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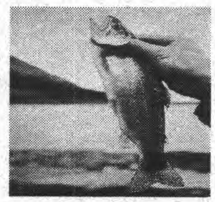
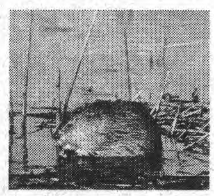


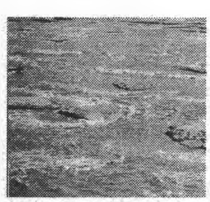


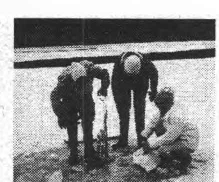
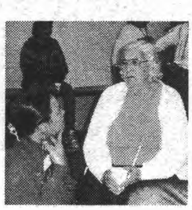
NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 59

ECOTOXICOLOGY OF DEPOSITIONAL SEDIMENTS

ATHABASCA RIVER

MAY AND SEPTEMBER, 1993



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by

Kristin Day and T. B. Reynoldson
National Water Research Institute

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

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Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
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(Dr. F. J. Wrona, Ph.D., Science Director) — 7 June 95 (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
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Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

(Lucille Partington, Co-chair) — 2 June 95 (Date)

(Robert McLeod, Co-chair) — June 12, 1995 (Date)

ECOTOXICOLOGY OF DEPOSITIONAL SEDIMENTS ATHABASCA RIVER, MAY AND SEPTEMBER, 1993

STUDY PERSPECTIVE

Organic contaminants which enter aquatic ecosystems can become associated with particles of organic and inorganic materials in depositional zones. The presence and persistence of contaminants in these sediment depositional zones may constitute a source of toxicity to organisms which live on or near the substrate. As an example, benthic invertebrates are bottom-dwelling organisms that are very sensitive to environmental change. Toxicity from contaminants may have direct impacts on these species as well as indirect effects on other organisms which use them as food. Benthic invertebrates are considered good overall indicators of contaminants in sediments because, as a group, they are in direct contact with sediment solids. Sediment quality can be described through a three part study (TRIAD) examining the benthic invertebrate community structure, the toxicity of depositional sediments on selected life forms, followed by contaminant analyses of these sediments if results from toxicity testing are positive.

Related Study Questions

1a) *How has the aquatic ecosystem, including fish and/or other aquatic organisms, been affected by exposure to organochlorines or other toxic compounds?*

4a) *What are the contents and nature of the contaminants entering the system and what is their distribution and toxicity in the aquatic ecosystem with particular reference to water, sediments and biota?*

13b) *What are the cumulative effects of man-made discharges on the water and aquatic environment?*

14) *What long term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems? These programs must ensure that all stakeholders have the opportunity for input.*

This project was designed to test the toxicity of depositional sediments from the upper Athabasca River using freshwater benthic invertebrates in chronic exposure studies under laboratory conditions. Additional analyses were performed on the *in situ* benthic invertebrate community structure to describe species distribution and abundance. Information from these tests will be used to determine cumulative effects of the Hinton combined effluent by comparing upstream and downstream sites.

In 1993, sediments and benthic invertebrates were collected from depositional areas on the upper Athabasca River upstream and downstream of Hinton; eight sites in May and seven sites in September. Sediments from these sites were subjected to chronic toxicity tests in the laboratory using four species of bottom-dwelling invertebrates; an amphipod, a chironomid, a mayfly and an oligochaete worm. The tests measured the effects of exposure to potentially contaminated sediments over a 10-day or 28-day period using the young of each species. The endpoints that were measured include survival, growth (amphipod, chironomid and mayfly) and reproduction (oligochaete worm). Sediments tested with the four species of invertebrates exhibited low toxicity in the laboratory with the exception of sediments collected downstream of Hinton, near the mouth of the Berland River and at the Windfall Bridge. At these two sites, reproduction of the oligochaete worm was reduced compared to the upstream control sites. Invertebrate species diversity was also reduced at Windfall Bridge for samples collected in the fall of 1993. Elevated levels of several metals at both sites, the high percentage of sand at the Berland River site, as well as other unmeasured contaminants may have contributed to the observed toxicity and reduced diversity.

Toxicity testing under laboratory conditions in this study indicated that further work is required. Nonetheless, this information will be incorporated into a multivariate statistical model to determine the environmental health for the reach of the river that was investigated. Results from this research will also assist with the task of cumulative effects assessment and development of biomonitoring guidelines for the rivers.

REPORT SUMMARY

The following report summarizes the results from the toxicological testing of depositional sediments in the upper Athabasca River using freshwater benthic invertebrates in chronic exposure studies under laboratory conditions as well as analyses of the *in situ* benthic invertebrate community structure. Sediments were collected at one or two sites upstream from Hinton (one control at site ARC in May 1993 and two controls at sites ARC and ARC2 in September 1993) and at five to six sites at varying distances downstream from Hinton on the same dates in the spring and fall. The four species of benthic invertebrates used in the tests were the amphipod, *Hyalella azteca*, the chironomid, *Chironomus riparius*, the mayfly, *Hexagenia spp.* and the oligochaete worm, *Tubifex tubifex*. The toxicity tests were conducted under controlled laboratory conditions and utilized young of each species. The tests measured the effects of exposure to potentially contaminated sediments over 10-d to 28-d depending on species. The endpoints determined were survival, growth (*H. azteca, C. riparius and Hexagenia*) and reproduction (*T. tubifex*). The structure of the benthic invertebrate communities at all sites were determined using percent abundance and three diversity indices (Shannon-Wiener, Simpson's and Margalef's).

All sediments tested with the four species of invertebrates exhibited low toxicity in the laboratory with the exception of sediments collected upstream of the Berland River (BR) and near Windfall Bridge (WB). At these two sites, reproduction by the tubificid worm, *T. tubifex*, was reduced compared to the control sites and this reduction was statistically significant at WB. Diversity was also reduced at Windfall Bridge for samples collected in the fall of 1993 for benthic invertebrate community structure. Levels of several metals, *i.e.*, arsenic, nickel, chromium and cadmium were slightly above the low effects level (LEL) set for another province (Ontario) at these two sites. In addition, the particle size distribution at BR-T consisted of a high percentage of sand. These two factors as well as other unmeasured contaminants may have contributed to the observed toxicity and reduced diversity.

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1.0 INTRODUCTION

Many organic contaminants which enter aquatic ecosystems become associated with particles of organic material in low-energy depositional zones in the benthic environments. The presence and persistence of contaminants which sorb to organic material in these zones may consititute a source of toxicity to organisms which live in or near the substrate such as epibenthic and burrowing invertebrates. Such toxicity may have direct detrimental effects on these species as well as indirect effects on the other organisms which use them as food (i.e., many species of fish, amphibians or shore-birds).

There have been very few studies in riverine environments in Canada which address the question of the toxicity of contaminants in sediments to organisms which live in or near this environment. This is mainly due to a shortage of standardized methodologies for assessing toxicity to benthic organisms as well as the lack of a multi-disciplinary approach to determining the effects of contaminants on ecosystem health. Benthic invertebrates have been traditionally considered the best overall indicators of contamination in sediments because, as a group, they are in direct contact with sediment solids as well as the interstitial waters and they have been effective in a wide range of studies (Burton et al. 1992; ASTM 1993; USEPA 1994). The Sediment Quality Triad (Chapman 1990) is an effects-based approach used to describe sediment quality which incorporates measures of sediment chemistry (grain size, metals, organic content, etc.), sediment toxicity (whole-sediment laboratory bioassays) and benthic infaunal community structure (diversity, richness, etc.).

Several species of invertebrates have been recommended as suitable organisms for the acute and chronic laboratory testing of sediments. The freshwater amphipod, *Hyalella azteca*, and the chironomids, *Chironomus tentans* or *C. riparius*, have received the most attention but other organisms have also been used such as the mayfly, *Hexagenia* spp.and the oligochaete worms, *Lumbriculus variegatus* or *Tubifex tubifex*. These organisms are found in lakes, ponds and streams throughout North America and have a variety of feeding habits which range from grazing on the surface of sediments for algae and organic detritus (e.g., *H. azteca)* to burrowing and ingesting sediment particles (e.g., *T. tubifex*). Thus, benthic invertebrates can be exposed to contaminanted sediments through a variety of mechanisms from passive diffusion of toxicants dissolved in the intersitial water to ingestion of particles of sediment to which contaminants have sorbed.

The objectives for this study were as follows: (1) to collect fine sediments from depositional areas upstream (two sites) and downstream (five sites) of Hinton in the upper Athabasca River; (2) to assess the toxicity of these sediments to four species of benthic invertebrates (the amphipod, *Hyalella azteca,* the chironomid, *C. riparius*, the mayfly, *Hexagenia* and the oligochaete worm, *T. tubifex*) in chronic laboratory toxicity tests; (3) to describe benthic invertebrate species distributions and abundances across stations; (4) characterize the sediments for their physical and chemical variables; (5) evaluate the toxicity of sediments using the Sediment Quality Triad.

2.0 METHODS

2.1 COLLECTION OF SEDIMENTS

2.1.1. SITES OF COLLECTION OF SEDIMENTS FOR BENTHIC INVERTEBRATE COMMUNITY ANALYSIS AND TOXICITY TESTS

Forty samples were collected in May 1993 (eight sites: ARC (Control), ATHA, HB, OB, EL, BR, BER, WB; five replicates each) and 35 samples (seven sites; ARC (Control), ARC2 (Control), HB, OB, EL, BR, WB; five replicates each) were collected in September 1993 using either a Ponar or Eckman grab for analysis of the benthic invertebrate community structure. The samples were preserved in formalin until analysis in the laboratory. Additional samples were collected in the fall of 1993 for use in whole sediment toxicity tests. For these tests, five replicates were collected at each site using an Ekman dredge and kept separate for use in bioassays (true field replicates). The samples were kept at 4°C following collection until they could be used in toxicity tests (approximately 6-8 weeks). The specific locations of the samples are outlined in more detail in Table 1.

2.2 PHYSICAL AND CHEMICAL ANALYSES OF SEDIMENTS

Particle size determination of each manipulated sediment was performed on lypholysized samples at the National Water Research Insititute in Burlington, Ontario, Canada, following the procedure outlined by Duncan and LaHaie (1979). Large particles (>0.88 mm) were removed from the sediment sample prior to analysis. The sediment was then placed in a sodium metaphosphate solution, mixed for fifteen minutes and wet-sieved through a 0.063 μm mesh. The material remaining on the sieve was dried, added to the large particles previously removed and the total was recorded as percent sand and gravel. The remaining suspension was analyzed using a sedigraph analyzer and results were expressed as percentage silt and clay.

Major elements, total phosphorous, total organic carbon (TOC), loss on ignition (LOI) and total Kjeldahl nitrogen were analyzed by Bondar Clegg & Co. Ltd, Ottawa, Canada using standard techniques outlined in USEPA (1981). Concentrations of metals were determined by acid digestion followed by ICP-AES analysis (Multi-channel Jarrell-ASH AtomComp 1100) using the methods of McLaren (1981).

2.3 WHOLE-SEDIMENT TOXICITY TESTS

2.3.1 Culture and Conduction of Tests

Chronic toxicity tests with four species of benthic invertebrates, the amphipod, *Hyalella azteca;* the chironomid, *Chironomus riparius;* the mayfly, *Hexagenia* spp. and the oligochaete tubificid worm, *Tubifex tubifex*, were conducted with all sediments collected from the Athabasca River as well as a clean control sediment from Long Point, Lake Erie, for biological quality assurance.

Complete details of the culture of organisms and conditions of each toxicity test for *C. riparius* and *T. tubifex* are described elsewhere (Reynoldson *et al.* 1991; Day *et al.* 1994; Reynoldson *et al.* 1995).

Culture of *H. azteca* was conducted according to the procedure described in Borgmann *et al.* (1989). Eggs of the mayfly *Hexagenia* spp. (both *H. limbata* and *H. rigida*) were collected during late June and July in 1991 according to the method of Hanes and Ciborowski (1992) and organisms were cultured using the procedure of Bedard et al. (1992). Tests with *H. azteca, C. riparius* and *T. tubifex* were conducted in replicates of 5 (true field replicates) in 250 mL glass beakers containing 60 to 100 mL of sediment with approximately 100 to 140 mL of overlying water (City of Burlington dechlorinated tap water). Tests with the mayfly, *Hexagenia* were conducted in replicates of 5 in 1 L glass jars with 150 mL of test sediment and 850 mL overlying water. The sediment was allowed to settle for 24 h prior to addition of the test organisms. Tests were initiated with the random addition of 15 organisms per beaker for *H. azteca* and *C. riparius*, 10 organisms per jar for *Hexagenia* spp. and 4 organisms per beaker for *T. tubifex*. Juveniles of *H. azteca* were 3 to 7 d old at test initiation; *C. riparius* larvae were first instars and were approximately 3 d post-oviposition; *Hexagenia* nymphs were 1.5 to 2 months old (approximately 5 to 10 mg wet weight) and *T. tubifex* adults were 8-9 weeks old.

The organisms were fed during the course of exposure e.g., 8 mg of moistened Nutrafin^R fish food flakes was added twice weekly to beakers containing the midge, *C. riparius* and the amphipod, *H. azteca*. *Hexagenia* were fed 0.5 mL of YCT (yeast:cerophyll;trout chow) twice weekly and 8 mg Nutrafin^R was mixed in with each sediment in each container at the beginning of the bioassays with *T. tubifex*.

Tests were conducted at 23 ± 1°C with a 16L:8D photoperiod. Tests were static with the periodic addition of distilled water to replace water lost during evaporation. Each beaker was covered with a plastic petri dish with a central hole for aeration using a Pasteur pipette and air line. Dissolved oxygen concentrations and pH were measured at the beginning, middle and end of each exposure period. Tests were terminated after 10 d for *C. riparius*, 21 d for *Hexagenia* and 28 d for *H. azteca* and *T. tubifex* by passing the sediment samples through a 500 μm mesh sieve. Sediment from the *T. tubifex* test was passed through an additional 250 μm mesh sieve at test completion to obtain cocoons and young worms. Endpoints measured in the tests were: *H. azteca*, survival and growth (increase in mg dry wt/ind.); *C. riparius*, survival and growth (increase in mg dry wt/ind.), *Hexagenia* spp., survival and growth (increase in mg dry wt./ind. from day 0 to 21-d); and *T. tubifex*, survival and production of coccoons and live young. Mean dry weights of *H. azteca, C. riparius* and *Hexagenia* spp.were determined after drying the surviving animals from each replicate as a group to a constant weight in a drying oven (60 °C). Initial weight of *H. azteca* and *C. riparius* was considered to be zero. Initial weight of *Hexagenia* was determined from a subset of animals.

2.3.2 Statistical Analysis of Toxicity Data

The data for each species and measured endpoint were tested for normality and a statistical comparison of the responses of each species in sediment for a given site was conducted using analysis of variance (ANOVA). If significant effects were found and these data passed the tests for normality and homogeneity, comparison of means was performed using the Student-Newman-Keuls pairwise multiple comparison. All comparisons for toxicity were related to the results for the two upstream control sites, ARC and ARC2. All statistical analyses were performed using the microcomputer software package, Sigmastat™ (Jandel, California) and significance is at a level of $P \leq 0.05$ unless otherwise noted.

Responses in sediments were also compared to acceptability levels of survival, growth and/or production of young for the same four species used by Day *et al.* (1995) and obtained from a range of reference sediments (258 stations) in the Great Lakes with large differences in grain size and organic carbon. These acceptability criteria were set at the 5th percentile on the normal distribution curve for the range in responses for each endpoint and species in 258 reference sites and are as follows: *C. riparius* - % survival ≥ 68.0, growth ≥ 0.22 mg dry wt/ind.; *H. azteca* - % survival ≥ 74.7, growth ≥ 0.22 mg dry wt/ind.; *Hexagenia* spp. - % survival ≥ 84.0, growth mg dry wt/ind. ≤ 0.50; *T. tubifex* - ≥ 31 cocoons, ≥ 35 total young (Table 2).

2.4 PROCESSING OF SAMPLES FOR INVERTEBRATE COMMUNITY ANALYSIS

2.4.1 Sample Processing

The processing of samples collected for benthic invertebrate community analysis generally followed the procedures described by Alberta Environment (1990). Samples were first prepared by removing the formalin in which they were stored and rinsing them through a series of sieves. Mesh sizes of 1 mm, 229 μm and 74 μm were used. Organic material was separated from inorganic material (sand) in the two finest fractions by elutriation. The three fractions obtained were stored in 80% ethanol. The finest fraction (< 74 μm) was kept but not sorted.

The coarse fraction (> 1 mm) of each sample was sorted in its entirety under a dissecting scope at a magnification of at least 7X. Because these depositional samples contained a large amount of organic debris, it was decided that the fine fraction would be subsampled according to the method of Wrona *et al.* (1982; cited in Saffran, 1994). Subsampling was standardized to at least one quarter (five 50 mL subsamples) of the fine fraction. Subsample counts were often low (< 100 organisms) but it was felt that the time taken to sort the entire fraction would have been excessive for the amount of data obtained in these cases.

The cone subsampler (Wrona *et al.* (1982; cited in Saffran, 1994) was also used to facilitate identification of Oligochaeta. When the number of worms was greater than 400, one quarter was removed for identification. The proportions of different families were then applied to the total number of oligochaetes in the sample, which had previously been counted.

2.4.2 Quality assurance/quality control

Sample cleaning, fractioning and subsampling were consistantly performed by one person who also supervised the sorting process. Four spring samples and four fall samples (10.7% of the total samples) were chosen at random to verify sorting efficiency. Re-sorting was undertaken by an individual not involved in the original sorting. A recovery of 95%, as suggested in Environment Canada (1993) was considered to be the minimum acceptable standard. The results of the QA/QC analysis are presented in Saffran et al. (1994).

2.4.3 Biotic indices used in data comparisons

Diversity indices are mathematical expressions which use three components of community structure; namely, richness (number of species present), eveness (uniformity in the distribution of individuals among the species) and abundance (total number of organisms present), to describe the response of a community to the quality of its environment (Metcalfe 1989). In this study, three of the most widely used measures of diversity were used to describe the data collected from the Athabasca River. These three indices are as follows:

Shannon-Wiener $$d = -\sum Ni / N \ \log2 \ Ni / N$$

Simpson $$d = 1 - \left[N_i(N_i-1)/N(N-1) \right]$$

Margalef $$d = (S - 1)/ \log_e N$$

Where: d = diversity
N = total number of individuals of all species collected
N_i = number of individuals belonging to the ith species
S = number of species

3.0 RESULTS

3.1 TOXICITY TESTS

The results of the bioassays are summarized in Figures 1 to 4 and in Appendix A. In general, there was no indication of toxicity at any of the sites for three of four species and for seven of eight chronic endpoints. For example, survival of *C. riparius*, *Hexagenia* and *H. azteca* in sediments collected downstream of Hinton was equal to or greater than survival of these species in sediments collected either upstream of Hinton (control sites), in the reference Lake Erie sediment used for QA/QC or the mean survival measured in 258 uncontaminated sediments from the nearshore areas of the Great Lakes (dotted line). Growth of all three species was similarly not reduced at any of the sites.

Only one toxicity test endpoint was lowered by exposure to sediments collected downstream of Hinton. Production of live young by the tubificid worm, *T. tubifex*, was significantly reduced in sediments collected above the Berland River (BR) and near Windfall Bridge (WB). Production of cocoons was not similary affected.

3.2 BENTHIC INVERTEBRATE COMMUNITY STRUCTURE

Tables 3 and 4 (and Appendix B) list the taxonomical groupings and species (where identified) of benthic invertebrates identified at all sites. Tables 3 and 4 also present the percent abundance of the total number of organisms counted in five replicate samples collected. The spring samples generally contained fewer organisms than the fall samples (see report by Saffran *et al.* 1994 in Appendix B).

Chironomids, especially the Chironomini and Orthocladiinae groups, dominated the spring samples collected at the control (ARC) site in terms of percent abundance. Chironomids were also very abundant in sediments collected downstream at Obed Bridge (OB). Samples collected at other downstream sites contained large percentages of tubificid worms (e.g., see data for Blue Ridge (BER), upstream of the Berland River (BR), and Windfall Bridge (WB)). The site upstream of the Emerson Lakes (ATHA) which was only sampled in the spring had a large percentage of ostracods.

The three diversity indices calculated for the spring samples (Fig. 5; Appendix A) were all relatively low (including the control samples). The greatest diversity in the spring was found at the Obed Bridge site (OB) and the site upstream of Emerson Lakes (ATHA).

Chironomids also dominated the two control sites sampled in the fall (i.e., ARC and ARC2). A high percentage of tubificid worms was found at most other sites located downstream of Hinton with the exception of the site at Weldwood Haul bridge which had a mixture of cladocerans, copepods and ostracods as well as several groups of chironomids (Appendix B). Diversity indices calculated for these sites indicated again that diversity at all sites was low (Fig.6). Diversity was the highest at the Weldwood Bridge site (HB). The lowest diversity was found at the Windfall Bridge site (WB) and this low diversity was statistically lower than all other sites, especially the control sites, for 2/3 indices (Shannon-Wiener and Simpson's).

3.3 PHYSICAL-CHEMICAL ANALYSES

The major nutrients (total N and P) and several metals of concern as well as the percent total organic carbon (TOC), loss on ignition (LOI), silt, sand and clay, are presented in Table 5.

Concentrations of metals at most sites were below the Low Effects Concentrations (LEL) set by the Province of Ontario (Persaud *et al.* 1992) for freshwater sediments with the exception of arsenic at BR and WB, chromium at all sites, cadmium at EL and nickel and copper at WB. WB and BR are the two sites where reproduction was lower in *T. tubifex* and diversity of the benthos was reduced (Windfall Bridge, only).

Examination of the physical parameters for sediments collected from all sites (percent sand, silt and clay) indicated that the sediments varied considerably in their particle size distribution with the Berland River site having the highest percentage of sand (74.3%). The percentage of clay was highest at the Windfall Bridge site.

4.0 DISCUSSION

Sediments located downstream of Hinton in the upper Athabasca River do not appear to be particularly toxic to benthic invertebrates living in or near the benthos or to invertebrates exposed to such sediments after removal from these habitats. Survival and growth of three benthic invertebrates in culture in the laboratory and exposed to field-collected sediments, i.e., *H. azteca, C. riparius* and *Hexagenia,* were all high and above the acceptability criteria for other reference sites and in comparison to control sites. However, sediments collected from the Athabasca River near the Windfall Bridge (WB) and upstream of the Berland River (BR) indicated sublethal effects to tubificid worms (*i.e.*, statistically reduced reproduction in comparison to control sediments, ARC and ARC2). Production of young at one site (i.e., upstream of the Berland River) was also lower than the range of production of young noted for 258 clean sediments collected from depositional areas in the nearshore areas of the Laurentian Great Lakes. The three components of community structure, i.e., richness, abundance and evenness measured using diversity indices were also reduced at the Windfall Bridge site. Tubificid worms were prevalent at this site although taxonomic determination to the level of genus or species was not conducted and therefore it is unknown if the species, *T. tubifex*, was present. Diversity at all sites was low in general but this is considered normal for depositional areas in rivers and streams located in the prairie provinces (T.B. Reynoldson, per. comm.).

The Berland River site had a high percentage of sand which would not be nutritionally acceptable to tubificid worms in comparison to sediment(s) with a greater component of organic material. However, the protocol for the tubificid bioassay includes a food component designed to 'even' out the responses of the organism with regard to nutrition. The Berland River (BR) and the Windfall Bridge (WB) sites also had levels of arsenic, chromium, coper and nickel higher than the criterea set for the Province of Ontario for low effects to invertebrates and thus the presence of such contaminants or other unreported contaminants in these sediments could be causing toxicity and resulting in reduced diversity.

5.0 CONCLUSIONS

Sediments located downstream of Hinton in the upper Athabasca River are not particularly toxic to benthic invertebrates living in and near the sediments with the exception of sediments upstream of the Berland River and near Windfall bridge where toxicity to tubificid worms (reduced reproduction) was noted and where species diversity (WB, only) was lower. A slight elevation of arsenic and chromium was noted at these two sites and further information on the presence/absence of other contaminants in these sediments may help further interpretation of the data with regard to what is causing the observed toxicity and lower diversity.

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TABLES

Table 1. Description and coding for depositional sites sampled on the Upper Athabasca River in May and September/October, 1993.

Location	Description	Site Label
Athabasca River u/s Hinton Control 1	200 meters above Maskuta Creek right side in open bay. No bar to main current. Silt with organic layers	ARC B - Spring B,C,T - Fall
Athabasca River u/s Hinton (Control 2)	In protected bay just downstream of ARC, more sand and less organic debris than ARC	ARC2 B,C,T - Fall
Athabasca River at Weldwood Haul Bridge	Approx. 1 km below Weldwood Haul Bridge right bank opposite Fish Ck. Small bay sand overlain with brown silt-clay 1 cm thick	HB B - Spring B,C,T - Fall
Athabasca River at Obed	Small rock bay 1 km. below Obed bridge right side. Near Baseline Ck. More silt than at previous sites. Organic debris 3 cm below surface.	OB B - Spring B,C,T - Fall
Athabasca River at Emerson Lakes	Left side approx. 300 meters below May sampling Location. Open bay with sandy beach	EL B - Spring B,C,T - Fall
Athasbasca River upstream of EL	-	ATHA B - Spring
Athabasca River u/s of Berland River	Sampled in bay 250 meters below May sampling site. About 1.5 km above bridge. Shallow, fairly sandy, numberous emerging and in-place invertebrates	BR B - Spring B,C,T - Fall
Athabasca River at Windfall	Same site as sampled in May, 2 km below bridge, right side. Very good depositional zone. Fines in abundance. Numerous invertebrates.	WB B - Spring B,C,T - Fall
Blue Ridge	-	BER B - Spring

Table 2. MEAN VALUES FOR PERCENT SURVIVAL, INCREASE IN BIOMASS (MG DRYWEIGHT PER INDIVIDUAL) OR REPRODUCTION OF FOUR SPECIES OF BENTHIC INVERTEBRATES IN SEDIMENT COLLECTED FROM 258 REFERENCE SITES IN NEARSHORE AREAS OF THE LAURENTIAN GREAT LAKES. TOXICITY IS INDICATED WHEN VALUED ARE BELOW THE LEVEL OF THE 5TH PERCENTILE OF RESPONSES FOR EACH SPECIES.

Species (Endpoint)	Mean Values (±S.D.) for Reference Sites in the Great Lakes	Value at the 5th percentile on the normal distribution curve below which toxicity is indicated
Chironomus riparius		
% Survival	84.3 (11.0)	68 %
Growth[1]	0.34 (0.07)	0.22
Hyalella azteca		
% Survival	88.6(7.1)	74.7 %
Growth[1]	0.49 (0.14)	0.22
Hexagenia spp.		
% Survival	96.0 (5.4)	84 %
Growth[2]		
Unfed[3]	4.81 (4.46)	0.38
Fed[4]	2.86 (1.06)	0.58
Tubifex tubifex		
Cocoons		
Unfed[5]	34 (7)	24
Fed[6]	38 (5)	31
Total Young		
Unfed[5]	64 (30)	21
Fed[6]	113 (36)	35

[1]Biomass measured as mg dry weight/individual at test termination

[2]Change in biomass measured as mg dry weight/individual from test intiation to test termination

[3]Based on unpublished data from 50 reference sites in the nearshore areas of the Great Lakes where mayfly nymphs were not fed a supplemental diet

[4]Based on unpublished data from 208 reference sites in the nearshore areas of the Great Lakes where mayfly nymphs were fed a supplemntal diet of 0.5 mL yeast-Cerophyll-trout chow 3X weekly

[5]Based on unpublished data from 50 reference sites in the nearshore areas of the Great Lakes were adult tubificids were not fed a supplemental diet

[6]Based on unpublished data from 208 reference sites in the nearshore areas of the Great Lakes where adult tubificids were fed a supplemental diet of 80 mg NutrafinTM at test initiation

Table 3. CONTRIBUTION OF TAXA TO TOTAL ABUNDANCE FOR SAMPLES COLLECTED IN MAY 1993 FROM EIGHT SITES ON THE UPPER ATHABASCA RIVER..

	% ABUNDANCE OF TOTAL NUMBERS							
SPECIES/SITE	ARC	ATHA	HB	OB	EL	BR	BER	WB
ANNELIDA								
OLIGOCHAETA								
HAPLOTAXIDA								
Naididae		0.3			0.04		0.2	
Tubificidae	7.8	2.4	47.1	3.2	57.9	90.5	57.4	81.9
ARTHROPODA								
ARACHNOIDA								
ACARI			0.4	5.5	0.2			0.1
CRUSTACEA	2.0							
CLADOCERA		1.7	5.3	0.1	0.2	0.5		
COPEPODA		12.9	3.2	2.8		0.5		
OSTRACODA		65.6	3.4		0.5	0.3		
INSECTA								
DIPTERA								
Ceratopogonidae				0.3				
Chironomidae								
Chironomini	67.2	7.8	19.1	43.8	17.8	5.9	21.9	9.1
Tanytarsini	2.7	4.8	0.4	2.6	0.3	0.5	0.1	0.3
Orthocladiinae	11.3	1.3	4.4	3.4	0.7	0.3	12.5	0.1
Diamesinae	7.2	0.1	1.8	35.6	21.9	1.2	4.3	7.5
Tanypodinae			7.4	1.2		0.2		0.1
Chironomid adult	0.7			0.03				
Chironomid pupae		0.1	5.3	1.5	0.04		1.0	
Empididae								
Chelifera	0.3							
Hemerodromia				0.03				
				0.06				
EPHEMEROPTERA								
Ephemerellidae				0.09			0.1	
Serratella				0.1	0.04			0.1
Baetidae			0.2					
Baetis								
HEMIPTERA								
TRICHOPTERA								
MEGALOPTERA								
MOLLUSCA								
GASTROPODA								
PULMONATA								
Lymnaeidae		0.2				0.02		
Planorbidae								
PELECYPODA	0.7		0.2					
Sphaeriidae								
Pisidium		0.4	0.1		0.04	0.06		0.1
NEMATODA		2.1	1.3		0.1	0.2	2.6	
TARDIGRADA			0.2					

Table 4. CONTRIBUTION OF TAXA TO TOTAL ABUNDANCE FOR SAMPLES COLLECTED IN SEPTEMBER 1993 FROM SEVEN SITES ON THE UPPER ATHABASCA RIVER.

	% ABUNDANCE OF TOTAL NUMBERS						
SPECIES/SITE	ARC	ARC2	HB	OB	EL	BR	WB
ANNELIDA							
OLIGOCHAETA							
HAPLOTAXIDA							
Naididae	0.8	0.6	1.0	1.1	1.3	1.1	0.03
Tubificidae	2.1	13.9	24.7	66.3	65.6	58.0	84.2
ARTHROPODA							
ARACHNOIDA							
ACARI	0.3	0.6	0.1	0.1	0.4	0.06	
CRUSTACEA							
CLADOCERA	15.4	17.6	9.1	9.9	10.6	4.9	3.2
COPEPODA	5.0	0.8	12.2	0.5	0.2	5.2	0.2
OSTRACODA	10.4	5.5	13.7	1.0	0.7	0.4	1.1
INSECTA							
DIPTERA							
Ceratopogonidae	0.04			0.01			0.02
Chironomidae							
Chironomini	12.1	14.6	8.9	8.2	10.3	22.6	5.8
Tanytarasini	34.8	33.9	7.8	3.4	0.8	5.8	0.7
Orthocladiinae	6.1	5.9	8.7	1.8	0.8	0.3	
Diamesinae	10.4	5.4	6.8	6.0	7.9	0.7	0.1
Tanypodinae	1.1	0.4	0.2	0.6	1.0	0.1	3.9
Chironomid adult	0.7		4.1				
Chironomid pupae		0.3				0.01	
Empididae	0.09				0.03		
Chelifera	0.3			0.03			
Hemerodromia							
EPHEMEROPTERA							
Ephemerellidae				0.06	0.08	0.04	
Serratella							
Baetidae							0.2
Baetis	0.07		0.1				
HEMIPTERA				0.01			0.01
TRICHOPTERA				0.03			0.01
MEGALOPTERA					0.01		
MOLLUSCA							
GASTROPODA							
PULMONATA							
Lymnaeidae	0.04		0.1	0.02	0.01	0.03	0.01
Planorbidae			0.1				
Physidae				0.01			
							0.2
PELECYPODA							
Sphaeriidae				0.7		0.4	0.7
Pisidium			0.7		0.1		
NEMATODA	1.1	0.6	1.8	0.3	0.1	0.3	0.2

Table 5. CHEMICAL PARAMETERS FOR SEDIMENTS COLLECTED FROM THE ATHABASCA RIVER.

SITE	P PPM	N PPM	Cu PPM	Pb PPM	Zn PPM	Ni PPM	Cd PPM	Cr PPM	As PPM	% TOC	% LOI	% Sand	% Silt	% Clay
EL-T	633	1220	12	20	45	15	1.7	36	<5	1.16	22.6	23.3	51.7	25
BR-T	779	940	13	30	69	15	0.3	35	11	0.46	19.7	74.3	22.8	2.9
WB-T	706	1510	16	24	59	21	<0.2	43	8	1.51	22.2	3.5	68.5	28.1
ARC-T	640	852	13	20	47	15	<0.2	36	<5	0.73	24.8	58.7	34.5	6.8
ARC2-T	611	985	12	24	50	15	0.2	35	<5	0.72	23.0	18.7	64.7	16.5
HB-T	732	938	14	22	49	17	0.4	36	<5	1.47	23.4	64.9	28.5	6.6
OB-T	669	1010	13	21	54	17	<0.2	35	<5	1.37	21.6	62.9	34.9	2.2
OMOEE1														
LEL	600	550	16	31	120	16	0.6	26	6	1.00	-	-	-	-
SEL	2000	4800	110	250	820	75	10	110	33	10	-	-	-	-

1 Province of Ontario's sediment quality criteria for metals; LEL (lowest observed effects level) and SEL (severe effects level)

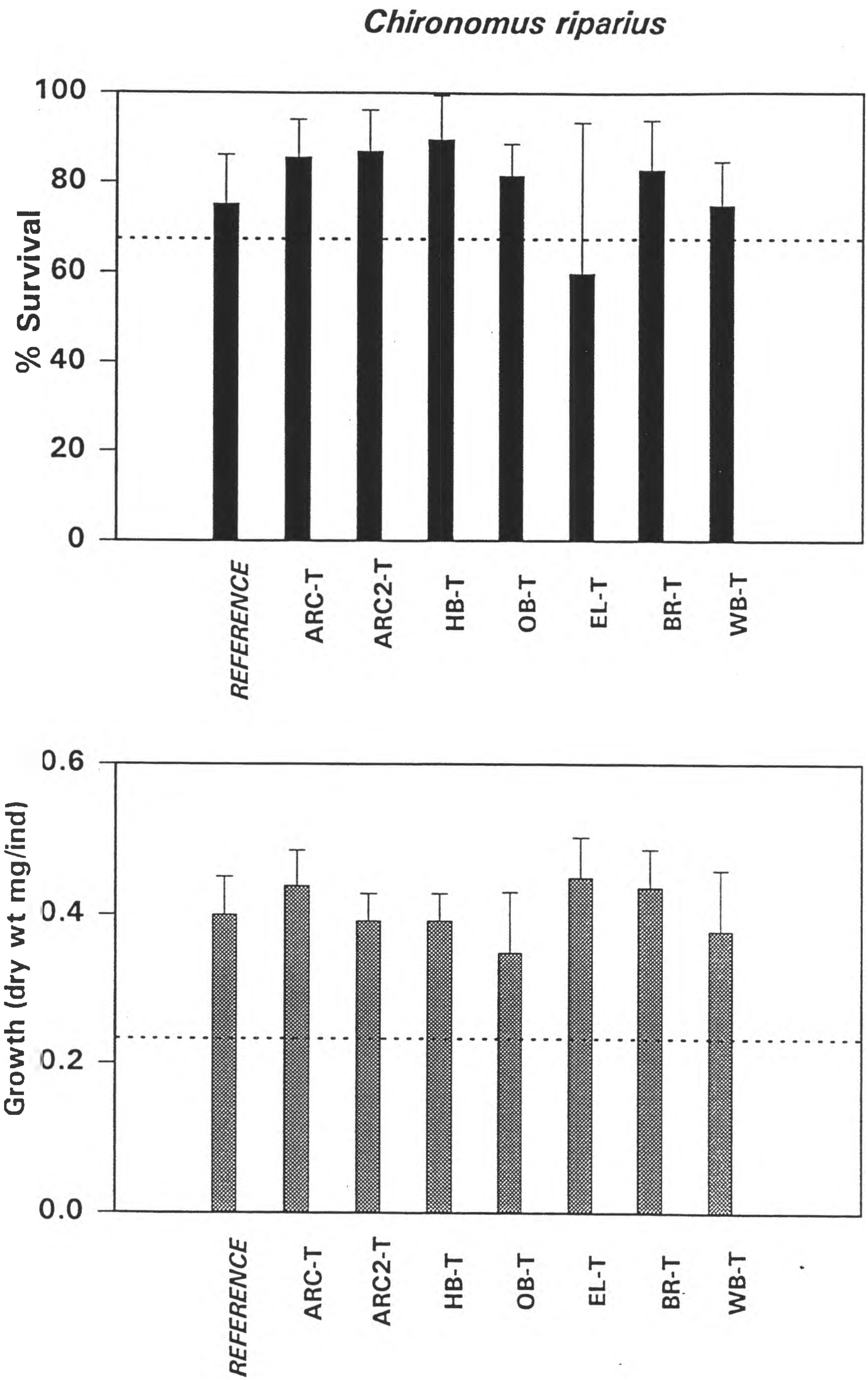
APPENDIX A: RAW DATA AND DIVERSITY INDICES

RAW DATA FROM THE UPPER ATHABASCA RIVER:

	SITE	SPECIES		SPECIES		SPECIES		SPECIES	
		CHSUR	CHGRO	HXSUR	HEXGRO	HYSUR	HYGRO	TTCOC	TTOFF
Athabasca	EL-T	66.67	0.5	90	5.863	100	0.429	49	139
		93.33	0.371	100	5.42	100	0.725	43	128
		93.33	0.495	100	5.786	86.67	0.489	49	142
		93.33	0.431	100	5.095	93.33	0.539	49	163
		66.67	0.446	100	5.278	100	0.227	52	85
		59.5(33.9)	0.45(0.05)	98(4.5)	5.48(0.32)	96(5.9)	0.48(0.18)	48(3)	131(29)
	BR-T	86.67	0.454	100	6.356	93.33	0.605	40	3
		100	0.383	100	5.485	100	0.4	50	2
		73.33	0.507	100	5.759	100	0.312	49	5
		73.33	0.445	100	2.95	93.33	0.538	48	3
		80	0.393	100	5.037	86.67	0.516	48	20
		82.7(11.2)	0.44(0.05)	100 (0)	5.12(1.30)	94.7(5.6)	0.52(0.19)	47(4)	7(8)
	WB-T	60	0.394	100	7.141	93.33	0.782	46	32
		86.67	0.271	100	8.425	80	1	46	36
		73.33	0.403	100	7.564	93.33	0.696	35	1
		73.33	0.339	100	6.605	80	0.843	50	91
		80	0.488	100	6.165	93.33	0.419	47	25
		74.7(9.9)	0.38(0.08)	100(0)	7.18(0.87)	87.9(7.3)	0.75(0.22)	45(6)	37(33)
	LONG POINT	80	0.415	100	5.975	100	0.567	47	123
		73.33	0.378	100	5.58	93.33	0.586	46	95
		73.33	0.37	100	5.186	100	0.323	40	75
		86.67	0.352	100	6.016	100	0.578	48	83
		60	0.488	100	6.456	93.33	0.584	45	92
		75(11.)	0.40(0.05)	100(0)	5.23(0.74)	95.9(4.7)	0.48(0.10)	44(3)	113(26)
	ARC-T	86.67	0.402	90	3.942	100	0.286	42	104
		80	0.483	90	4.256	100	0.558	40	149
		100	0.374	90	4.206	100	0.526	33	135
		80	0.468	90	4.758	100	0.523	49	181
		80	0.462	100	4.333	93.33	0.448	44	135
		85.3(8.7)	0.44(0.05)	92(4.5)	4.30(0.29)	98.7(2.9)	0.47(0.11)	42(6)	113(26)
	ARC2-T	100	0.331	100	5.13	100	0.392	44	139
		86.67	0.426	100	3.86	93.33		44	79
		86.67	0.409	90	4.741	100	0.443	46	136
		73.33	0.389	100	4.591	80	0.443	46	152
		86.67	0.405	90	4.165	100	0.425	47	137
		86.6(9.4)	0.39(0.04)	96(5.5)	4.50(0.49)	94.7(8.7)	0.43(0.02)	45(1)	129(29)
	HB-T	100	0.376	100	3.853	86.67	0.342	41	92
		86.67	0.455	90	3.857	93.33	0.449	44	142
		80	0.368	100	3.763	73.33	0.685	47	131
		80	0.379	100	3.448	100	0.549	44	142
		100	0.38	100	3.75	100	0.309	45	159
		89.3(10.1)	0.392(0.04)	98(4.5)	3.73(0.17)	90.7(11.2)	0.47(0.15)	44(2)	133(25)
	OB-T	86.67	0.291	100	4.079	100	0.309	43	137
		86.67	0.364	100	4.473	93.33	0.546	37	81
		86.67	0.422	100	2.195	100	0.628	43	88
		73.33	0.43	100	3.4	100	0.469	32	155
		73.33	0.245	100	3.287	73.33	0.379	38	83
		81.3(7.3)	0.35(0.08)	100(0)	3.49(0.87)	93.3(11.5)	0,47(0.13)	39(5)	109(35)

ATHABASCA RIVER - 1993

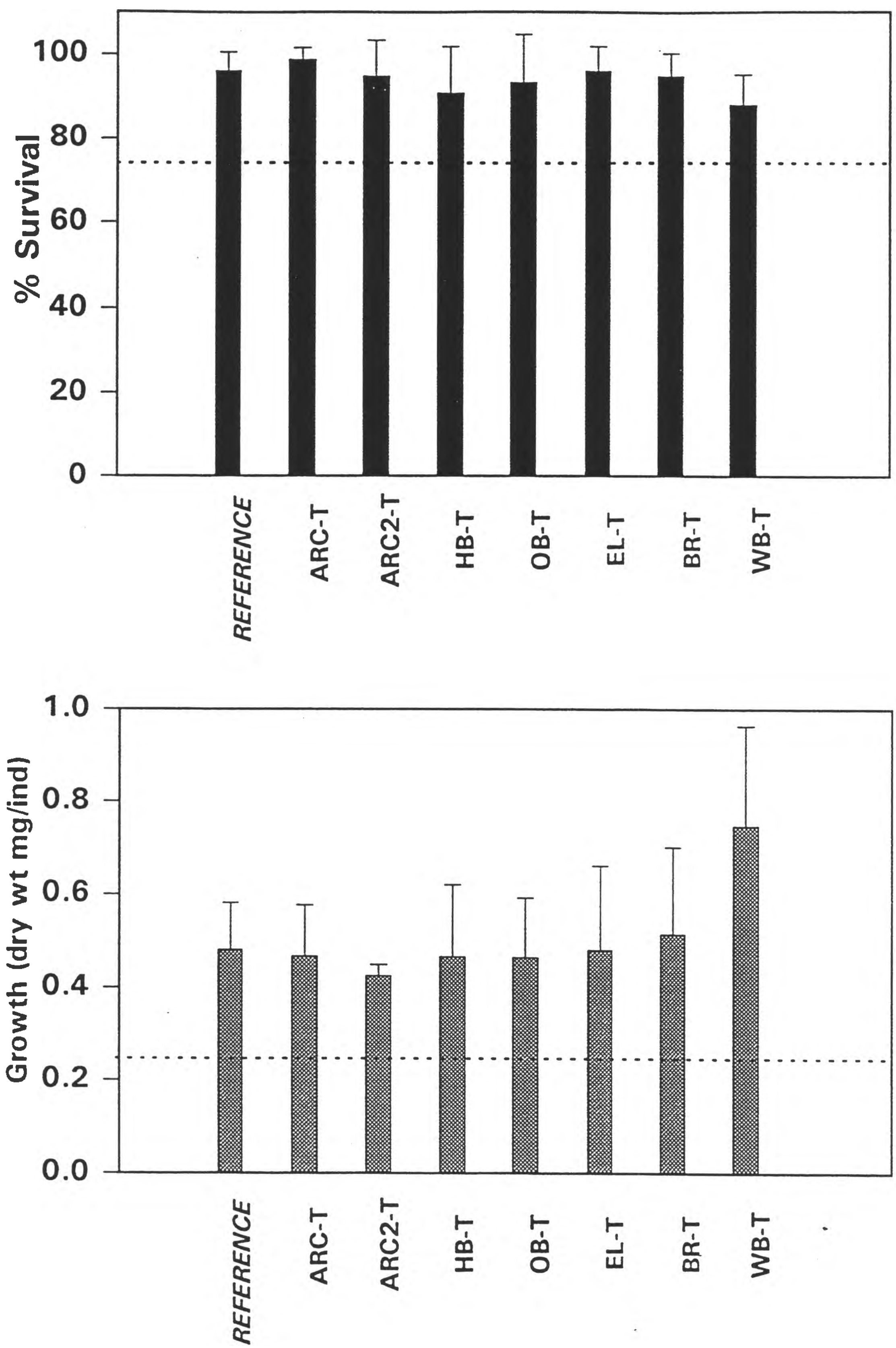
Fig. 1



ATHABASCA RIVER - 1993

Fig. 2

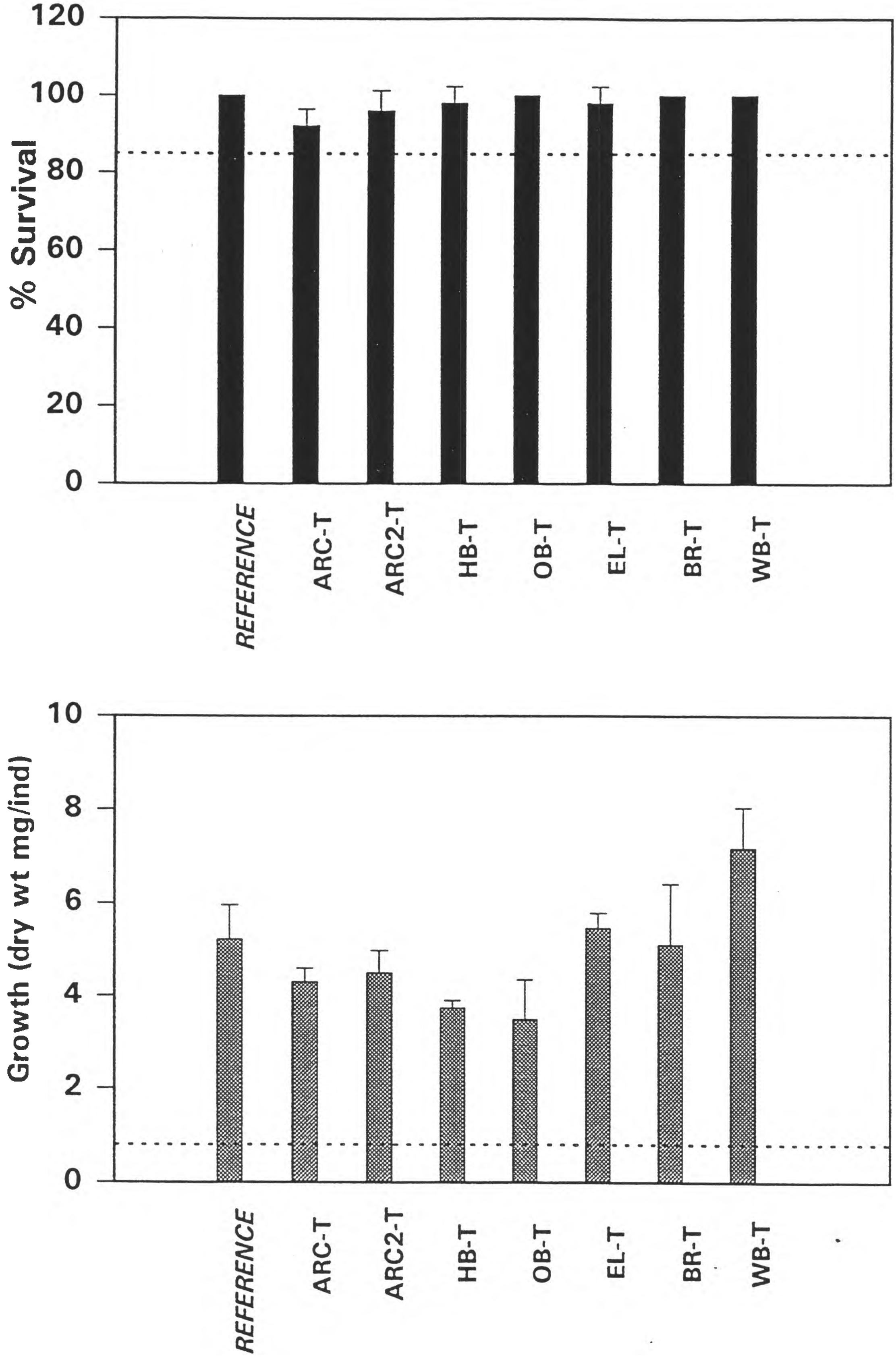
Hyalella azteca



ATHABASCA RIVER - 1993

Fig. 3

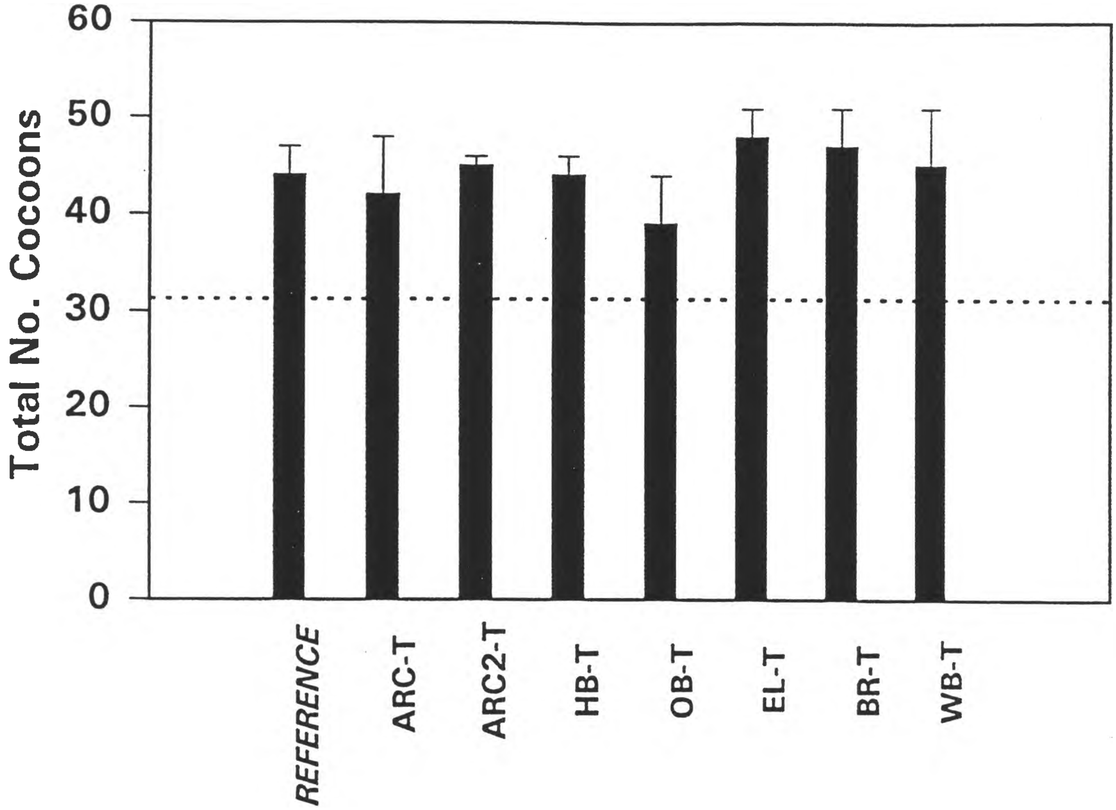
Hexagenia spp.

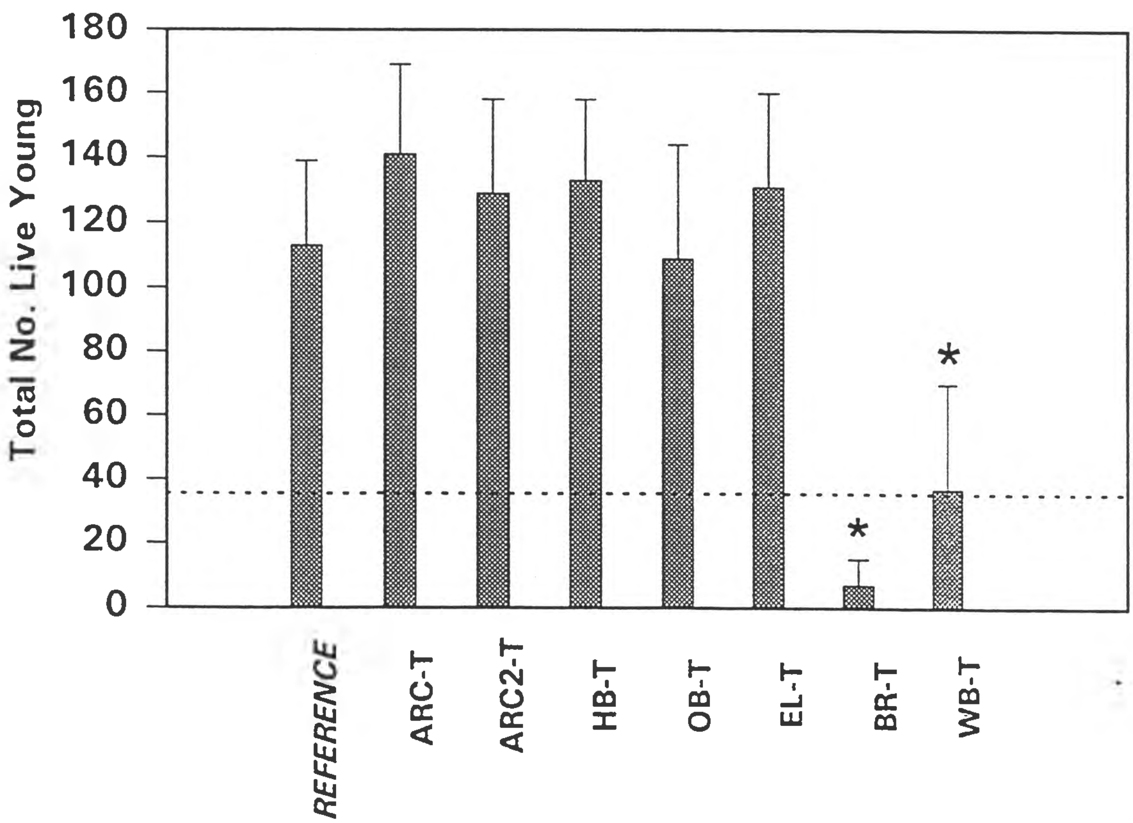


ATHABASCA RIVER - 1993

Fig. 4

Tubifex tubifex





SUMMARY OF TOTAL INVERTEBRATE COUNTS FROM EIGHT SITES ON THE UPPER ATHABASCA RIVER, MAY 1993.

EL 93/05/05

	1.00	2.00	3.00	4.00	5.00
HAPLOTAXIDA	102.00	179.00	178.00	372.00	375.00
ACARI		2.00			4.00
CLADOCERA		4.00			
OSTRACODA	4.00	7.00			
DIPTERA	97.00	168.00	128.00	296.00	302.00
Ephemerellidae					1.00
PELECYPODA	1.00				
NEMATODA	1.00	1.00			1.00
TOTAL	205.00	361.00	306.00	668.00	683.00

SHANNON-WEINER INDEX

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	-0.50	-0.50	-0.45	-0.47	-0.40
ACARI		-0.04			-0.04
CLADOCERA		-0.07			
OSTRACODA	-0.11	-0.11			
DIPTERA	-0.51	-0.51	-0.55	-0.52	-0.55
Ephemerellidae					-0.01
PELECYPODA	-0.04				
NEMATODA	-0.04	-0.02			-0.01
Total	1.20	1.26	0.98	0.99	0.99

SIMPSON'S INDEX

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	10302.00	31862.00	31506.00	138012.00	[illegible]
ACARI	0.00	2.00	0.00	0.00	12.00
CLADOCERA	0.00	12.00	0.00	0.00	0.00
OSTRACODA	12.00	42.00	0.00	0.00	0.00
DIPTERA	9312.00	28056.00	16256.00	87320.00	90902.00
Ephemerellidae	0.00	0.00	0.00	0.00	0.00
PELECYPODA	0.00	0.00	0.00	0.00	0.00
NEMATODA	0.00	0.00	0.00	0.00	0.00
Total	0.33	0.34	0.49	0.49	0.50

EL MARGALEF'S INDEX

1B	2B	3B	4B	5B
0.75	0.85	0.17	0.15	0.59

WHB 93/05/05

	1.00	2.00	3.00	4.00	5.00
HAPLOTAXIDA	114.00	124.00	48.00	52.00	46.00
ACARI	2.00				1.00
CLADOCERA					43.00
COPEPODA	10.00	12.00			4.00
OSTRACODA			8.00	12.00	8.00
DIPTERA	94.00	30.00	35.00	52.00	102.00
EPHEMEROPTERA	2.00				
PLECOPTERA (small)	2.00				
PELECYPODA			1.00		
NEMATODA	2.00			8.00	1.00
TARDIGRADA	2.00				
TOTAL	228.00	166.00	92.00	124.00	205.00

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	-0.50	-0.31	-0.49	-0.35	-0.48
ACARI	-0.06				-0.04
CLADOCERA					-0.47
COPEPODA	-0.20	-0.27			-0.11
OSTRACODA			-0.31	-0.33	-0.18
DIPTERA	-0.53	-0.45	-0.55	-0.53	-0.50
EPHEMEROPTERA	-0.06				
PLECOPTERA	-0.06				
PELECYPODA			-0.07		
NEMATODA	-0.06			-0.26	-0.04
TARDIGRADA	-0.06				
Total	1.52	1.05	1.40	1.65	1.53

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	12882.00	15252.00	2256.00	2652.00	2070.00
ACARI	2.00	0.00	0.00	0.00	0.00
CLADOCERA	0.00	0.00	0.00	0.00	1806.00
COPEPODA	90.00	132.00	0.00	0.00	12.00
OSTRACODA	0.00	0.00	56.00	132.00	56.00
DIPTERA	8742.00	870.00	1190.00	2652.00	10302.00
EPHEMEROPTERA	2.00	0.00	0.00	0.00	0.00
PLECOPTERA	2.00	0.00	0.00	0.00	0.00
PELECYPODA	0.00	0.00	0.00	0.00	0.00
NEMATODA	2.00	0.00	0.00	56.00	0.00
TARDIGRADA	2.00	0.00	0.00	0.00	0.00
Total	0.58	0.41	0.58	0.64	0.66

HB

1B	2B	3B	4B	5B
1.29	0.39	0.66	0.62	1.13

ATHA 93/05/07

	1.00	2.00	3.00	4.00	5.00
HAPLOTAXIDA	14.00	17.00	6.00	8.00	12.00
CLADOCERA	12.00		4.00	16.00	4.00
COPEPODA	40.00	176.00	4.00	20.00	32.00
OSTRACODA	240.00	192.00	256.00	2800.00	412.00
DIPTERA	49.00	150.00	13.00	51.00	39.00
PULMONATA	1.00		1.00	1.00	1.00
PELECYPODA		5.00	1.00	1.00	1.00
NEMATODA	8.00	16.00		16.00	4.00
TOTAL	364.00	556.00	285.00	2913.00	505.00

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	-0.18	-0.15	-0.12	-0.02	-0.13
CLADOCERA	-0.16		-0.09	-0.04	-0.06
COPEPODA	-0.33	-0.53	-0.09	-0.05	-0.25
OSTRACODA	-0.40	-0.53	-0.14	-0.05	-0.24
DIPTERA	-0.39	-0.58	-0.20	-0.10	-0.29
PULMONATA	-0.02		-0.03	-0.00	-0.02
PELECYPODA		-0.06	-0.03	-0.00	-0.02
NEMATODA	-0.12	-0.15		-0.04	-0.06
Total	1.62	1.95	0.69	0.32	1.05

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	182.00	272.00	30.00	56.00	132.00
CLADOCERA	132.00	0.00	12.00	240.00	12.00
COPEPODA	1560.00	30800.00	12.00	380.00	992.00
OSTRACODA	57360.00	36672.00	65280.00	7837200.00	169332.00
DIPTERA	2352.00	22350.00	156.00	2550.00	1482.00
PULMONATA	0.00	0.00	0.00	0.00	0.00
PELECYPODA	0.00	20.00	0.00	0.00	0.00
NEMATODA	56.00	240.00	0.00	240.00	12.00
Total	0.53	0.71	0.19	0.08	0.32

ATHA

1B	2B	3B	4B	5B
1.02	0.79	1.06	0.88	1.12

ARC 93/05/05

	1.00	2.00	3.00	4.00	5.00
HAPLOTAXIDA		10.00	4.00	5.00	4.00
ACARI		5.00		1.00	
DIPTERA	40.00	34.00	36.00	98.00	54.00
PLECOPTERA (small)			2.00		
TOTAL	40.00	49.00	42.00	104.00	58.00

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA		-0.47	-0.32	-0.21	-0.27
ACARI		-0.34		-0.06	
DIPTERA	0.00	-0.37	-0.19	-0.08	-0.10
PLECOPTERA			-0.21		
Total	0.00	1.17	0.72	0.36	0.36

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	0.00	90.00	12.00	20.00	12.00
ACARI	0.00	20.00	0.00	0.00	0.00
DIPTERA	1560.00	1122.00	1260.00	9506.00	2862.00
PLECOPTERA	0.00	0.00	2.00	0.00	0.00
Total	0.00	0.48	0.26	0.11	0.13

ARC

1B	2B	3B	4B	5B
0.00	0.51	0.54	0.43	0.25

OB 93/05/05

	1.00	2.00	3.00	4.00	5.00
HAPLOTAXIDA	18.00	5.00	4.00	41.00	29.00
ACARI	2.00	12.00		152.00	
CLADOCERA				4.00	
COPEPODA		72.00	4.00	8.00	
DIPTERA	154.00	735.00	397.00	677.00	648.00
EPHEMEROPTERA		1.00			2.00
NEMATODA					4.00
TOTAL	174.00	825.00	405.00	882.00	683.00

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	-0.34	-0.04	-0.07	-0.21	-0.19
ACARI	-0.07	-0.09		-0.44	
CLADOCERA				-0.04	
COPEPODA		-0.31	-0.07	-0.06	
DIPTERA	-0.16	-0.15	-0.03	-0.29	-0.07
EPHEMEROPTERA		-0.01			-0.02
NEMATODA					-0.04
Total	0.57	0.60	0.16	1.03	0.33

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	306.00	20.00	12.00	1640.00	812.00
ACARI	2.00	132.00	0.00	22952.00	0.00
CLADOCERA	0.00	0.00	0.00	12.00	0.00
COPEPODA	0.00	5112.00	12.00	56.00	0.00
DIPTERA	23562.00	539490.00	157212.00	457652.00	419256.00
EPHEMEROPTERA	0.00	0.00	0.00	0.00	2.00
NEMATODA	0.00	0.00	0.00	0.00	12.00
Total	0.21	0.70	0.04	0.38	0.10

OB

1B	2B	3B	4B	5B
0.39	0.60	0.33	0.59	0.46

BR 93/05/06

	1.00	2.00	3.00	4.00	5.00
HAPLOTAXIDA	653.00	1664.00	426.00	1316.00	324.00
CLADOCERA		8.00		16.00	
COPEPODA	8.00		12.00	4.00	
OSTRACODA	8.00			4.00	
DIPTERA	46.00	119.00	55.00	63.00	106.00
PULMONATA	1.00				
PELECYPODA			2.00	1.00	
NEMATODA				8.00	
TOTAL	716.00	1791.00	495.00	1412.00	430.00

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	-0.12	-0.10	-0.19	-0.09	-0.31
CLADOCERA		-0.03		-0.07	
COPEPODA	-0.07		-0.13	-0.02	
OSTRACODA	-0.07			-0.02	
DIPTERA	-0.23	-0.26	-0.33	-0.20	-0.50
PULMONATA	-0.01				
PELECYPODA			-0.05	-0.01	
NEMATODA				-0.04	
Total	0.53	0.39	0.70	0.47	0.81

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	425756.00	2767232.00	181050.00	1730540.00	104652.00
CLADOCERA	0.00	56.00	0.00	240.00	0.00
COPEPODA	56.00	0.00	132.00	12.00	0.00
OSTRACODA	56.00	0.00	0.00	12.00	0.00
DIPTERA	2070.00	14042.00	2970.00	3906.00	11130.00
PULMONATA	0.00	0.00	0.00	0.00	0.00
PELECYPODA	0.00	0.00	2.00	0.00	0.00
NEMATODA	0.00	0.00	0.00	56.00	0.00
Total	0.16	0.13	0.25	0.13	0.37

BR

1B	2B	3B	4B	5B
0.61	0.27	0.48	0.83	0.16

BER 93/05/06

	1.00	2.00	3.00	4.00	5.00
HAPLOTAXIDA	146.00	209.00	137.00	47.00	155.00
DIPTERA	85.00	87.00	94.00	100.00	113.00
EPHEMEROPTERA	1.00				
NEMATODA		8.00	8.00		16.00
TOTAL	232.00	296.00	231.00	147.00	284.00

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	-0.42	-0.35	-0.45	-0.53	-0.46
DIPTERA	-0.53	-0.52	-0.53	-0.38	-0.53
EPHEMEROPTERA	-0.03				
NEMATODA		-0.14	-0.17		-0.24
Total	0.99	1.01	1.14	0.90	1.22

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	21170.00	43472.00	18632.00	2162.00	23870.00
DIPTERA	7140.00	7482.00	8742.00	9900.00	12656.00
EPHEMEROPTERA	0.00	0.00	0.00	0.00	0.00
NEMATODA	0.00	56.00	56.00	0.00	240.00
Total	0.47	0.42	0.48	0.44	0.49

BER

1B	2B	3B	4B	5B
0.37	0.35	0.37	0.20	0.36

WB 93/05/06

	1.00	2.00	3.00	4.00	5.00
HAPLOTAXIDA	464.00	733.00	231.00	185.00	143.00
ACARI	1.00				1.00
DIPTERA	78.00	126.00	45.00	87.00	47.00
PELECYPODA			1.00		
TOTAL	543.00	859.00	277.00	272.00	191.00

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	-0.19	-0.20	-0.22	-0.38	-0.31
ACARI	-0.02				-0.04
DIPTERA	-0.40	-0.41	-0.43	-0.33	-0.50
PELECYPODA			-0.03		
Total	0.61	0.60	0.67	0.90	0.85

Taxon	1B	2B	3B	4B	5B
HAPLOTAXIDA	214832.00	536556.00	53130.00	34040.00	20306.00
ACARI	0.00	0.00	0.00	0.00	0.00
DIPTERA	6006.00	15750.00	1980.00	7482.00	2162.00
PELECYPODA	0.00	0.00	0.00	0.00	0.00
Total	0.25	0.25	0.28	0.44	0.38

WB

1B	2B	3B	4B	5B
0.32	0.15	0.36	0.18	0.38

Fig. 5

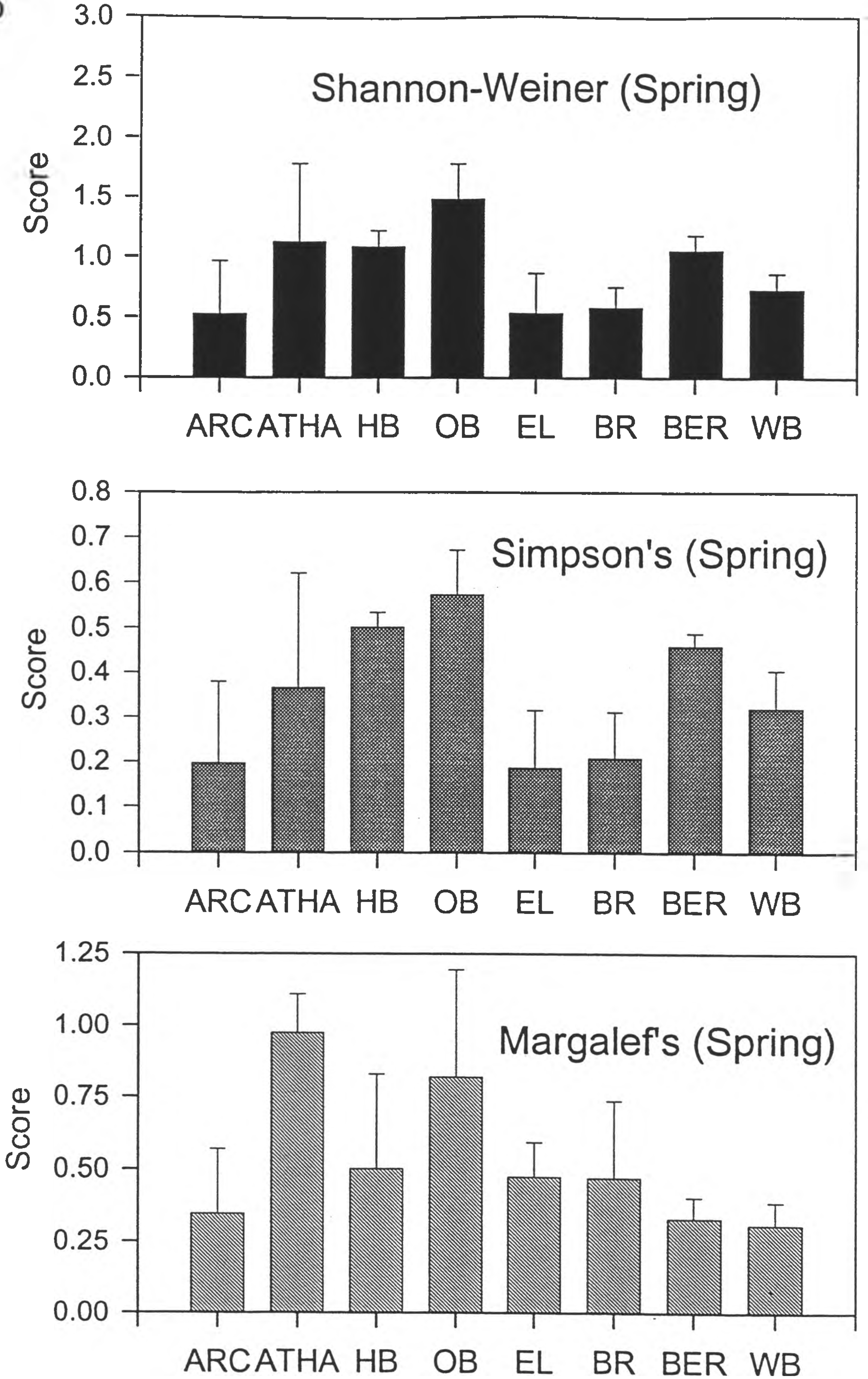

Shannon-Weiner (Spring)
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ARC ATHA HB OB EL BR BER WB
Simpson's (Spring)
Score
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ARC ATHA HB OB EL BR BER WB
Margalef's (Spring)
Score
1.25
1.00
0.75
0.50
0.25
0.00
ARC ATHA HB OB EL BR BER WB

Table 1. SUMMARY OF TOTAL INVERTEBRATE COUNTS FROM SEVEN SITES ON THE UPPER ATHABASCA RIVER IN SEPTEMBER 1993.

BR 93/09/17

Taxon	1B	2B	3B	4B	5B	Total Counts	Shannon-Weiner 1B	2B	3B	4B	5B	POOLED	Simpson's 1B	2B	3B	4B	5B
HAPLOTAXIDA	2036.00	1404.00	630.00	420.00	206.00	4696.00	-0.27	-0.23	-0.32	-0.37	-0.32	-0.31	4143260.00	1969812.00	396270.00	175980.00	42230.00
ACARI					6.00	6.00					-0.03	0.00	0.00	0.00	0.00	0.00	30.00
CLADOCERA	108.00	244.00	20.00	48.00	48.00	468.00	-0.12	-0.19	-0.07	-0.13	-0.14	-0.13	11556.00	59292.00	380.00	2256.00	2256.00
COPEPODA	164.00	120.00	64.00	57.00	100.00	505.00	-0.16	-0.12	-0.16	-0.15	-0.23	-0.15	26732.00	14280.00	4032.00	3192.00	9900.00
OSTRACODA		24.00	4.00		12.00	40.00		-0.04	-0.02		-0.05	-0.02	0.00	552.00	12.00	0.00	132.00
DIPTERA	750.00	482.00	387.00	608.00	625.00	2852.00	-0.34	-0.28	-0.37	-0.33	-0.38	-0.36	561750.00	231842.00	149382.00	369056.00	390000.00
EPHEMEROPTERA (small)					4.00	4.00					-0.02	-0.00	0.00	0.00	0.00	0.00	12.00
PULMONATA			1.00	1.00	1.00	3.00			-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
PELECYPODA	12.00	12.00	1.00	3.00	7.00	35.00	-0.02	-0.02	-0.01	-0.02	-0.03	-0.02	132.00	132.00	0.00	6.00	42.00
NEMATODA	8.00	16.00			4.00	28.00	-0.02	-0.03			-0.02	-0.02	56.00	240.00	0.00	0.00	12.00
TOTAL (n)	3078.00	2302.00	1107.00	1137.00	1013.00	9637.00	1.71	1.31	1.39	1.46	1.68	1.51	0.50	0.44	0.55	0.57	0.57

MARGALEF'S INDEX

1B	2B	3B	4B	5B
0.62	0.74	0.86	0.71	1.30

WB 93/09/17 D.P., K.S.

Taxon	B1	B2	B3	B4	B5	Total Counts	Shannon-Weiner 1B	2B	3B	4B	5B	POOLED	Simpson's 1B	2B	3B	4B	5B
HAPLOTAXIDA	2936.00	2166.00	1242.00	2004.00	4192.00	12540.00	-0.24	-0.30	-0.27	-0.18	-0.19	-0.14	8617160.00	4689390.00	1541322.00	4014012.00	17568672.00
CLADOCERA	336.00	48.00	8.00	8.00	76.00	476.00	-0.32	-0.11	-0.04	-0.03	-0.09	-0.11	112560.00	2256.00	56.00	56.00	5700.00
COPEPODA	12.00	12.00				24.00	-0.03	-0.04				-0.01	132.00	132.00	0.00	0.00	0.00
OSTRACODA	40.00	28.00	21.00	17.00	52.00	158.00	-0.07	-0.07	-0.08	-0.05	-0.07	-0.05	1560.00	756.00	420.00	272.00	2652.00
DIPTERA	228.00	252.00	291.00	272.00	508.00	1551.00	-0.25	-0.34	-0.45	-0.38	-0.34	-0.24	51756.00	63252.00	84390.00	73712.00	257556.00
HEMIPTERA		1.00	1.00			2.00		-0.00	0.01			-0.00	0.00	0.00	0.00	0.00	0.00
TRICHOPTERA					1.00	1.00					-0.00	-0.00	0.00	0.00	0.00	0.00	0.00
PULMONATA			1.00			1.00			-0.01			-0.00	0.00	0.00	0.00	0.00	0.00
PELECYPODA	42.00	21.00	4.00	16.00	24.00	107.00	-0.07	-0.06	-0.02	-0.03	-0.04	-0.04	1722.00	420.00	12.00	240.00	552.00
NEMATODA	1.00		4.00		20.00	25.00	-0.00		-0.02		-0.03	-0.01	0.00	0.00	12.00	0.00	380.00
TOTAL	3595.00	2528.00	1572.00	2317.00	4873.00	14885.00						0.00					
							0.99	0.81	0.90	0.67	0.76	0.87	0.32	0.26	0.34	0.24	0.25

MARGALEF'S INDEX

1B	2B	3B	4B	5B
0.73	0.77	0.81	0.52	0.71

OB 93/09/17

Taxon	B1	B2	B3	B4	B5	Total Counts	Shannon-Weiner 1B	2B	3B	4B	5B	POOLED	Simpson's 1B	2B	3B	4B	5B
ANNELIDA																	
OLIGOCHAETA																	
HAPLOTAXIDA	412.00	6709.00	2215.00	1568.00	3015.00	13919.00	-0.36	-0.15	-0.28	-0.38	-0.41	-0.27	169332.00	45003972.00	4904010.00	2457056.00	9087210.00
ACARI	4.00	1.00	4.00	22.00	5.00	36.00	-0.02	-0.00	-0.01	-0.03	-0.01	-0.01	12.00	0.00	12.00	462.00	20.00
CLADOCERA	128.00	552.00	368.00	336.00	660.00	2044.00	-0.22	-0.18	-0.24	-0.34	-0.40	-0.23	16256.00	304152.00	135056.00	112560.00	434940.00
COPEPODA	16.00	20.00	20.00	20.00	20.00	96.00	-0.05	-0.01	-0.03	-0.03	-0.03	-0.02	240.00	380.00	380.00	380.00	380.00
OSTRACODA	68.00	20.00	32.00	60.00	24.00	204.00	-0.15	-0.01	-0.04	-0.11	-0.04	-0.05	4556.00	380.00	992.00	3540.00	552.00
DIPTERA	696.00	669.00	747.00	1102.00	919.00	4133.00	-0.34	-0.21	-0.33	-0.35	-0.46	-0.32	483720.00	446892.00	557262.00	1213302.00	843642.00
EPHEMEROPTERA				12.00		12.00				-0.03		-0.00	0.00	0.00	0.00	132.00	0.00
HEMIPTERA	1.00				1.00	2.00	-0.01				-0.00	-0.00	0.00	0.00	0.00	0.00	0.00
PLECOPT (small)	1.00					1.00	-0.01					-0.00	0.00	0.00	0.00	0.00	0.00
TRICHOPTERA	1.00	2.00	1.00		1.00	5.00	-0.01	-0.00	-0.00		-0.00	-0.00	0.00	2.00	0.00	0.00	0.00
PULMONATA	1.00		2.00	1.00		4.00	-0.01		-0.00	-0.00		-0.00	0.00	0.00	2.00	0.00	0.00
PELECYPODA	23.00	47.00	10.00	29.00	29.00	138.00	-0.07	-0.03	-0.02	-0.06	-0.05	-0.03	506.00	2162.00	90.00	812.00	812.00
NEMATODA	20.00	8.00	12.00	4.00	12.00	56.00	-0.06	-0.01	-0.02	-0.01	-0.02	-0.02	380.00	56.00	132.00	12.00	132.00
TOTAL	1371.00	8028.00	3411.00	3154.00	4686.00	20650.00	1.88	0.88	1.42	1.00	1.42	1.39	0.64	0.29	0.52	0.62	0.55

MARGALEF'S INDEX

1B	2B	3B	4B	5B
1.32	0.89	1.11	1.12	1.06

ARC 93/09/15

Taxon	B1	B2	B3	B4	B5	Total Counts	Shannon-Weiner 1B	2B	3B	4B	5B	POOLED	Simpson's 1B	2B	3B	4B	5B
HAPLOTAXIDA	9.00	24.00	34.00	36.00	61.00	164.00	-0.06	-0.13	-0.18	-0.16	-0.16	-0.10	72.00	552.00	1122.00	1260.00	3660.00
ACARI		4.00	11.00	2.00	2.00	19.00		-0.03	-0.08	-0.02	-0.01	-0.02	0.00	12.00	110.00	2.00	2.00
CLADOCERA	128.00	108.00	96.00	160.00	368.00	860.00	-0.32	-0.34	-0.34	-0.41	-0.46	-0.29	16256.00	11556.00	9120.00	25440.00	135056.00
COPEPODA	56.00	36.00	40.00	52.00	96.00	280.00	-0.21	-0.17	-0.20	-0.21	-0.22	-0.15	3080.00	1260.00	1560.00	2652.00	9120.00
OSTRACODA		84.00	44.00	164.00	288.00	580.00		-0.30	-0.21	-0.41	-0.41	-0.24	0.00	6972.00	1892.00	26732.00	82656.00
DIPTERA	441.00	750.00	652.00	669.00	1100.00	3612.00	-0.26	-0.33	-0.34	-0.43	-0.46	-0.28	194040.00	561750.00	424452.00	446892.00	1208900.00
EPHEMEROPTERA	4.00					4.00	-0.03					-0.01	12.00	0.00	0.00	0.00	0.00
PULMONATA			1.00	1.00		2.00			-0.01	-0.01		-0.00	0.00	0.00	0.00	0.00	0.00
NEMATODA		21.00	30.00	12.00		63.00		-0.11	-0.16	-0.07		-0.05	0.00	420.00	870.00	132.00	0.00
TOTAL	638.00	1027.00	908.00	1096.00	1915.00	5584.00	1.28	1.41	1.52	1.72	1.71	1.64	0.47	0.43	0.47	0.38	0.61

MARGALEF'S INDEX

1B	2B	3B	4B	5B
0.62	0.87	1.03	1.00	0.66

ARCT 93/09/15

Taxon	B1	B2	B3	B4	B5	Total Counts	Shannon-Weiner 1B	2B	3B	4B	5B	POOLED	Simpson's 1B	2B	3B	4B	5B
HAPLOTAXIDA	277.00	265.00	28.00	30.00	257.00	857.00	-0.47	-0.50	-0.14	-0.12	-0.48	-0.28	76452.00	69960.00	756.00	870.00	65792.00
ACARI	9.00	4.00	4.00	4.00	12.00	33.00	-0.03	-0.03	-0.03	-0.03	-0.07	-0.03	72.00	12.00	12.00	12.00	132.00
CLADOCERA	272.00	192.00	120.00	204.00	252.00	1040.00	-0.47	-0.44	-0.36	-0.42	-0.48	-0.31	73712.00	36672.00	14280.00	41412.00	63252.00
COPEPODA	16.00	16.00		4.00	12.00	48.00	-0.08	0.09		-0.03	-0.07	-0.04	240.00	240.00	0.00	12.00	132.00
OSTRACODA	64.00	24.00	76.00	80.00	80.00	324.00	-0.21	-0.12	-0.28	-0.24	-0.27	-0.16	4032.00	552.00	5700.00	6320.00	6320.00
DIPTERA	679.00	575.00	788.00	1005.00	534.00	3581.00	-0.50	-0.48	-0.29	-0.10	-0.51	-0.30	460362.00	330050.00	620156.00	1005006.00	186760.00
PLECOPTERA (small)		4.00				4.00		-0.03				-0.00	0.00	12.00	0.00	0.00	0.00
NEMATODA	16.00		8.00		12.00	36.00	-0.08		-0.03		-0.07	-0.03	240.00	0.00	56.00	0.00	132.00
TOTAL	1333.00	1080.00	1024.00	1323.00	1161.00	5923.00	1.83	1.76	1.16	1.14	1.93	1.67	0.63	0.62	0.39	0.40	0.80

MARGALEF'S INDEX

1B	2B	3B	4B	5B
0.83	0.86	0.72	0.70	0.85

EB 93/09/15

Taxon	B1	B2	B3	B4	B5	Total Counts	Shannon-Weiner 1B	2B	3B	4B	5B	POOLED	Simpson's 1B	2B	3B	4B	5B
HAPLOTAXIDA	268.00	300.00	156.00	305.00	418.00	1447.00	-0.49	-0.53	-0.34	-0.50	-0.52	-0.35	71556.00	89700.00	24180.00	92720.00	174306.00
ACARI				6.00		6.00				-0.04		-0.01	0.00	0.00	0.00	30.00	0.00
CLADOCERA	36.00	44.00	108.00	56.00	232.00	476.00	-0.27	-0.27	-0.28	-0.21	-0.43	-0.22	1260.00	1892.00	11556.00	3080.00	53592.00
COPEPODA	36.00	40.00	256.00	204.00	104.00	640.00	-0.27	-0.26	-0.44	-0.44	-0.28	-0.26	1260.00	1560.00	65280.00	41412.00	10712.00
OSTRACODA	28.00	116.00	244.00	148.00	180.00	716.00	-0.23	-0.45	-0.43	-0.37	-0.38	-0.27	756.00	13340.00	59292.00	21756.00	32220.00
DIPTERA	115.00	194.00	886.00	445.00	453.00	2093.00	-0.48	-0.52	-0.51	-0.53	-0.55	-0.37	13110.00	37442.00	784110.00	197580.00	204756.00
HEMIPTERA			1.00		4.00	5.00			-0.01		-0.02	-0.01	0.00	0.00	0.00	0.00	12.00
PULMONATA	5.00		5.00		5.00	15.00	-0.07		-0.03		-0.03	-0.01	20.00	0.00	20.00	0.00	20.00
PELECYPODA	9.00	6.00	10.00	9.00	1.00	35.00	-0.10	-0.07	-0.05	-0.03	-0.01	-0.01	72.00	30.00	90.00	72.00	0.00
NEMATODA	16.00	16.00	16.00	20.00	24.00	92.00	-0.16	-0.14	-0.07	-0.10	-0.10	-0.07	240.00	240.00	240.00	380.00	552.00
TOTAL	513.00	616.00	1482.00	1193.00	1421.00	5225.00	2.06	2.24	2.15	2.24	2.28	2.37	0.66	0.75	0.71	0.75	0.76

MARGALEF'S INDEX

1B	2B	3B	4B	5B
1.12	0.93	1.10	0.99	1.10

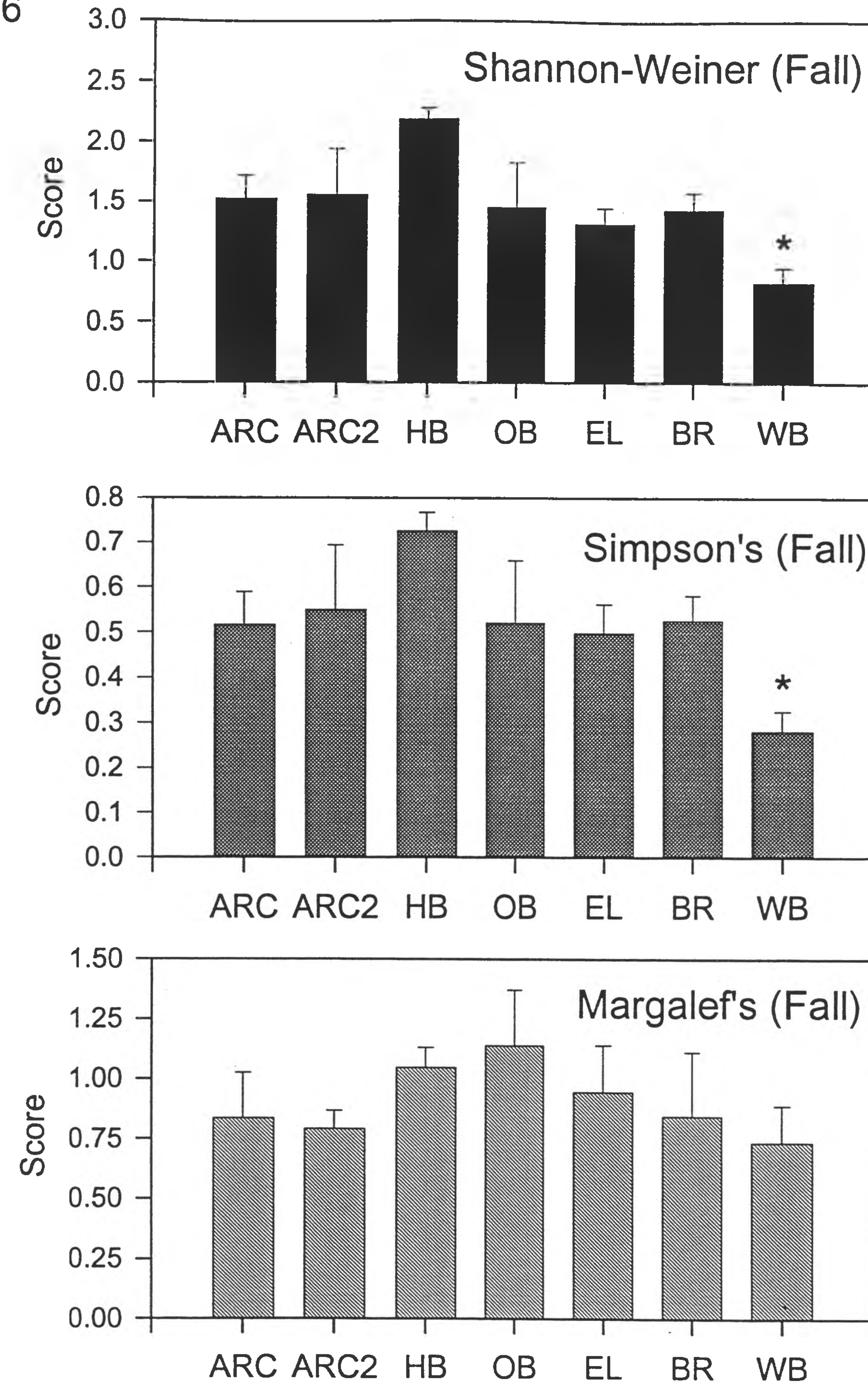
III.	[illegible]	B1	B2	B3	B4	B5	
	HAPLOTAXIDA	1729.00	2571.00	3358.00	1819.00	1781.00	10658.00
	ACARI	15.00	13.00	13.00	14.00	13.00	68.00
	CLADOCERA	480.00	600.00	148.00	64.00	196.00	1688.00
	COPEPODA	4.00	8.00	12.00			24.00
	OSTRACODA	17.00	24.00	44.00	12.00	12.00	109.00
	DIPTERA	533.00	765.00	392.00	657.00	679.00	3326.00
	EPHEMEROPTERA	4.00	4.00	4.00			12.00
	MEGALOPTERA	1.00					1.00
	PLECOPTERA	1.00					1.00
	PULMONATA		1.00		1.00		2.00
	PELECYPODA	7.00	6.00	2.00	1.00	5.00	21.00
NEMATODA			12.00	4.00	4.00		20.00
	TOTAL	2791.00	4004.00	4177.00	1772.00	2686.00	15930.00

	1B	2B	3B	4B	5B	
HAPLOTAXIDA	-0.43	-0.41	-0.30	-0.46	-0.30	-0.27
ACARI	-0.04	-0.03	-0.02	-0.00	-0.04	-0.02
CLADOCERA	-0.44	-0.41	-0.29	-0.17	-0.28	-0.24
COPEPODA	-0.01	-0.02	-0.02			-0.01
OSTRACODA	-0.04	-0.04	-0.06	-0.05	-0.05	-0.03
DIPTERA	-0.46	-0.45	-0.41	-0.55	-0.50	-0.35
EPHEMEROPTERA	-0.01	-0.01	-0.01			-0.01
MEGALOPTERA	-0.00					-0.00
PLECOPTERA	-0.00					-0.00
PULMONATA		-0.00		0.01		-0.00
PELECYPODA	-0.02	-0.01	-0.00	-0.01	-0.02	-0.01
NEMATODA		-0.03	-0.01	-0.02		-0.01
TOTAL	1.46	1.42	1.12	1.50	1.26	1.34

	1B	2B	3B	4B	5B
HAPLOTAXIDA	2987712.00	6607470.00	12615806.00	1037342.00	3170180.00
ACARI	210.00	156.00	156.00	182.00	156.00
CLADOCERA	229920.00	159400.00	120756.00	4032.00	38120.00
COPEPODA	12.00	56.00	132.00	0.00	0.00
OSTRACODA	272.00	552.00	1892.00	132.00	132.00
DIPTERA	283556.00	584460.00	478172.00	430992.00	460362.00
EPHEMEROPTERA	12.00	12.00	12.00	0.00	0.00
MEGALOPTERA	0.00	0.00	0.00	0.00	0.00
PLECOPTERA	0.00	0.00	0.00	0.00	0.00
PULMONATA	0.00	0.00	0.00	0.00	0.00
PELECYPODA	42.00	30.00	2.00	0.00	20.00
NEMATODA	0.00	132.00	12.00	12.00	0.00
TOTAL	0.55	0.55	0.39	0.53	0.49

1B	2B	3B	4B	5B
1.13	1.08	0.93	0.94	0.43

Fig. 6



Shannon-Weiner (Fall)
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ARC
ARC2
HB
OB
EL
BR
WB
*
Simpson's (Fall)
Score
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ARC
ARC2
HB
OB
EL
BR
WB
*
Margalef's (Fall)
Score
1.50
1.25
1.00
0.75
0.50
0.25
0.00
ARC
ARC2
HB
OB
EL
BR
WB

APPENDIX B: SUMMARIES OF TOTAL INVERTEBRATE COUNTS FROM SAFFRAN

For ease of reference this appendix contains Tables 2 and 3 extracted from a previous report, namely;

> Saffran, K. 1995. *Northern River Basins Study Project Report No. 50, Aquatic Macroinvertebrate Identifications, Athabasca River, May and September, 1993.* Northern River Basins Study, Edmonton, Alberta

Table 2. Summary of total invertebrate counts from eight sites on the upper Athabasca River, May 1993.

AREL	**93/05/05** Sorters*: P.H., D.P., K.S.	1	2	3	4	5
ANNELIDA						
	OLIGOCHAETA					
	HAPLOTAXIDA					
	Naididae			1		
	Tubificidae	102	179	177	372	573
ARTHROPODA						
	ARACHNOIDA					
	ACARI		2			4
	CRUSTACEA					
	CLADOCERA		4			
	OSTRACODA	4	7			
	INSECTA					
	DIPTERA					
	Chironomidae					
	Chironomini	31	114	54	106	126
	Tanytarsini		4			3
	Orthocladiinae		7		4	6
	Diamesinae	66	41	70	186	166
	Tanypodinae					1
	Chironomid Pupae		2	4		
	EPHEMEROPTERA					
	Ephemerellidae					
	Serratella					1
MOLLUSCA						
	PELECYPODA					
	Sphaeriidae					
	Pisidium	1				
NEMATODA		1	1			1
	TOTAL	205	361	306	668	881

* Sorters: P.H. = Paul Hvengaard, D.L. = Darcy Lightle, D.P. = Dee Patriquin, K.S. = Karen Saffran, and N.W. = Nancy Westworth

WHB	93/05/05 Sorters: D.P., K.S	1	2	3	4	5
ANNELIDA						
	OLIGOCHAETA					
	HAPLOTAXIDA					
	Tubificidae	114	124	48	52	46
ARTHROPODA						
	ARACHNOIDA					
	ACARI	2				1
	CRUSTACEA					
	CLADOCERA					43
	COPEPODA	10	12			4
	OSTRACODA			8	12	8
	INSECTA					
	DIPTERA					
	Chironomidae					
	Chironomini	55	12	24	33	32
	Tanytarsini	1			1	1
	Orthocladiinae	25	2		9	
	Diamesinae		8		6	1
	Tanypodinae	3	6	6		45
	Chironomid Pupae	10	2	5	3	23
	EPHEMEROPTERA					
	Baetidae					
	Baetis	2				
	PLECOPTERA (small)	2				
MOLLUSCA						
	PELECYPODA					
	Sphaeriidae					
	Pisidium			1		
NEMATODA		2			8	1
TARDIGRADA		2				
	TOTAL	228	166	92	124	205

ARATHAB 93/05/07 Sorters: D.P., K.S.	1	2	3	4	5
ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Naididae		4		3	
Tubificidae	14	13	6	5	12
ARTHROPODA					
CRUSTACEA					
CLADOCERA	12		4	16	4
COPEPODA	40	176	4	20	32
OSTRACODA	240	192	256	2800	412
INSECTA					
DIPTERA					
Ceratopogonidae		1			
Chironomidae					
Chironomini	14	119	6	9	17
Tanytarsini	31	17		34	18
Orthocladiinae	3	8	5	8	4
Diamesinae		4			
Tanypodinae	1		1		
Chironomid Pupae		1	1		
MOLLUSCA					
GASTROPODA					
PULMONATA					
Lymnaeidae	1		1	1	1
PELECYPODA					
Sphaeriidae					
Pisidium		5	1	1	1
NEMATODA	8	16		16	4
TOTAL	364	556	285	2913	505

ARC	**93/05/05** Sorters: P.H., D.P., K.S.	1	2	3	4	5
ANNELIDA						
	OLIGOCHAETA					
	HAPLOTAXIDA					
	Tubificidae		10	4	5	4
ARTHROPODA						
	ARACHNOIDA					
	ACARI		5		1	
	INSECTA					
	DIPTERA					
	Chironomidae					
	Chironomini	18	26	35	74	44
	Tanytarsini	8				
	Orthocladiinae	9			15	9
	Diamesinae	4	8		8	1
	Chironomid Adult	1			1	
	Empididae					
	Chelifera			1		
	PLECOPTERA (small)			2		
	TOTAL	40	49	42	104	58

OB	**93/05/05** Sorters: D.P., K.S.	1	2	3	4	5
ANNELIDA						
	OLIGOCHAETA					
	HAPLOTAXIDA					
	Tubificidae	18	5	4	41	29
ARTHROPODA						
	ARACHNOIDA					
	ACARI	2	12		152	
	CRUSTACEA					
	CLADOCERA				4	
	COPEPODA		72	4	8	
	INSECTA					
	DIPTERA					
	Ceratopogonidae				1	
	Chironomidae					
	Chironomini	46	417	207	262	388
	Tanytarsini	1	23	26	12	16
	Orthocladiinae	3	21	44	27	8
	Diamesinae	102	268	119	349	234
	Tanypodinae	1	5	1	24	2
	Chironomid Pupae		1			
	Chironomid Adult	1	13		16	14
	Empididae					
	Chelifera				1	
	Hemerodromia	1			1	
	EPHEMEROPTERA					
	Ephemerellidae					
	Serratella		1			2
NEMATODA						4
	TOTAL	175	838	405	898	697

ARBR	**93/05/06** Sorters: D.P, K.S.			1	2	3	4	5
ANNELIDA								
	OLIGOCHAETA							
	HAPLOTAXIDA							
		Tubificidae		653	1664	426	1316	324
ARTHROPODA								
	CRUSTACEA							
	CLADOCERA				8		16	
	COPEPODA			8		12	4	
	OSTRACODA			8			4	
	INSECTA							
	DIPTERA							
		Chironomidae						
			Chironomini	39	90	47	49	61
			Tanytarsini		15			7
			Orthocladiinae	6	1	6	1	1
			Diamesinae		13	1	8	35
			Tanypodinae	1		1	5	2
MOLLUSCA								
	GASTROPODA							
	PULMONATA							
		Lymnaeidae		1				
	PELECYPODA							
		Sphaeriidae						
			Pisidium			2	1	
NEMATODA							8	
			TOTAL	716	1791	495	1412	430

ARBER	**93/05/06** Sorters: D.P., K.S.					
		1	2	3	4	5
ANNELIDA						
OLIGOCHAETA						
HAPLOTAXIDA						
	Enchytraeidae					1
	Naididae	1				
	Tubificidae	145	209	137	47	154
ARTHROPODA						
INSECTA						
DIPTERA						
	Chironomidae					
	Chironomini	41	59	54	52	58
	Tanytarsini		1			
	Orthocladiinae	31	11	19	47	43
	Diamesinae	10	15	19	1	7
	Chironomid Pupae	3	1	2		5
EPHEMEROPTERA						
	Ephemerellidae	1				
NEMATODA			8	8		16
	TOTAL	232	304	239	147	284

ARW	**93/05/06** Sorters: D.P., K.S.	1	2	3	4	5
ANNELIDA						
OLIGOCHAETA						
HAPLOTAXIDA						
Tubificidae		464	733	231	185	143
ARTHROPODA						
ARACHNOIDA						
ACARI		1				1
INSECTA						
DIPTERA						
Chironomidae						
Chironomini		48	49	27	42	28
Tanytarsini			4		1	1
Orthocladiinae		2	17		1	
Diamesinae		28	55	17	43	18
Tanypodinae			1	1		
EPHEMEROPTERA						
Ephemerellidae						
Serratella						1
MOLLUSCA						
PELECYPODA						
Sphaeriidae						
Pisidium				1		
TOTAL		543	859	277	272	192

Table 3. Summary of total invertebrate counts from eight sites on the upper Athabasca river, September 1993.

ABR **93/09/17** Sorters: D.P., K.S.	1B	2B	3B	4B	5B
ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Naididae	32	8	3	17	47
Tubificidae	2004	2396	627	403	159
ARTHROPODA					
ARACHNOIDA					
ACARI					6
CRUSTACEA					
CLADOCERA	108	244	20	48	48
COPEPODA	164	120	64	57	100
OSTRACODA		24	4		12
INSECTA					
DIPTERA					
Chironomidae					
Chironomini	662	409	317	370	422
Tanytarsini	64	54	51	219	173
Orthocladiinae	1	7	4	8	9
Diamesinae	11	12	15	11	20
Tanypodinae	12				1
Chironomid Pupae					1
EPHEMEROPTERA (small)					4
MOLLUSCA					
GASTROPODA					
PULMONATA					
Lymnaeidae			1	1	1
PELECYPODA					
Sphaeriidae					
Pisidium	12	12	1	3	7
NEMATODA	8	16			4
TOTAL	3078	3302	1107	1137	1014

WB	93/09/17 Sorters: D.P., K.S.					
		B1	B2	B3	B4	B5
ANNELIDA						
OLIGOCHAETA						
HAPLOTAXIDA						
Naididae						4
Tubificidae		2936	2166	1242	2004	4188
ARTHROPODA						
CRUSTACEA						
CLADOCERA		336	48	8	8	76
COPEPODA		12	12			
OSTRACODA		40	28	21	17	52
INSECTA						
DIPTERA						
Ceratopogonidae		1			1	1
Chironomidae						
Chironomini		198	138	121	138	264
Tanytarsini		9	36	16	9	28
Diamesinae		17			1	
Tanypodinae		3	88	153	123	215
Tabanidae						
Chrysops				1		
HEMIPTERA						
Corixidae			1	1		
TRICHOPTERA						
Limnephilidae						1
MOLLUSCA						
GASTROPODA						
PULMONATA						
Lymnaeidae				1		
PELECYPODA						
Sphaeriidae						
Pisidium		42	21	4	16	24
NEMATODA		1		4		20
	TOTAL	3595	2538	1572	2317	4873

OB	93/09/17 Sorters: D.L., D.P., K.S.				
	B1	B2	B3	B4	B5
ANNELIDA					
OLIGOCHAETA					
HAPLOTAXIDA					
Naididae	48	31	36	65	43
Tubificidae	364	6678	2179	1503	2972
ARTHROPODA					
ARACHNOIDA					
ACARI	4	1	4	22	5
CRUSTACEA					
CLADOCERA	128	552	368	336	660
COPEPODA	16	20	20	20	20
OSTRACODA	68	20	32	60	24
INSECTA					
DIPTERA					
Ceratopogonidae					1
Chironomidae					
Chironomini	255	317	354	340	418
Tanytarsini	152	120	65	209	158
Orthocladiinae	41	24	51	186	77
Diamesinae	231	189	271	310	240
Tanypodinae	13	15	6	57	25
Empididae					
Chelifera	4	4			
EPHEMEROPTERA					
Ephemerellidae				12	
HEMIPTERA					
Corixidae	1				1
PLECOPTERA (small)	1				
TRICHOPTERA					
Brachycentridae					
Brachycentrus	1	2	1		1

CONTINUED.../

OB	**93/09/17**	/...CONTINUED				
			B1	B2	B3	B4	B5
MOLLUSCA							
	GASTROPODA						
	PULMONATA						
		Lymnaeidae			2	1	
		Physidae					
		Physa	1				
	PELECYPODA						
		Sphaeriidae					
		Pisidium	23	47	10	29	29
NEMATODA			20	8	12	4	12
		TOTAL	1371	8028	3411	3154	4686

ARC	**93/09/15** Sorters: D.L., D.P., K.S.					
		B1	B2	B3	B4	B5
ANNELIDA						
	OLIGOCHAETA					
	HAPLOTAXIDA					
	Naididae	1	20	2	6	16
	Tubificidae	8	4	32	30	45
ARTHROPODA						
	ARACHNOIDA					
	ACARI		4	11	2	2
	CRUSTACEA					
	CLADOCERA	128	108	96	160	368
	COPEPODA	56	36	40	52	96
	OSTRACODA		84	44	164	288
	INSECTA					
	DIPTERA					
	Ceratopogonidae				2	
	Chironomidae					
	Chironomini	89	172	166	135	111
	Tanytarsini	238	384	264	342	714
	Orthocladiinae	43	45	81	31	143
	Diamesinae	60	124	137	147	110
	Tanypodinae	2	23	4	11	21
	Chironomid Pupae	1	2		1	1
	Empididae	8				
	EPHEMEROPTERA					
	Baetidae					
	Baetis	4				
MOLLUSCA						
	GASTROPODA					
	PULMONATA					
	Lymnaeidae			1	1	
NEMATODA			21	30	12	
	TOTAL	638	1027	908	1096	1915

ARC2	**93/09/15** Sorters: D.L., D.P., K.S.	B1	B2	B3	B4	B5
ANNELIDA						
	OLIGOCHAETA					
	HAPLOTAXIDA					
	Naididae	9	4	6	8	6
	Tubificidae	268	261	22	22	251
ARTHROPODA						
	ARACHNOIDA					
	ACARI	9	4	4	4	12
	CRUSTACEA					
	CLADOCERA	272	192	120	204	252
	COPEPODA	16	16		4	12
	OSTRACODA	64	24	76	80	80
	INSECTA					
	DIPTERA					
	Chironomidae					
	Chironomini	143	204	206	191	122
	Tanytarsini	338	221	515	658	274
	Orthocladiinae	62	73	37	101	77
	Diamesinae	123	69	27	41	57
	Tanypodinae	8	5		9	4
	Chironomid Pupae	5	3	3	3	2
	PLECOPTERA (small)		4			
NEMATODA		16		8		12
	TOTAL	1333	1080	1024	1325	1161

HB	93/09/15 Sorters: K.S., N.W.	B1	B2	B3	B4	B5
ANNELIDA						
	OLIGOCHAETA					
	HAPLOTAXIDA					
	Naididae	16	11	7	13	8
	Tubificidae	252	189	149	292	410
ARTHROPODA						
	ARACHNOIDA					
	ACARI				6	
	CRUSTACEA					
	CLADOCERA	36	44	108	56	232
	COPEPODA	36	40	256	204	104
	OSTRACODA	28	116	244	148	180
	INSECTA					
	DIPTERA					
	Chironomidae					
	Chironomini	39	46	131	136	112
	Tanytarsini	20	36	136	113	102
	Orthocladiinae	24	45	185	90	109
	Diamesinae	23	42	133	67	90
	Tanypodinae	9	25	101	39	40
	Chironomid Adult					4
	HEMIPTERA					
	Corixidae			1		4
MOLLUSCA						
	GASTROPODA					
	PULMONATA					
	Lymnaeidae	4		1		
	Planorbidae	1				1
	PELECYPODA					
	Sphaeriidae					
	Pisidium	9	6	10	9	1
NEMATODA		16	16	16	20	24
	TOTAL	513	616	1478	1193	1421

EL	93/09/15 Sorters: D.L, K.S., N.W.	B1	B2	B3	B4	B5
ANNELIDA						
	OLIGOCHAETA					
	HAPLOTAXIDA					
	Naididae	76	70	26	4	35
	Tubificidae	1653	2501	3532	1015	1746
ARTHROPODA						
	ARACHNOIDA					
	ACARI	15	13	13	14	13
	CRUSTACEA					
	CLADOCERA	480	600	348	64	196
	COPEPODA	4	8	12		
	OSTRACODA	17	24	44	12	12
	INSECTA					
	DIPTERA					
	Chironomidae					
	Chironomini	244	388	360	323	325
	Tanytarsini	13	23	20	32	46
	Orthocladiinae	20	18	26	33	29
	Diamesinae	210	290	280	227	251
	Tanypodinae	46	46	6	38	28
	Empididae					
	Chelifera				4	
	EPHEMEROPTERA					
	Ephemerellidae	4	4	4		
	MEGALOPTERA					
	Sialidae					
	Sialis	1				
	PLECOPTERA (small)	1				
MOLLUSCA						
	GASTROPODA					
	PULMONATA					
	Lymnaeidae		1		1	
	PELECYPODA					
	Sphaeriidae					
	Pisidium	7	6	2	1	5
NEMATODA			12	4	4	
	TOTAL	2791	4004	4677	1772	2686

APPENDIX C: TERMS OF REFERENCE

NORTHERN RIVER BASINS STUDY

SCHEDULE A - TERMS OF REFERENCE

Project 2326-C1: Ecotoxicology of Depositional Sediments in the Upper Athabasca River

I. PROJECT BACKGROUND, RATIONALE AND RELEVANCE:

The assessment of water and sediment quality is essential to the execution of any proposed watershed management strategy. In addition, it is critical to determining the need for the success of any point and non-point source abatement programs. In any such strategy, it is also important to identify and protect desirable and self-sustaining aquatic communities but this is difficult using current techniques. Traditional environmental monitoring programs have emphasized the collection of biotic and abiotic samples for the analytical determination of residues of contaminants in a chemical-by-chemical approach and (more rarely) compared the biota of upstream sites (above a point-source) to downstream sites to determine the extent of declines in communities. Although this approach has proved valuable in establishing cause-and-effect in certain circumstances, it doesn't provide information on the types of biological communities which should be present if and when contamination is discontinued or removed.

Recent developments in multivariate statistical analyses have shown that the type of species assemblages (especially macroinvertebrate communities) at a reference site in a riverine or nearshore environment may be predicted using physical and chemical variables not affected by anthropogenic activities. This approach has potential in determining environmental health and in the setting of ecosystem objectives in a watershed. For example, a set of reference sites can be sampled within a watershed for their benthic community assemblages and selected chemical/physical variables measured. Community type at a potentially contaminated site with similar physical and chemical variables can then be predicted using a statistical model. A comparison between the existing community at a contaminated site and the predicted community can then be made to see if deterioration in community structure has occurrred. This approach can also be used in determining whether remediation has allowed a return to the expected community.

Additional classification of reference and contaminated sites based on responses from toxicity tests conducted in the laboratory using samples from these sames sites as above can be added as a second set of guidelines for determining impairment. This approach has been shown to be successful in the development of sediment quality guidelines in the near-shore areas of the Great Lakes.

It is the intent of this research to develop biological guidelines for benthic biota in the northern river basins using predictive models based on community structure from a number of clean (reference) and contaminated sites and with sediment bioassays. The results from this study will answer a number of crucial Study Board Questions and advance science in the development of biological sediment criteria. It will also add to a National Programme aimed at developing National Sediment Guidelines.

II. REQUIREMENTS

The triad approach (use of benthic community structure, laboratory toxicity tests, and physical-chemical parameters incorporated into predictive multivariate statistical models) will be carried out in a 'feasibility' study in the fall of 1993. Depositional sediments from two sites upstream and five sites downstream from the bleached kraft mill effluent at Hinton will be sampled by the NRBS in mid-September. This project will provide information on the toxicity of the sediments to four species of benthic invertebrates using chronic toxicity tests conducted in the laboratory.

The following methodology is to be employed for chronic toxicity testing of the sediments:

1) Five field replicate samples of sediment were collected at the seven river sites. These were placed in plastic bags and held at 4° C before chronic toxicity testing.

2) Culture of *C. riparius* are to be conducted according to the ASTM (1992) procedure. Culture of *H. azteca* are to be conducted according to the procedure described in Borgmann *et al* (1989). Eggs of the mayfly *Hexagenia* spp. (a mixture of *H. limbata and H. rigida*) are to be collected and organisms are to be cultured using the procedure of Hanes and Ciborowski (1992) and Bedard *et al* (1992).

3) Tests with *H. azteca*, *C. riparius* and *T. tubifex* are to be conducted in 250 glass beakers containing 60 to 100 mL of sieved (500 um), homogenized sediment with approximately 100 to 140 mL of overlying carbon-filtered, dechlorinated and aerated Lake Ontario water. Tests with the mayfly, *Hexagenia*, are to be conducted in 1 L glass jars with 150mL of test sediment and 850 mL overlying water. The sediment is allowed to settle for 24 h prior to the addition of animals. Test are to be initiated with the random addition of 15 organisms per beaker for *H. azteca* and *C. riparius*, 10 organisms per beaker for *Hexagenia* spp. and 4 organisms per beaker for *T. tubifex*. Juveniles of *H. azteca* are to be 3 to 7 d old at test initiation; *C. riparius* larvae are first instars and approximately 3 d post-oviposition; *Hexagenia* nymphs are 1.5 to 2 months old (approximately 5 to 10 mg wet weight) and *T. tubifex* adults are 8-9 weeks old. Tests are to be conducted at 23±1·C with a 16L:8D photoperiod.

Tests are to be static with the periodic addition of distilled water to replace water lost during evaporation. Each beaker should be covered with a plastic petri dish with a central hole for aeration using a Pasteur pipette and air line. Tests are to be terminated after 10 d for *C. riparius*, 21 d for *Hexagenia* and 28 d for *H. azteca* and *T. tubifex*. Endpoints to be measured in the tests are: *H. azteca*, survival and growth (mean dry weight in mg); *C. riparius*, survival and growth; *Hexagenia*, survival and growth; and *T tubifex*, survival and production of coccoons and young.

III. REPORTING REQUIREMENTS

1) The Contractor is to provide ten copies of the draft report to the NRBS Component Coordinator by December 31st, 1993. The draft report is to summarize and interpret the toxictiy testing carried out by the Contractor in II, above.

2) Three weeks after the receipt of review comments on the draft report, the Contractor is to provide the Component Coordinator with two unbound, camera copies and ten cerlox bound copies of the final report. The final report is to include the following: an acknowledgement section that indicates any local or native involvement in the project, table of contents, list of tables, list of figures and an appendix with the Terms of Reference for this project. Text for the report should be in Times Roman 12 point font. If photographs are to be included in the report they should be high contrast black and white. All tables and figures in the report should be clearly reproducible by a black and white photocopier. Along with copies of the final report, the Contractor is to supply an electronic version of the report in Word Perfect 5.1 format. Electronic copies of tables, figures and data appendices in the report are also to be submitted to the Component Coordinator along with the final report. These should be submitted in a spreadsheet (Quattro Pro preferred, but also Excel or Lotus) or database (dBase IV) format. Where appropriate, data in tables, figures and appendices should be geo-referenced

IV. CONTACTS

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SCHEDULE A

This project has been proposed by the Contaminants Component of the NRBS. The Contaminants Component Leader is:

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V. LITERATURE CITED

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