp.	2	1	0	3	1
Tanytarsini Tribe					
Micropsectra sp.	1	2	2	0	1
Rheotanytarsus sp.	1	1	0	1	2
Tanytarsus sp.	1	0	0	0	0
Orthocladiinae					
Corynoneura sp.	1	0	0	0	0
Cricotopus/Orthocladius spp.	85	52	38	39	26
Synorthocladius sp.	0	1	0	0	0
Thienemanniella sp.	0	1	0	1	0
Tvetenia sp.	2	1	0	2	1
Tanypodinae					
Pentaneurini Tribe					
Larsia sp.	0	0	0	1	0
Haplotaxida					
Enchytraeidae	1	1	0	1	0

(continued)

Site 6 - May 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Naididae	0	2	0	5	3
Tubificidae	1	0	1	0	1
Nematoda	0	0	0	1	0

Site 7 - May 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	4	1	1	3	0
Ephemerellidae					
Ephemerella inermis	8	2	8	8	1
Heptageniidae					
Heptagenia sp.	2	0	1	1	0
Rhithrogena sp.	2	7	3	0	0
Siphlonuridae					
Ameletus sp.	0	0	0	0	1
Trichoptera					
Brachycentridae					
Brachycentrus sp.	1	0	0	0	0
Plecoptera					
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	0	1	2	0	2
Chloroperlinae (early instar)	0	1	0	0	0
Nemouridae					
Nemoura sp.	0	0	1	0	0
Perlodidae					
Cultus sp.	0	0	1	0	0
Isoperla sp.	0	0	0	2	1
Diptera					
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	0	0	2	2	0
Paralauterborniella nigrohalteralis	0	0	1	0	0
Polypedilum sp.	1	1	3	2	0
Tanytarsini Tribe					
Micropsectra sp.	7	5	6	3	0
Rheotanytarsus sp.	4	0	1	2	1
Diamesinae					
Diamesini Tribe					
Potthastia gaedii gp.	0	0	0	0	1
Orthocladiinae					
Corynoneura sp.	1	0	0	1	1
Cricotopus/Orthocladius spp.	18	10	28	22	23
Krenosmittia sp.	0	1	0	0	0
Nanocladius sp.	2	0	0	0	0
Thienemanniella sp.	0	2	0	0	0

(continued)

Site 7 - May 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Tvetenia sp.	1	0	0	0	0
Haplotaxida					
Enchytraeidae	2	8	7	3	3
Naididae	8	7	3	3	3
Tubificidae	0	0	0	0	1
Nematoda	0	0	0	0	1

Site 1 - October 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	10	7	8	5	4
Ephemerellidae					
Ephemerella inermis	30	27	24	14	9
Heptageniidae					
Rhithrogena sp.	15	25	26	25	16
Siphlonuridae					
Ameletus sp.	2	1	2	2	8
Trichoptera					
Brachycentridae					
Brachycentrus sp.	0	1	1	2	1
Hydropsychidae					
Hydropsyche sp.	0	0	0	1	0
Plecoptera					
Capniidae	29	26	19	10	13
Chloroperlidae					
Chloroperlinae (early instar)	4	0	2	1	0
Perlidae					
Claassenia sabulosa	0	0	0	1	2
Perlodidae					
Isogenoides sp.	10	9	7	4	1
Isoperla sp.	0	0	0	1	0
Taeniopterygidae					
Taenionema sp.	21	14	14	13	4
Diptera					
Empididae					
Chelifera sp.	0	0	0	0	1
Hemerodromia sp.	1	0	0	0	0
Tipulidae					
Hexatoma sp.	1	0	2	1	0
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	1	1	0	0	0
Polypedilum sp.	2	3	4	2	1
Robackia demeijerei	0	1	0	1	1
Tanytarsini Tribe					
Micropsectra sp.	0	1	0	1	0
Rheotanytarsus spp.	9	5	4	3	2

(continued)

Site 1 - October 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Orthocladiinae					
Brillia sp.	0	0	1	0	0
Cricotopus/Orthocladius spp.	42	41	26	30	24
Eukiefferiella sp.	0	4	4	1	2
Heterotrissocladius sp.	1	0	0	0	0
Nanocladius sp.	0	1	0	0	0
Parakiefferiella sp.	2	3	0	0	0
Rheocricotopus sp.	1	0	0	0	0
Tvetenia spp.	2	2	1	2	0
Prodiamesinae					
Monodiamesa sp.	0	0	0	1	0
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	3	0	1	1	0
Hydracarina	1	0	1	0	0
Haplotaxida					
Enchytraeidae	24	10	4	14	3
Naididae	5	4	0	1	1
Nematoda	0	1	1	0	0

Site 2 - October 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	9	14	12	5	19
Ephemerellidae					
Ephemerella inermis	80	139	217	84	247
Heptageniidae					
Heptagenia sp.	1	0	1	0	2
Rhithrogena sp.	9	42	42	38	84
Siphlonuridae					
Ameletus sp.	3	1	2	0	2
Trichoptera					
Brachycentridae					
Brachycentrus sp.	2	2	0	1	3
Hydropsychidae					
Hydropsyche sp.	0	1	1	0	2
Plecoptera					
Capniidae	38	49	63	43	86
Chloroperlidae					
Chloroperlinae (early instar)	0	0	3	5	2
Perlidae					
Claassenia sabulosa	0	1	0	1	1
Perlodidae					
Cultus sp.	1	2	1	0	1
Isogenoides sp.	0	2	7	0	0
Isoperla sp.	3	1	6	3	5
Taeniopterygidae					
Taenionema sp.	2	2	3	3	20
Diptera					
Empididae					
Chelifera sp.	0	1	0	0	0
Hemerodromia sp.	0	4	1	0	0
Tipulidae					
Hexatoma sp.	0	0	3	0	0
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	13	9	19	6	38
Polypedilum sp.	25	69	86	62	89
Robackia demeijerei	0	1	0	0	0
Tanytarsini Tribe					
Cladotanytarsus sp.	0	2	0	6	4

(continued)

Site 2 - October 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Micropsectra sp.	11	26	48	34	48
Rheotanytarsus spp.	85	175	127	131	184
Sublettea sp.	0	0	5	0	0
Orthocladiinae					
Cricotopus/Orthocladius spp.	175	308	195	315	572
Heleniella sp.	0	1	0	0	0
Nanocladius sp.	2	10	0	0	2
Orthocladius (*Symposiocladius*) *lignicola*	0	0	1	0	0
Parakiefferiella spp.	0	2	5	0	4
Parametriocnemus sp.	0	0	1	0	2
Rheocricotopus sp.	0	1	1	0	0
Synorthocladius sp.	1	0	1	4	2
Thienemanniella sp.	3	4	3	6	4
Tvetenia spp.	7	16	16	20	39
Prodiamesinae					
Monodiamesa sp.	2	2	4	2	0
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	9	3	6	6	7
Hydracarina	2	4	20	8	50
Haplotaxida					
Enchytraeidae	13	4	9	10	4
Naididae	3	2	2	2	0
Tubificidae	0	0	1	0	0
Nematoda	3	9	3	0	7

Site 3 - October 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Ametropodidae					
Ametropus sp.	0	0	0	1	0
Baetidae					
Baetis sp.	17	12	13	15	21
Ephemerellidae					
Ephemerella inermis	12	8	27	38	40
Heptageniidae					
Rhithrogena sp.	7	15	19	39	34
Leptophlebiidae					
Paraleptophlebia sp.	0	0	0	1	0
Siphlonuridae					
Ameletus sp.	0	3	3	3	1
Trichoptera					
Brachycentridae					
Brachycentrus sp.	0	0	1	1	2
Hydropsychidae					
Arctopsyche sp.	0	0	0	1	1
Hydropsyche sp.	1	2	1	6	5
Limnephilidae (early instar)	0	0	0	2	0
Plecoptera					
Capniidae	11	18	11	26	26
Chloroperlidae					
Chloroperlinae (early instar)	0	0	0	1	0
Perlidae					
Claassenia sabulosa	1	0	0	0	0
Hesperoperla pacifica	0	0	0	0	1
Perlodidae					
Cultus sp.	0	1	0	0	0
Isogenoides sp.	0	1	2	0	5
Isoperla sp.	2	1	0	1	4
Taeniopterygidae					
Taenionema sp.	41	32	33	57	71
Diptera					
Empididae					
Hemerodromia sp.	0	0	0	2	0
Tipulidae					
Hexatoma sp.	0	0	0	1	2

(continued)

Site 3 - October 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	0	0	0	0	2
Polypedilum sp.	2	0	2	4	2
Tanytarsini Tribe					
Micropsectra sp.	2	2	0	8	0
Rheotanytarsus sp.	16	38	22	68	36
Sublettea sp.	4	0	0	6	6
Diamesinae					
Diamesini Tribe					
Diamesa sp.	0	1	0	0	0
Orthocladiinae					
Brillia sp.	2	7	2	8	11
Cardiocladius sp.	6	2	5	12	24
Cricotopus/Orthocladius spp.	460	634	569	1,177	1,041
Eukiefferiella spp.	14	24	24	20	28
Synorthocladius sp.	0	0	4	0	0
Thienemanniella sp.	0	2	2	0	0
Tvetenia spp.	0	10	8	4	8
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	2	2	0	3	10
Hydracarina	0	0	0	0	2
Haplotaxida					
Enchytraeidae	0	0	4	0	0
Naididae	0	4	0	18	28
Tubificidae	0	0	1	0	0
Nematoda	2	0	5	3	4

Site 4 - October 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	66	70	41	27	52
Ephemerellidae					
Ephemerella inermis	103	96	107	157	102
Heptageniidae					
Rhithrogena sp.	35	30	15	39	32
Leptophlebiidae					
Paraleptophlebia sp.	4	0	0	0	0
Siphlonuridae					
Ameletus sp.	0	5	0	1	1
Trichoptera					
Brachycentridae					
Brachycentrus sp.	1	1	0	1	1
Hydropsychidae					
Arctopsyche sp.	1	0	0	0	1
Hydropsyche sp.	4	6	4	6	2
Plecoptera					
Capniidae	44	37	40	54	56
Chloroperlidae					
Chloroperlinae (early instar)	0	0	0	0	1
Perlidae					
Claassenia sabulosa	1	0	0	1	0
Perlodidae					
Cultus sp.	4	2	0	4	1
Isogenoides sp.	6	6	5	9	6
Isoperla sp.	8	0	0	0	14
Pteronarcyidae					
Pteronarcys sp.	0	0	0	1	0
Taeniopterygidae					
Taenionema sp.	102	82	64	35	96
Diptera					
Empididae					
Hemerodromia sp.	0	0	0	4	4
Tipulidae					
Hexatoma sp.	0	0	0	0	1
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	4	0	0	0	4
Polypedilum sp.	4	0	0	12	0

(continued)

Site 4 - October 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Tanytarsini Tribe					
Micropsectra sp.	0	8	12	12	0
Rheotanytarsus sp.	90	63	64	158	159
Diamesinae					
Diamesini Tribe					
Diamesa sp.	0	0	0	0	1
Orthocladiinae					
Brillia sp.	0	0	6	4	4
Cardiocladius sp.	0	8	8	4	9
Cricotopus/Orthocladius spp.	1,182	1,215	1,394	1,265	1,468
Eukiefferiella sp.	13	9	12	24	20
Thienemanniella sp.	0	0	0	4	4
Tvetenia spp.	13	17	36	33	49
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	8	5	0	2	0
Hydracarina	0	0	0	4	8
Haplotaxida					
Enchytraeidae	8	8	8	0	4
Naididae	37	32	44	29	32
Tubificidae	1	0	0	6	5
Nematoda	5	6	12	1	5

Site 5 - October 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	17	32	54	8	8
Ephemerellidae					
Ephemerella inermis	42	28	104	38	44
Heptageniidae					
Rhithrogena sp.	44	33	36	35	30
Leptophlebiidae					
Paraleptophlebia sp.	4	0	4	0	0
Siphlonuridae					
Ameletus sp.	1	3	1	0	2
Trichoptera					
Brachycentridae					
Brachycentrus sp.	8	11	17	8	15
Hydropsychidae					
Arctopsyche sp.	0	0	0	1	0
Hydropsyche sp.	3	4	2	5	0
Plecoptera					
Capniidae (early instar)	27	19	33	15	17
Chloroperlidae					
Chloroperlinae	0	4	0	0	0
Perlodidae					
Claassenia sabulosa	0	4	0	4	1
Perlodidae					
Isogenoides sp.	7	1	1	1	3
Isoperla sp.	0	9	13	4	0
Taeniopterygidae					
Taenionema sp.	33	17	66	24	26
Diptera					
Empididae					
Hemerodromia sp.	8	0	5	0	4
Tipulidae					
Hexatoma sp.	0	0	0	1	4
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	16	8	4	4	12
Polypedilum sp.	2	16	20	8	12
Tanytarsini Tribe					
Micropsectra sp.	20	12	12	20	8
Rheotanytarsus sp.	94	81	101	78	94
Sublettea sp.	0	0	0	0	8

(continued)

Site 5 - October 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Orthocladiinae					
Brillia sp.	0	4	0	12	0
Cardiocladius sp.	0	0	4	8	4
Cricotopus/Orthocladius spp.	1,696	1,372	1,567	1,225	1,390
Eukiefferiella sp.	40	48	28	28	73
Parakiefferiella sp.	0	4	4	0	0
Parametriocnemus sp.	0	0	4	0	0
Synorthocladius sp.	0	4	0	0	0
Thienemanniella sp.	4	0	4	0	0
Tvetenia sp.	5	14	42	28	26
Prodiamesinae					
Monodiamesa sp.	4	0	0	0	0
Tanypodinae					
Thienemannimyia gp.	4	4	0	8	6
Hydracarina	4	4	0	1	0
Haplotaxida					
Enchytraeidae	0	0	0	4	4
Naididae	4	12	12	5	0
Nematoda	1	0	4	0	4

Site 6 - October 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	11	28	8	21	20
Ephemerellidae					
Ephemerella inermis	46	44	16	19	31
Heptageniidae					
Rhithrogena sp.	12	18	29	24	5
Leptophlebiidae					
Paraleptophlebia sp.	0	4	0	0	0
Siphlonuridae					
Ameletus sp.	2	2	1	7	1
Trichoptera					
Brachycentridae					
Brachycentrus sp.	3	2	1	0	2
Hydropsychidae					
Hydropsyche sp.	4	0	5	0	1
Plecoptera					
Capniidae	35	32	8	12	7
Chloroperlidae					
Chloroperlinae (early instar)	0	0	0	0	5
Perlodidae					
Isogenoides sp.	0	0	1	0	1
Isoperla sp.	0	0	1	0	4
Pteronarcyidae					
Pteronarcys sp.	0	0	0	1	0
Taeniopterygidae					
Taenionema sp.	36	58	12	23	68
Diptera					
Empididae					
Hemerodromia sp.	0	1	0	0	0
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	4	1	0	0	4
Polypedilum sp.	36	12	4	12	12
Tanytarsini Tribe					
Micropsectra sp.	12	8	0	8	8
Rheotanytarsus sp.	214	73	202	164	183
Sublettea sp.	0	0	0	0	12

(continued)

Site 6 - October 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Diamesinae					
Diamesini Tribe					
Diamesa sp.	4	0	0	0	0
Orthocladiinae					
Brillia sp.	4	0	0	1	4
Cardiocladius sp.	0	0	0	0	12
Corynoneura sp.	0	0	0	4	0
Cricotopus/Orthocladius spp.	883	926	1,138	889	1,020
Eukiefferiella sp.	8	4	24	12	5
Nanocladius sp.	0	4	0	0	0
Parakiefferiella sp.	4	0	0	0	0
Rheocricotopus sp.	0	4	0	0	0
Synorthocladius sp.	0	0	4	0	0
Thienemanniella sp.	0	0	0	0	4
Tvetenia sp.	13	28	8	11	12
Prodiamesinae					
Monodiamesa sp.	4	0	0	0	0
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	0	4	4	4	0
Hydracarina	4	0	0	0	4
Haplotaxida					
Enchytraeidae	0	0	0	4	0
Naididae	11	12	4	20	12
Nematoda	0	8	1	5	5

Site 7 - October 1990

Taxa	Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	68	42	88	51	90
Ephemerellidae					
Ephemerella inermis	80	133	106	62	146
Heptageniidae					
Heptagenia sp.	0	0	4	0	4
Rhithrogena sp.	17	50	35	34	24
Siphlonuridae					
Ameletus sp.	2	3	0	5	7
Trichoptera					
Brachycentridae					
Brachycentrus sp.	0	1	0	0	2
Hydropsychidae					
Hydropsyche sp.	5	0	4	2	1
Plecoptera					
Capniidae	57	46	51	14	50
Chloroperlidae					
Chloroperlinae (early instar)	0	0	4	0	0
Perlidae					
Claassenia sabulosa	0	0	4	1	0
Perlodidae					
Cultus sp.	0	0	1	1	2
Isogenoides sp.	0	0	0	0	1
Isoperla sp.	8	5	2	10	12
Pteronarcyidae					
Pteronarcys sp.	0	1	0	2	0
Taeniopterygidae					
Taenionema sp.	164	119	269	93	92
Diptera					
Empididae					
Hemerodromia sp.	0	0	4	5	4
Chironomidae					
Chironominae					
Chironomini Tribe					
Cyphomella sp.	0	9	8	4	20
Polypedilum sp.	13	8	9	41	20
Tanytarsini Tribe					
Micropsectra sp.	16	17	4	36	12
Rheotanytarsus sp.	154	165	162	142	164
Sublettea sp.	0	12	8	24	0

(continued)

Site 7 - October 1990 (concluded)

Taxa	Sample 1	2	3	4	5
Diamesinae					
Diamesini Tribe					
Diamesa sp.	4	0	0	0	0
Orthocladiinae					
Brillia sp.	0	0	0	0	4
Cardiocladius sp.	22	9	13	24	6
Corynoneura sp.	0	8	0	0	4
Cricotopus/Orthocladius spp.	826	758	1,065	953	901
Eukiefferiella sp.	4	9	4	0	8
Parakiefferiella sp.	4	0	0	4	0
Synorthocladius sp.	0	0	0	8	0
Thienemanniella sp.	4	0	0	8	4
Tvetenia spp.	21	14	16	16	25
Prodiamesinae					
Monodiamesa sp.	0	0	4	4	0
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	8	13	5	4	12
Hydracarina	4	8	0	0	0
Haplotaxida					
Enchytraeidae	12	8	4	4	4
Naididae	16	40	12	13	14
Tubificidae	0	0	0	5	0
Nematoda	12	10	8	0	7

APPENDIX D

NUMBER OF TAXA, NUMBER OF ORGANISMS, STANDING CROP AND SPECIES DIVERSITY OF BENTHIC INVERTEBRATE SAMPLES MAY AND OCTOBER 1990

Appendix D-1. **Number (N) of taxa, number of organisms, standing crop and species diversity of benthic invertebrate samples with means and 95% confidence limits (CL) per site, May 1990.**

Site-Sample	Number of Taxa	Number of Organisms	Standing Crop N/m^2	Species Diversity*
1-1	16	57	639	2.17
1-2	12	46	516	1.97
1-3	16	58	650	1.89
1-4	11	31	348	1.95
1-5	13	95	1,065	1.53
Mean ± 95% CL	14 ± 3	57 ± 29	643 ± 329	1.90 ± 0.29
2-1	18	81	908	2.08
2-2	20	85	953	2.46
2-3	17	91	1,020	1.89
2-4	18	124	1,390	1.91
2-5	22	173	1,939	2.11
Mean ± 95% CL	19 ± 2	111 ± 48	1,242 ± 539	2.09 ± 0.28
3-1	21	404	4,529	1.57
3-2	13	125	1,401	1.29
3-3	19	160	1,794	1.59
3-4	21	86	2,085	1.69
3-5	17	117	1,312	1.72
Mean ± 95% CL	18 ± 4	198 ± 147	2,224 ± 1645	1.57 ± 0.21
4-1	28	316	3,543	2.02
4-2	25	457	5,123	1.83
4-3	28	422	4,731	1.83
4-4	35	554	6,211	2.11
4-5	38	563	6,312	2.05
Mean ± 95% CL	31 ± 7	462 ± 127	5,184 ± 1,419	1.97 ± 0.16
5-1	16	92	1,031	1.89
5-2	11	72	807	1.73
5-3	7	36	404	1.52
5-4	10	62	695	1.71
5-5	12	51	572	1.77
Mean ± 95% CL	11 ± 4	63 ± 26	702 ± 295	1.72 ± 0.16
6-1	14	103	1,155	0.90
6-2	14	69	774	1.18
6-3	7	45	504	0.70
6-4	15	71	796	1.75
6-5	10	40	448	1.37
Mean ± 95% CL	12 ± 4	66 ± 31	735 ± 349	1.18 ± 0.51
7-1	14	61	684	2.22
7-2	12	46	516	2.14
7-3	15	68	762	2.06
7-4	12	52	583	1.96
7-5	12	39	437	1.61
Mean ± 95% CL	13 ± 2	53 ± 14	596 ± 161	2.00 ± 0.29

* Shannon-Weaver Index

Appendix D-2. Number (N) of taxa, number of organisms, standing crop and species diversity of benthic invertebrate samples with means and 95% confidence limits (CL) per site, October 1990.

Site-Sample	Number of Taxa	Number of Organisms	Standing Crop N/m^2	Species Diversity*
1-1	22	216	2,422	2.48
1-2	21	187	2,096	2.41
1-3	20	152	1,704	2.42
1-4	24	137	1,536	2.47
1-5	17	93	1,043	2.29
Mean ± 95% CL	21 ± 3	157 ± 59	1,760 ± 657	2.42 ± 0.10
2-1	25	502	5,628	2.15
2-2	33	909	10,191	2.13
2-3	34	915	10,258	2.36
2-4	23	795	8,913	2.06
2-5	29	1,530	17,152	2.13
Mean ± 95% CL	29 ± 6	930 ± 465	10,428 ± 5,217	2.17 ± 0.14
3-1	18	602	6,749	1.09
3-2	21	819	9,182	1.08
3-3	21	758	8,498	1.19
3-4	28	1,526	17,108	1.13
3-5	26	1,415	15,863	1.28
Mean ± 95% CL	23 ± 5	1,024 ± 518	11,480 ± 5,805	1.15 ± 0.10
4-1	24	1,744	19,552	1.40
4-2	20	1,706	19,126	1.29
4-3	17	1,872	20,987	1.17
4-4	27	1,897	21,267	1.42
4-5	29	2,142	24,013	1.39
Mean ± 95% CL	23 ± 6	1,872 ± 213	20,989 ± 2,385	1.33+0.13
5-1	24	2,088	23,408	0.96
5-2	25	1,748	19,596	1.10
5-3	25	2,142	24,013	1.27
5-4	25	1,573	17,635	1.11
5-5	23	1,795	20,123	1.10
Mean ± 95% CL	24 ± 1	1,869 ± 298	20,955 ± 3,339	1.11 ± 0.14
6-1	21	1,350	15,135	1.35
6-2	21	1,273	14,271	1.25
6-3	19	1,471	16,491	0.90
6-4	19	1,241	13,913	1.18
6-5	25	1,442	16,166	1.23
Mean ± 95% CL	21 ± 3	1,355 ± 125	15,195 ± 1,405	1.18 ± 0.21
7-1	23	1,521	17,052	1.76
7-2	24	1,488	16,682	1.88
7-3	26	1,894	21,233	1.63
7-4	28	1,570	17,601	1.69
7-5	28	1,640	18,386	1.79
Mean ± 95% CL	26 ± 3	1,623 ± 201	18,191 ± 2,257	1.75 ± 0.12

* Shannon-Weaver Index

APPENDIX E

ANALYSIS OF VARIANCE RESULTS

One-way ANOVA on the Number of Taxa for Sites, May 1990.

DUE TO	DF	SS	MS	F-RATIO
Site	6	1,409.4	234.9	22.10 *
Error	28	297.6	10.6	
Total	34	1,707.0		

* Significant ($p < 0.01$) (Table $F_{(0.01;\ 6,28)} = 3.53$)

SNK (a posteriori test) for the Number of Taxa, May 1990.

MEAN	SITE	MEAN NUMBER OF TAXA	MEANS NOT SIGNIFICANTLY DIFFERENT ($p > 0.05$)
$\bar{Y}_1$	5	11	
$\bar{Y}_2$	6	12	
$\bar{Y}_3$	7	13	
$\bar{Y}_4$	1	14	
$\bar{Y}_5$	3	18	
$\bar{Y}_6$	2	19	
$\bar{Y}_7$	4	31	

$k = 7$	$\bar{Y}_7 - \bar{Y}_1 = 31 - 11$	$= 20$*	$LSR_7 = 6.537$
$k = 6$	$\bar{Y}_7 - \bar{Y}_2 = 31 - 12$	$= 19$*	$LSR_6 = 6.299$
	$\bar{Y}_6 - \bar{Y}_1 = 19 - 11$	$= 8$*	
$k = 5$	$\bar{Y}_7 - \bar{Y}_3 = 31 - 13$	$= 18$*	$LSR_5 = 6.003$
	$\bar{Y}_6 - \bar{Y}_2 = 19 - 12$	$= 7$*	
	$\bar{Y}_5 - \bar{Y}_1 = 18 - 11$	$= 7$*	
$k = 4$	$\bar{Y}_7 - \bar{Y}_4 = 31 - 14$	$= 17$*	$LSR_4 = 5.626$
	$\bar{Y}_6 - \bar{Y}_3 = 19 - 13$	$= 6$*	
	$\bar{Y}_5 - \bar{Y}_2 = 18 - 12$	$= 6$*	
	$\bar{Y}_4 - \bar{Y}_1 = 14 - 11$	$= 3$**	
$k = 3$	$\bar{Y}_7 - \bar{Y}_5 = 31 - 18$	$= 13$*	$LSR_3 = 5.097$
	$\bar{Y}_6 - \bar{Y}_4 = 19 - 14$	$= 5$**	
	$\bar{Y}_5 - \bar{Y}_3 = 18 - 13$	$= 5$**	
$k = 2$	$\bar{Y}_7 - \bar{Y}_6 = 31 - 19$	$= 12$*	$LSR_2 = 4.219$

* Significant at $p < 0.05$
** Not significant at $p > 0.05$
k Number of groups over which the range is computed.
LSR_a Least significant range for 2, 3 ... a means.

One-way ANOVA on the Number of Organisms for Sites, May 1990.

DUE TO	DF	SS	MS	F-RATIO
Site	6	669,780	111,630	28.26 *
Error	28	110,598	3,950	
Total	34	780,378		

* Significant ($p < 0.01$) (Table $F_{(0.01;\ 6,28)} = 3.53$)

SNK (a posteriori test) for the Number of Organisms, May 1990.

MEAN	SITE	MEAN NUMBER OF ORGANISMS	MEANS NOT SIGNIFICANTLY DIFFERENT ($p > 0.05$)
$\bar{Y}_1$	7	53	|
$\bar{Y}_2$	1	57	|
$\bar{Y}_3$	5	63	|
$\bar{Y}_4$	6	66	|
$\bar{Y}_5$	2	111	|
$\bar{Y}_6$	3	198	
$\bar{Y}_7$	4	462	

$k = 7$	$\bar{Y}_7 - \bar{Y}_1$	$= 462 - 53$	$= 409$*	$LSR_7 = 126.200$
$k = 6$	$\bar{Y}_7 - \bar{Y}_2$	$= 462 - 57$	$= 405$*	$LSR_6 = 121.590$
	$\bar{Y}_6 - \bar{Y}_1$	$= 198 - 53$	$= 145$*	
$k = 5$	$\bar{Y}_7 - \bar{Y}_3$	$= 462 - 63$	$= 399$*	$LSR_5 = 115.885$
	$\bar{Y}_6 - \bar{Y}_2$	$= 198 - 57$	$= 141$*	
	$\bar{Y}_5 - \bar{Y}_1$	$= 111 - 53$	$= 58$**	
$k = 4$	$\bar{Y}_7 - \bar{Y}_4$	$= 462 - 66$	$= 396$*	$LSR_4 = 108.605$
	$\bar{Y}_6 - \bar{Y}_3$	$= 198 - 63$	$= 135$*	
$k = 3$	$\bar{Y}_7 - \bar{Y}_5$	$= 462 - 111$	$=351$*	$LSR_3 = 98.402$
	$\bar{Y}_6 - \bar{Y}_4$	$= 198 - 66$	$= 132$*	
$k = 2$	$\bar{Y}_7 - \bar{Y}_6$	$= 462 - 198$	$=264$*	$LSR_2 = 81.454$
	$\bar{Y}_6 - \bar{Y}_5$	$= 198 - 111$	$= 87$*	

* Significant at $p < 0.05$

** Not significant at $p > 0.05$

k Number of groups over which the range is computed.

LSR_a Least significant range for 2, 3 ... a means.

One-way ANOVA on the Number of Taxa for Sites, October 1990.

DUE TO	DF	SS	MS	F-RATIO
Site	6	236.7	39.4	3.33 *
Error	28	331.6	11.8	
Total	34	568.3		

* Significant ($p < 0.05$) (Table $F_{(0.05;\ 6,28)} = 2.45$)

SNK (a posteriori test) for the Number of Taxa, October 1990.

MEAN	SITE	MEAN NUMBER OF TAXA	MEANS NOT SIGNIFICANTLY DIFFERENT ($p > 0.05$)
$\bar{Y}_1$	1 & 6	21	
$\bar{Y}_2$	3 & 4	23	
$\bar{Y}_3$	5	24	
$\bar{Y}_4$	7	26	
$\bar{Y}_5$	2	29	
$k = 5$	$\bar{Y}_5 - \bar{Y}_1 = 29 - 21$	= 8*	$LSR_5 = 6.334$
$k = 4$	$\bar{Y}_5 - \bar{Y}_2 = 29 - 23$	= 6*	$LSR_4 = 5.936$
	$\bar{Y}_4 - \bar{Y}_1 = 26 - 21$	= 5**	
$k = 3$	$\bar{Y}_5 - \bar{Y}_3 = 29 - 24$	= 5**	$LSR_3 = 5.378$

* Significant at $p < 0.05$
** Not significant at $p > 0.05$
k Number of groups over which the range is computed.
LSR_a Least significant range for 2, 3 ... a means.

One-way ANOVA on the Number of Organisms for Sites, October 1990.

DUE TO	DF	SS	MS	F-RATIO
Site	6	11,337,752	1,889,625	30.06 *
Error	28	1,760,351	62,870	
Total	34	13,098,103		

* Significant ($p < 0.01$) (Table $F_{(0.01;\ 6,28)} = 3.53$)

SNK (a posteriori test) for the Number of Organisms, October 1990.

MEAN	SITE	MEAN NUMBER OF ORGANISMS	MEANS NOT SIGNIFICANTLY DIFFERENT ($p > 0.05$)
$\bar{Y}_1$	1	157	
$\bar{Y}_2$	2	930	
$\bar{Y}_3$	3	1024	
$\bar{Y}_4$	6	1355	
$\bar{Y}_5$	7	1623	
$\bar{Y}_6$	5	1869	
$\bar{Y}_7$	4	1872	

$k = 7$	$\bar{Y}_7 - \bar{Y}_1 = 1872 - 157 = 1715^*$	$LSR_7 = 503.481$
$k = 6$	$\bar{Y}_7 - \bar{Y}_2 = 1872 - 930 = 942^*$	$LSR_6 = 485.091$
	$\bar{Y}_6 - \bar{Y}_1 = 1869 - 157 = 1712^*$	
$k = 5$	$\bar{Y}_7 - \bar{Y}_3 = 1872 - 1024 = 848^*$	$LSR_5 = 462.328$
	$\bar{Y}_6 - \bar{Y}_2 = 1869 - 930 = 939^*$	
	$\bar{Y}_5 - \bar{Y}_1 = 1623 - 157 = 1466^*$	
$k = 4$	$\bar{Y}_7 - \bar{Y}_4 = 1872 - 1355 = 517^*$	$LSR_4 = 433.285$
	$\bar{Y}_6 - \bar{Y}_3 = 1869 - 1024 = 845^*$	
	$\bar{Y}_5 - \bar{Y}_2 = 1623 - 930 = 693^*$	
	$\bar{Y}_4 - \bar{Y}_1 = 1355 - 157 = 1198^*$	
$k = 3$	$\bar{Y}_7 - \bar{Y}_5 = 1872 - 1623 = 249^{**}$	$LSR_3 = 392.580$
	$\bar{Y}_6 - \bar{Y}_4 = 1869 - 1355 = 514^*$	
	$\bar{Y}_5 - \bar{Y}_3 = 1623 - 1024 = 599^*$	
	$\bar{Y}_4 - \bar{Y}_2 = 1355 - 930 = 425^*$	
	$\bar{Y}_3 - \bar{Y}_1 = 1024 - 157 = 867^*$	

(continued)

SNK for the Number of Organisms, October 1990 (concluded)

k = 2	$\bar{Y}_5 - \bar{Y}_4$ = 1623 - 1355 = 268**		LSR_2 = 324.964
	$\bar{Y}_4 - \bar{Y}_3$ = 1355 - 1024 = 331*		
	$\bar{Y}_3 - \bar{Y}_2$ = 1024 - 930 = 94**		
	$\bar{Y}_2 - \bar{Y}_1$ = 930 - 157 = 773*		

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*	Significant at $p < 0.05$
**	Not significant at $p > 0.05$
k	Number of groups over which the range is computed.
LSR_a	Least significant range for 2, 3 ... a means.

APPENDIX F

RESULTS OF RA ANALYSIS (SPECIES DOMINANCE DISTRIBUTION MATRICES), MAY AND OCTOBER 1990

Appendix F-1. Species dominance distribution matrix for each sample site, May 1990.

Species Code / Site	5	5	5	5	5	3	4	4	4	3	3	4	6	1	4	6	6	3	3	6	1	6	1	1	1	2	2	7	2	2	7	2	7	7	7
Sample	4	2	3	1	5	4	3	1	5	5	2	4	3	2	2	5	1	3	1	2	5	4	1	3	4	1	4	5	5	3	4	2	2	3	1
004	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
049	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
089	1	1	1	+	+	+	+	+	+	+	-	+	+	-	+	+	+	+	+	-	-	-	-	+	-	+	+	+	+	-	-	-	-	-	-
068	-	+	-	-	-	+	+	-	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
040	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
009	3	2	2	2	1	1	+	+	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	1	+	+
012	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
007	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
002	+	+	1	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	-	+	+	+	-	+	-	-	+	+	+	+	+	+	+
021	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
034	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
039	-	-	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
064	-	+	-	-	-	+	+	+	+	+	+	+	-	+	+	-	-	+	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-
109	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
067	-	-	-	-	-	-	+	+	+	-	-	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
029	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	+	-	+	-
074	-	-	-	+	-	-	+	+	+	-	-	-	-	-	+	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
035	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
058	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
030	+	-	-	+	-	+	+	+	+	+	-	+	+	-	+	-	+	+	+	-	-	-	+	+	+	-	-	-	-	-	-	+	-	-	-
069	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
063	3	4	5	4	6	7	6	5	5	6	8	5	9	4	6	7	9	7	7	8	7	6	4	6	4	5	5	6	5	6	5	3	2	4	3
072	-	-	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	+	-	+	-	+	+	-	+	+	-	+	-	-	+
016	-	-	-	+	+	-	+	+	+	+	+	+	+	+	+	-	-	+	-	+	-	-	+	-	+	+	-	-	+	-	-	+	-	-	+
085	-	-	-	-	-	-	-	+	+	-	-	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
077	-	-	-	+	-	-	+	+	+	-	-	+	-	-	-	-	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	+	-	-	-
092	-	-	-	+	+	+	+	+	+	+	+	+	-	+	+	-	-	+	+	-	+	+	+	+	+	+	+	+	+	+	-	+	-	-	-
028	-	-	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
031	+	-	-	+	-	+	+	-	+	-	-	+	-	-	+	-	-	-	+	-	+	-	-	+	+	-	-	+	-	-	+	-	-	-	-
005	+	+	-	+	1	+	1	1	1	+	+	1	-	1	1	+	+	+	1	+	1	1	+	+	+	+	1	+	1	1	1	1	+	1	1
096	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
075	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
070	-	-	-	-	-	-	+	-	+	-	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-
073	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
071	-	+	-	-	-	+	+	+	+	-	-	+	-	-	+	-	-	-	-	+	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-
014	-	-	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
048	-	-	-	+	-	+	+	+	+	+	+	+	-	1	+	+	+	+	+	+	+	+	+	+	+	-	+	-	-	-	+	+	+	+	+
055	-	+	+	-	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1	-	+	+
057	-	-	-	-	-	+	+	-	-	-	+	+	-	-	+	-	-	-	+	-	-	-	-	-	-	+	+	-	-	+	-	+	-	-	-
038	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
052	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	-	+	+	-	+	-	-	-	-	-	-
098	-	-	-	+	-	+	+	+	+	+	-	+	-	-	+	-	-	+	-	+	+	+	-	-	-	-	+	+	-	+	-	-	+	+	-
087	+	+	+	-	-	-	+	+	+	-	+	+	-	1	+	-	+	+	+	+	+	+	1	1	2	+	+	+	+	+	+	+	2	1	+

(continued)

Appendix F-1. (concluded)

Species	Site																																		
	5	5	5	5	5	3	4	4	4	3	3	4	6	1	4	6	6	3	3	6	1	6	1	1	1	2	2	7	2	2	7	2	7	7	7
	Sample																																		
Code	4	2	3	1	5	4	3	1	5	5	2	4	3	2	2	5	1	3	1	2	5	4	1	3	4	1	4	5	5	3	4	2	2	3	1
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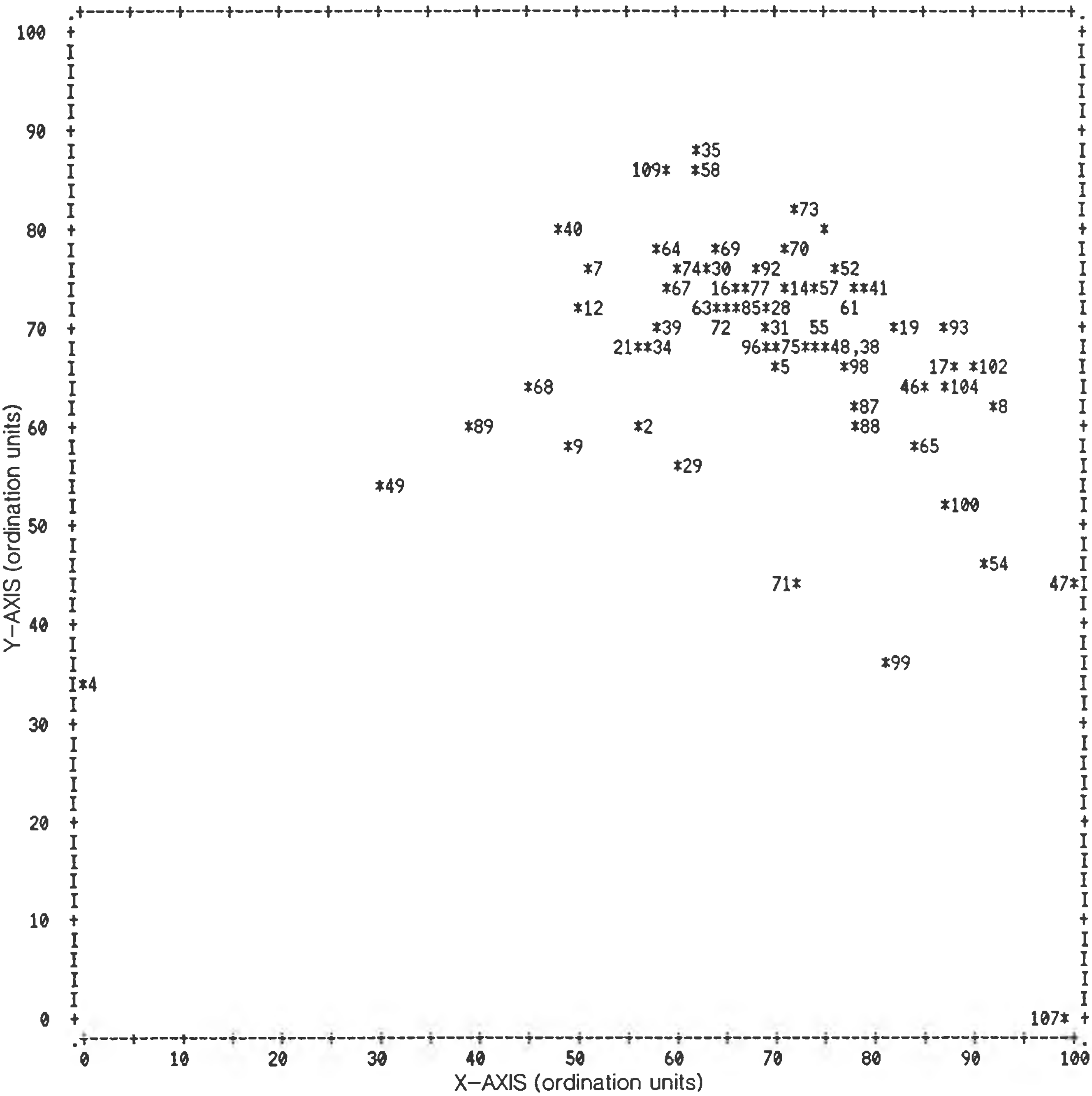
088	-	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	+	+	+	+	+	+	-	-	1	1	+	1	+	+	1	1	+	1
041	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-
099	-	-	-	-	-	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-
019	-	-	-	+	-	+	+	+	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	+	-	+	-	-	-
065	-	-	-	-	-	-	-	-	+	+	-	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+
046	-	-	-	-	-	-	-	+	+	-	-	+	-	-	+	-	+	-	-	-	+	-	-	-	-	+	+	-	+	+	+	+	-	+	-
104	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+
100	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
093	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-
017	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
102	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-
054	-	-	-	-	-	-	+	-	+	-	-	+	+	-	+	+	+	-	-	+	-	-	-	+	-	-	-	-	+	+	+	+	1	1	1
008	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	+	+	+	-	+	+
107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
047	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-

\+ present
\- absent
1 to 9 weighted abundance scores



Appendix F-2. **Reciprocal averaging ordination of species scores, May 1990.**

Appendix F-3. Species dominance distribution matrix for each sample site, October 1990.

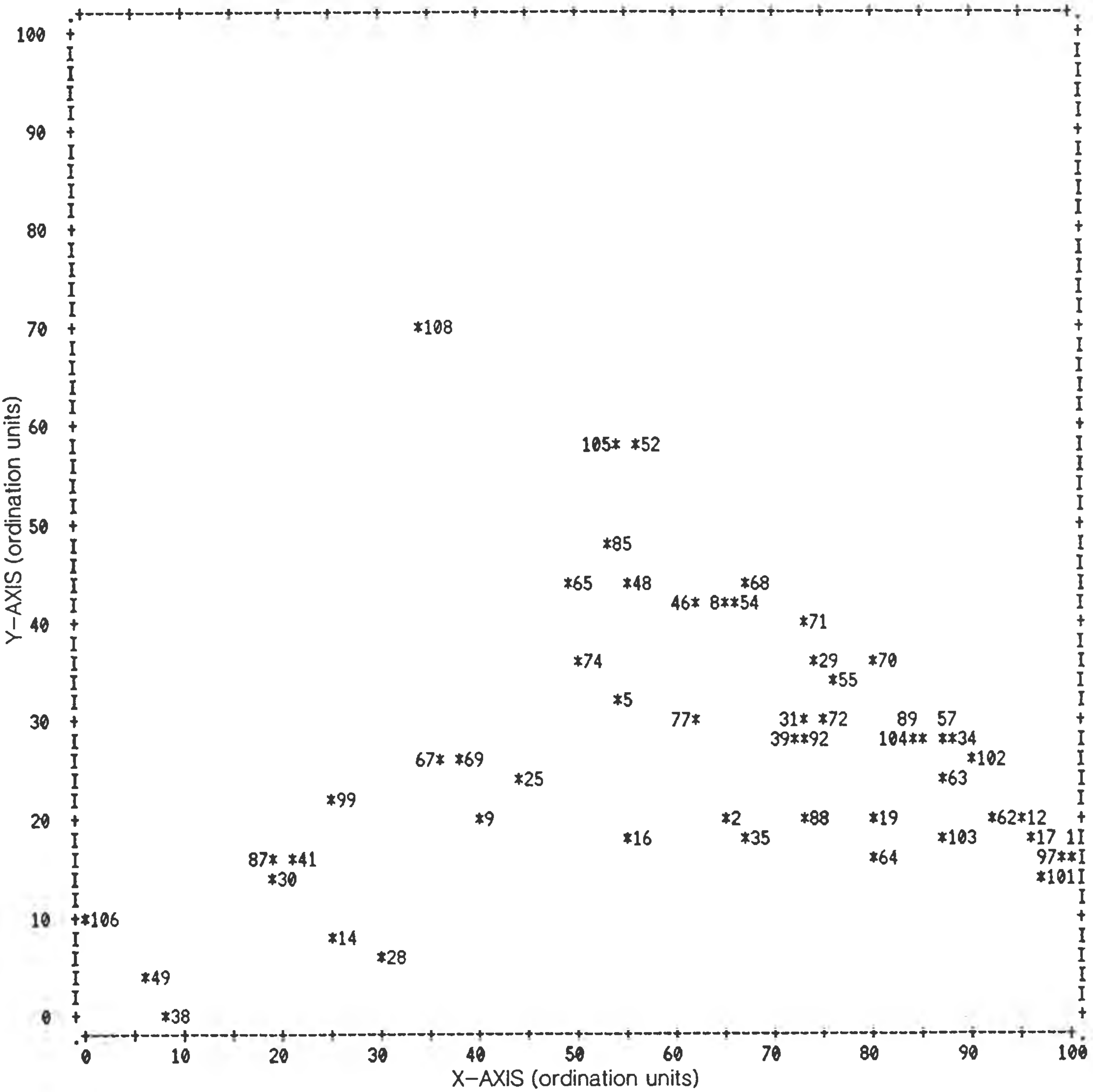
Site	1	1	1	1	1	2	2	2	2	2	7	7	7	7	7	4	4	4	6	4	6	5	4	3	3	6	3	5	6	5	5	3	3	5	6
Species Code / Sample	1	4	5	3	2	3	1	5	2	4	2	5	1	3	4	4	1	2	1	5	2	3	3	3	5	4	4	2	5	4	5	1	2	1	3
106	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
049	-	+	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
038	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
087	1	1	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	-	-	+	+	-	+	-	-	-	+	+	-	-	-	-
030	+	+	+	+	+	+	-	-	+	-	-	+	-	-	-	+	+	+	-	+	-	+	+	+	+	-	-	+	+	+	+	-	+	+	+
041	+	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	+	-	-	+	+	-	-	-	-
099	+	+	-	+	-	+	-	+	-	+	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-
014	+	+	1	+	+	+	+	+	+	-	+	+	+	-	+	+	-	+	+	+	+	+	-	+	+	+	+	+	+	-	+	-	+	+	+
028	-	+	+	-	-	-	-	+	+	+	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	+	-	+	+	+	-	-	-
108	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
067	+	-	-	-	+	+	-	+	+	-	-	-	+	-	+	-	-	-	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-
069	+	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
009	+	2	2	2	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
025	1	+	1	1	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
065	-	-	-	-	+	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
074	-	+	-	-	-	+	+	-	+	+	-	-	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
085	+	-	-	+	-	+	+	+	+	+	+	-	+	-	-	+	-	-	+	+	-	-	-	-	+	-	-	+	+	+	-	-	-	+	-
105	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
005	1	1	1	1	1	2	1	1	1	1	1	1	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
016	-	+	+	+	+	-	+	+	+	+	+	+	-	-	-	+	+	+	+	+	+	+	-	+	+	-	+	+	+	+	+	-	-	+	+
048	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+
052	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
077	+	+	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	-	-	-	+	+	+	+	-	+	+	+	+	+	+
046	+	-	-	-	+	+	+	+	+	+	+	+	-	+	+	-	+	-	+	+	+	+	-	-	+	-	-	+	+	+	+	-	-	+	-
008	-	-	-	-	-	+	+	+	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
002	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
054	-	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	+	+	-	-	+	+	+	+	+	+	+	+	+	-
068	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
035	1	1	+	1	+	+	+	+	+	+	+	+	1	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
039	+	-	-	-	-	+	-	-	+	-	-	+	-	+	+	+	-	-	-	+	+	+	-	-	-	-	+	-	-	-	+	-	-	+	-
071	-	-	-	-	-	+	+	+	+	+	-	+	+	-	+	+	-	-	-	+	-	+	-	+	-	-	-	-	+	-	-	-	+	+	-
092	-	-	-	+	+	+	+	+	+	-	+	+	+	+	-	+	+	+	-	+	+	+	+	+	+	+	+	-	+	-	+	+	-	+	+
088	+	+	+	-	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	-	-	+	+	+
031	-	+	-	-	-	+	+	+	+	+	+	+	+	+	+	-	+	-	-	+	-	+	-	-	+	-	+	+	+	+	-	+	+	-	+
029	-	-	-	-	-	+	+	+	+	-	-	+	-	+	+	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
072	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+
055	+	+	+	+	+	1	2	1	2	2	1	1	1	1	1	1	+	+	1	+	+	+	+	+	+	1	+	+	1	+	+	+	+	+	1
070	-	-	-	-	-	+	+	+	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	+
019	-	+	-	-	-	+	-	+	+	-	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	-	+	+	+	+	-	+	+	+	+
064	-	+	+	+	+	-	-	-	-	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
104	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-

(continued)

Appendix F-3. (concluded)

Species Code \ Site	1	1	1	1	1	2	2	2	2	2	7	7	7	7	7	4	4	4	6	4	6	5	4	3	3	6	3	5	6	5	5	3	3	5	6
Sample	1	4	5	3	2	3	1	5	2	4	2	5	1	3	4	4	1	2	1	5	2	3	3	3	5	4	4	2	5	4	5	1	2	1	3
089	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	+	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
063	2	2	3	2	2	2	4	4	4	4	6	6	6	6	7	8	8	8	8	8	8	9	9	9	9	8	9	9	8	9	9	9	9	9	9
057	-	-	-	-	-	+	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	+	+	-	-	-
103	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	+	-	-	+	+	-	-	+	+	+	+	+	+	+	+	-	+	+	-	-
034	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
102	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
062	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	-	+	-	+	-	+	+	+	+	-	+	-	+	+	+	+	+	-	-
012	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	-	-	-	-	+	-	-	-	-	-	-	+	-
017	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	+	-	+	-	-	+	-	-	-	-	-
101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
097	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-

+ present
- absent
1 to 9 weighted abundance score



Appendix F-4. **Reciprocal averaging ordination of species scores, October 1990.**

APPENDIX G

PERCENT COMPOSITION OF BENTHIC INVERTEBRATE FUNCTIONAL FEEDING GROUPS MAY AND OCTOBER 1990

Appendix G-1. Percent composition of benthic invertebrate functional feeding groups for each sample and site (pooled samples), May 1990.

Site-Sample	Functional Feeding Group (percent)						
	C	H	D	HC	DH	CD	O
1-1	3.5	-	29.8	-	61.4	-	5.3
1-2	-	-	23.9	-	69.6	-	6.5
1-3	5.2	-	29.3	-	65.5	-	-
1-4	9.7	-	29.0	-	54.8	-	6.5
1-5	4.2	-	12.6	-	83.2	-	-
Pooled Sample	4.2	-	23.0	-	70.0	-	2.8
2-1	1.2	-	28.4	-	65.4	1.2	3.7
2-2	4.7	-	31.8	-	54.1	-	9.4
2-3	3.3	-	20.9	-	69.2	-	6.6
2-4	4.0	-	37.9	-	57.3	-	0.8
2-5	-	-	31.2	-	63.0	-	5.8
Pooled Sample	2.3	-	30.7	-	61.7	0.2	5.1
3-1	1.7	-	16.1	-	82.2	-	-
3-2	-	-	11.2	-	86.4	-	2.4
3-3	5.0	-	11.3	-	80.0	-	3.8
3-4	3.2	-	11.3	-	83.9	-	1.6
3-5	4.3	-	15.4	-	75.2	-	5.1
Pooled Sample	2.6	-	13.7	-	81.9	-	1.8
4-1	2.5	-	19.0	-	77.5	0.3	0.6
4-2	2.0	-	21.9	-	75.5	-	0.7
4-3	2.6	-	22.0	-	74.4	0.2	0.7
4-4	2.7	-	29.4	-	64.8	0.2	2.9
4-5	1.8	-	24.7	-	72.3	0.4	0.9
Pooled Sample	2.3	-	24.0	-	72.2	0.2	1.3
5-1	4.3	-	9.8	-	78.3	-	7.6
5-2	-	-	26.4	-	73.6	-	-
5-3	-	-	22.2	-	77.8	-	-
5-4	4.8	1.6	17.7	-	75.8	-	-
5-5	2.0	-	13.7	-	80.4	-	3.9
Pooled Sample	2.6	0.3	17.3	-	77.0	-	2.9
6-1	1.0	-	9.7	-	89.3	-	-
6-2	1.4	-	13.0	-	84.1	-	1.4
6-3	2.2	2.2	6.7	-	86.7	-	2.2
6-4	4.2	1.4	15.5	-	78.9	-	-
6-5	-	-	20.0	-	80.0	-	-
Pooled Sample	1.8	0.6	12.5	-	84.5	-	0.6
7-1	-	-	41.0	-	57.4	-	1.6
7-2	4.3	-	50.0	-	45.7	-	-
7-3	4.4	-	30.9	-	64.7	-	-
7-4	3.8	-	26.9	-	69.2	-	-
7-5	7.7	-	25.6	-	66.7	-	-
Pooled Sample	3.8	-	35.0	-	60.9	-	0.4

Appendix G-2. **Percent composition of benthic invertebrate functional feeding groups for each sample and site (pooled samples), October 1990.**

Site-Sample	Functional Feeding Group (percent) C	H	D	HC	DH	CD	O
1-1	8.8	9.7	33.8	-	47.2	0.5	-
1-2	4.8	7.5	29.4	-	57.8	-	0.5
1-3	8.6	9.2	19.7	-	61.8	-	0.7
1-4	6.6	9.5	24.1	-	57.7	-	2.2
1-5	3.2	4.3	21.5	-	68.8	1.1	1.1
Pooled Sample	6.8	8.4	26.9	-	56.9	0.3	0.8
2-1	3.0	0.4	36.1	-	60.2	-	0.4
2-2	1.4	0.2	34.3	-	63.1	0.6	0.3
2-3	5.0	0.3	33.7	-	60.8	0.1	0.1
2-4	2.9	0.4	33.2	-	63.4	-	0.1
2-5	4.3	1.3	27.7	-	66.3	-	0.3
Pooled Sample	3.5	0.6	32.0	-	63.4	0.1	0.3
3-1	1.8	6.8	6.1	-	85.0	-	0.2
3-2	0.9	3.9	10.0	-	85.0	-	0.2
3-3	0.9	4.4	7.8	-	86.7	-	0.3
3-4	1.2	3.7	9.3	-	85.1	0.1	0.5
3-5	3.4	5.0	8.6	-	82.5	-	0.6
Pooled Sample	1.8	4.6	8.6	-	84.6	<0.1	0.4
4-1	1.5	5.8	11.6	-	80.7	-	0.3
4-2	1.2	4.8	10.0	-	83.5	-	0.4
4-3	0.7	3.4	11.9	-	83.8	-	0.2
4-4	1.3	1.8	15.9	-	80.4	0.2	0.4
4-5	1.9	4.5	15.1	-	78.2	0.2	0.2
Pooled Sample	1.3	4.0	13.0	-	81.2	0.1	0.3
5-1	0.7	1.6	8.4	-	88.4	0.4	0.5
5-2	1.5	1.0	9.0	-	87.6	-	0.9
5-3	0.8	3.1	10.3	-	84.7	0.2	0.9
5-4	1.7	1.5	10.6	-	85.3	-	0.9
5-5	1.0	1.4	9.6	-	86.9	0.2	0.8
Pooled Sample	1.1	1.8	9.5	-	86.6	0.2	0.8
6-1	0.3	2.7	22.6	-	73.9	-	0.5
6-2	0.3	4.6	13.0	-	81.9	0.1	0.2
6-3	0.4	0.8	15.4	-	82.9	-	0.4
6-4	0.3	1.9	18.5	-	79.4	-	-
6-5	1.8	4.7	17.4	-	75.9	-	0.2
Pooled Sample	0.6	2.9	17.4	-	78.8	<0.1	0.3
7-1	2.8	10.8	19.7	-	66.4	-	0.3
7-2	2.4	8.0	22.1	-	67.5	-	0.1
7-3	1.5	14.2	14.6	-	69.2	0.2	0.2
7-4	2.5	5.9	18.0	-	73.1	0.3	0.1
7-5	2.0	5.6	18.8	-	73.2	0.2	0.2
Pooled Sample	2.2	9.1	18.4	-	69.9	0.2	0.2