DISTRIBUTION AND ABUNDANCE OF MACROBENTHOS IN THE ATHABASCA RIVER NEAR FORT McMURRAY

by

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ABSTRACT

Benthic macroinvertebrates were collected at two-week intervals between 1982 May 13 and August 18 at 16 sites along an 85 km stretch of the Athabasca River between Fort McMurray and the Ells River. Samples were collected from gravel bars with a 0.1 m^2 cylinder sampler. All netting had a mesh size of 0.25 mm. Altogether, 348 samples were collected, containing a total of 27 229 specimens belonging to 68 taxonomic groups. The 32 species of Ephemeroptera comprised 21% of the total specimens. Chironomidae, Oligochaeta, Trichoptera, and Plecoptera comprised 53%, 18%, 2%, and 1% of the total specimens, respectively. Densities decreased between May 13 and May 28, then increased steadily to a maximum of 3 294 ind/m^2 in early July, after which densities declined again. Individuals belonging to size categories >2 mm, 1 to 2 mm, 0.5 to 1 mm, 0.25 to 0.5 mm comprised 16%, 20%, 48%, and 16% of the total individuals collected. Average size was largest in early June. The density of invertebrates downstream from the Suncor Tar Sands Mining and Extraction Plant was 31% lower than at sites upstream from the plant. There were no site-specific differences with regard to number of taxa or Shannon-Weaver diversity. Abundance and composition of invertebrates upstream of the Suncor plant were influenced by the confluence of the Clearwater River and by the effluent from the Fort McMurray Sewage Treatment Plant.

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1. INTRODUCTION

Although there is considerable potential for pollution of the Athabasca River as a result of tar sands development in the Fort McMurray region, only three studies have so far been carried out on the macrobenthos of the river. In 1975, samples were collected at monthly intervals from June to October at 15 stations extending along a 36 km stretch of the river from just upstream of the Suncor dyke to a few kilometres downstream of Fort MacKay (McCart et al. 1977). Samples were collected with an Ekman grab and with artificial substrates (B-B-Q baskets filled with limestone). During the same year, samples were also collected with B-B-Q baskets just upstream of Fort McMurray as part of the Athabasca River blackfly control program (Flannagan 1976). On 1977 October 07, and again on 1977 September 27, samples were collected with Ekman grabs and Surber samplers in the Athabasca River near Fort MacKay (Barton and Lock 1979).

During 1981, macrobenthos was collected at 16 stations along an 85 km stretch of the Athabasca River from just upstream of Fort McMurray to just downstream of the Ells River. The major objective was to determine if effluents from the Suncor tar sands operations have had a significant impact on the macrobenthos. A second objective was to determine seasonal variations in abundance and size of the macrobenthos. Such information will be useful in planning future monitoring studies.

2. DESCRIPTION OF STUDY AREA

2.1 HYDROLOGY

The hydrology of the Athabasca River in the vicinity of Fort McMurray has been described by Kellerhals et al. (1972), Doyle (1977), Beltaos (1978 and 1979), and Lipsett and Beltaos (1978). The character of the river changes significantly at Fort McMurray. For about 140 km upstream of the city the slope is 1.03% and the river drops through a series of rapids, some of which have been considered for hydroelectric development. The last of these rapids is located only 2 km upstream of the town. Downstream of Fort McMurray, the river flows almost directly northward with a slope of 0.07%.

The mean annual discharge at Fort McMurray (Station 07DA001) is 702 m^3/s with a range of 480 to 880 m^3/s. Mean annual discharge for 1981 was 481 m^3/s. In April, the discharge increases from the winter low of 200 m^3/s to a snowmelt peak of between 1 100 to 2 800 m^2/s. There are usually one or more rain peaks during the summer with discharges reaching maxima of up to 4 700 m^3/s. The water level may fluctuate by as much as 1 m/day. Discharge regime for the 1981 field season is shown in Figure 1.

The major tributary in the study area is the Clearwater River (Appendix 7.1, Figure 4), with a mean annual discharge of 137 m^3/s (Station 07CD001). The Clearwater River accounts for 13 to 29% of the annual flow of the Athabasca River. During 1981, mean annual discharge was 75 m^3/s, or 13.5% of the flow of the Athabasca River. Peak daily discharges from the Clearwater River may, however, account for as much as 38% of the flow of the Athabasca River. None of the remaining tributaries accounts for more than 3% of mean annual flow of the Athabasca River as shown below:

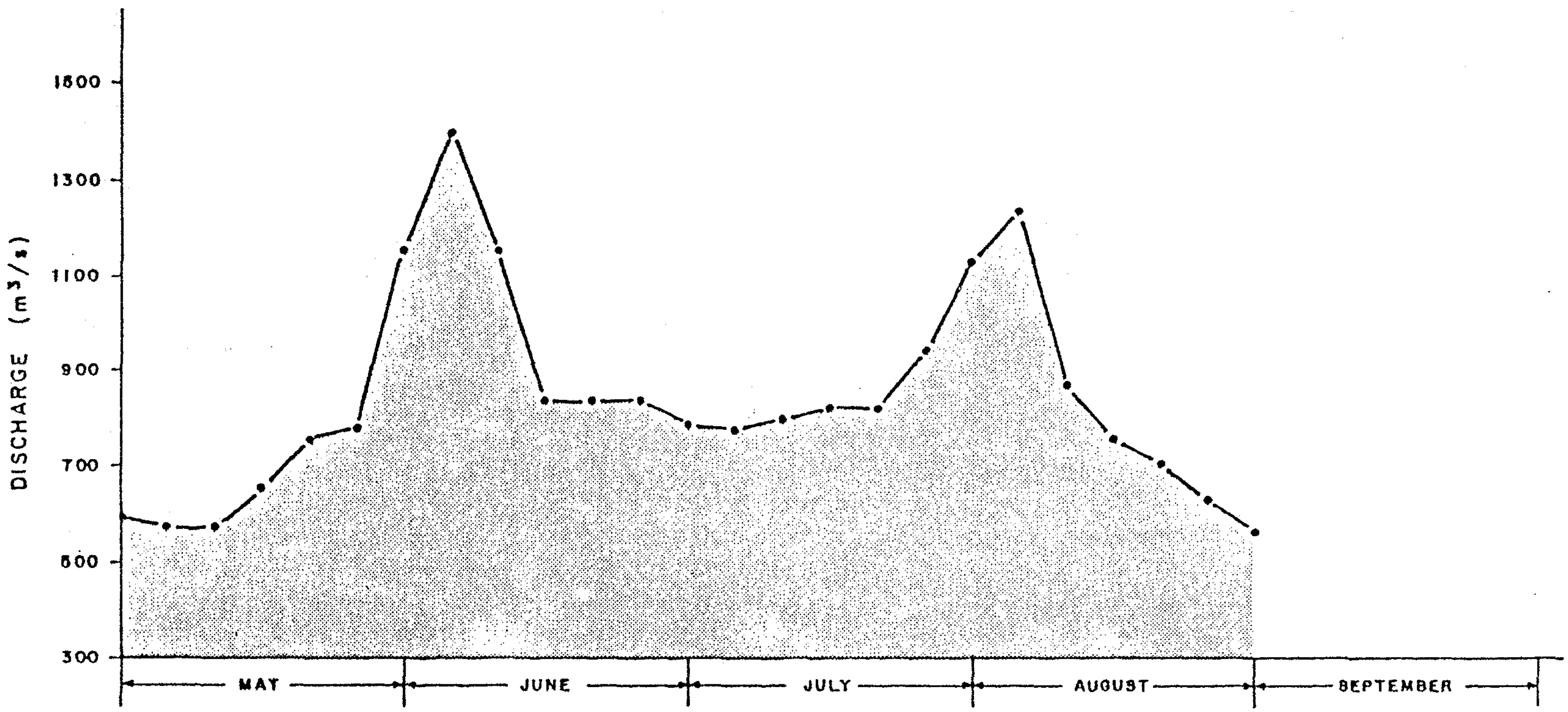

Figure 1. Discharge regime of the Athabasca River at Fort McMurray (Station 07DA001) during the 1981 field season.

Tributary	Station Number	Mean daily discharge (m^3/s) Long-term Mean	1981 Mean
Horse River	07CC001	8.67	discontinued
Poplar Creek	07DA007	1.05	0.35
Steepbank River	07DA006	6.16	2.01
Muskeg River	07DA008	4.52	1.30
MacKay River	07DB001	17.70	4.35
Ells River	07DA017	7.10	3.48

The long-term discharge value for Poplar Creek is based on data obtained since the diversion of the upper part of Beaver Creek into Poplar Creek.

The mean width and depth of the Athabasca River downstream of Fort MacKay are 400 m and 1.5 m, respectively. There are numerous islands, point bars, and mid-channel bars. A navigation channel with a depth of 4.5 m is maintained in the summer (Appendix 7.1, Figures 4 to 12).

The three major substrate types in the study area were sand (mean particle size 0.2 to 0.3 mm), limestone cobble (mean particle size 50 to 75 mm), and tar sand. Field surveys conducted in 1981 indicated that the three substrate types occurred in the ratio 75% sand : 20% cobble : 5% tar sand. The limestone cobbles were very rough and pitted.

2.2 PHYSICAL AND CHEMICAL PARAMETERS

Seasonal changes in water temperature have been reported by McCart et al. (1977), and Tripp and McCart (1979). Duration of ice cover is described in Kellerhals et al. (1972). Earliest and latest dates for ice break-up are April 16 and May 7, with the average date being April 28. Water temperatures reach about 10°C within 1 to 2 weeks after ice breakup. Temperatures then rise more slowly to a maximum of 18 to 20°C in July. Temperatures decline rapidly in September and reach 0°C by mid-October. The earliest and latest dates for freeze-up are October 22 and November 18, with the average date being November 5. Total number of day degrees is about 2 500.

Chemical data have been compiled by Akena and Christian (1981). Turbidity varies between 10 to 50 mg/L during the winter months but increases to between 250 to 4 000 mg/L during June and July depending upon discharge. At a depth of 0.25 m and an approximate turbidity of 100 mg/L, Barton and Lock (1979) found the photosynthetically-active radiation (400 to 700 nm) to be 45% of the value at the surface. The 1% and 0.1% light level occurred at 2 and 3 m, respectively. The pH varies between 7.5 and 8.0, dissolved oxygen oxceeds 80% saturation at all times, and conductivity varies between 200 μmhos in the summer and 350 μmhos in the winter. Organic components of the water have been described by Strosher and Peake (1978) and Nix et al. (1979).

Current velocity varies from 0 m/s near shore to 1.6 m/s in mic-channel. At the locations where samples were taken, the current varied from 0.1 to 0.5 m/s, with a mean of 0.3 m/s (Table 1).

Table 1. Current velocities (cm/s) at 16 sampling stations in the Athabasca River, 1981. Measurements were made with a Gurley Current Meter held 10 cm below the water surface adjacent to the cylinder sampler, and at a point were the water depth was 0.5 m.

Station	Date							
	May 13/14	May 28/29	June 9/10	June 23/24	July 7/8	July 21/22	Aug. 18/19	Mean
1E	30	30	29	30	36	22	28	29
1W	39	36	41	31	29	33	33	35
2E	37	33	33	32	24	32	29	31
2W	36	37	34	39	26	23	30	32
3E	44	43	45	40	23	40	36	39
3W	46	42	49	40	41	46	42	44
4E	62	56	68	46	40	22	42	48
4W	49	48	50	45	38	34	40	43
5E	26	21	30	27	34	26	31	28
5W	55	60	50	47	25	23	32	42
6E	49	51	30	35	14	21	27	32
6W	30	35	40	34	42	31	25	34
7E	45	37	30	26	31	21	23	30
7W	56	42	40	43	40	40	29	41
8E	47	23	70	23	18	12	12	29
8W	48	69	50	38	46	39	28	45
Mean	44	41	43	36	32	29	30	36

2.3 MICROBIAL PARAMETERS

Bacterial populations in the Athabasca River have been described by Nix et al. (1979), and Geesey and Costerton (1979). Densities of planktonic bacteria varied from 1×10^5 to 2×10^6 cells/mL. McCart et al. (1977) examined epiphytic algal communities which developed on glass slides suspended 0.5 m below the water surface in the Athabasca River. A total of 191 algal taxa were identified, of which 60% were diatoms; 20% were Chlorophyta; 10% Cyanophyta; and 10% non-diatom Chrysophyta. Densities varied from almost zero in April to 4×10^5 cells/mL in September. Diatoms were the dominant group in spring and summer, while filamentous Cyanophyta were dominant in fall and winter. The total amount of organic matter (detritus, bacteria, and algae) on the slides increased from 100 mg/m^2 in late winter to 750 mg/m^2 in summer. These values would suggest that benthic animals have an abundant supply of food.

2.4 HUMAN IMPACTS

Suncor (formerly Great Canadian Oil Sands Ltd.) operates a tar sands extraction and upgrading plant adjacent to the river betweem river miles 21 and 26. Under normal operating conditions, the plant discharges 40 000 m^3/day into the river, including 210 kg of oils and greases, 140 kg of ammonia, 10 kg of phenol, and 4 kg of sulphide. The chemical oxygen demand of the effluent is 4 200 kg/day. The river also receives effluent from the Fort McMurray sewage treatment plant located on the west side of the river, 2 km north of the Fort McMurray bridge. The facility consists of three aerated lagoons. The 14 000 m^3 of effluent discharged per day has a biochemical oxygen demand of 10 to 21 mg/L, a chemical oxygen demand of 77 mg/L, and a suspended solids concentration of 14 to 19 mg/L (Benner 1980). Methoxychlor was injected into the Athabasca River near the Town of Athabasca, 430 km upstream from Fort McMurray, on 1981 May 20 and June 19, in order to reduce populations of blackfly larvae. Similar injections, generally of concentrations of 0.3 ppm for 15 minutes, have been made since 1974. These treatments have been shown to increase drift rates as far downstream as Fort McMurray (Flannagan et al. 1979). The periodic hydraulic dredging of the navigation channel may also impact on macrobenthic populations, either through increased sedimentation or by re-suspending pollutants buried in the sediment.

2.5 DESCRIPTION OF 1981 SAMPLING STATIONS

Location of all sampling stations is shown on the maps (Figures 4 to 12) in Appendix 7.1. These maps will allow the stations to be relocated in any future monitoring programme. Sites 1, 2, 3, 6, 7, and 8 were chosen to coincide with the water sampling stations used by Dr. M. Akena, Water Quality Branch, Alberta Environment. Stations 4 and 5 were chosen because it was determined useful to have some sites closer to the Suncor facility. At each site, samples were collected from each side of the river, thus giving a total of 16 stations. All stations had a gravel substrate with a mean particle size of 8 to 13 cm. The surface water velocity at the sites averaged 36 cm/sec, but varied considerably from station to station and date to date (Table 1). Average values at individual stations varied from 28 cm/s (Station 5E) to 48 cm/s (Station 4E). Current velocities averaged over 40 cm/s on May 13, May 28, and June 9, declined to 36 cm/s on June 23, and remained approximately 30 cm/s for the remaining three collection dates.

3. PROCEDURE

3.1 FIELD SAMPLING

Samples were collected with a circular cylinder sampler covering an area of 0.1 m^2 (Figure 2). The sampler was covered with Nitex netting (MSE Engineering, 265 Canarctic Drive, Downsview, Ontario M3J 2N7) with a mesh size of 0.25 mm. Around the bottom of the sampler was a 15 cm wide plywood collar with a 10 cm thick layer of polyurethane foam glued to the bottom. The collecting bag on the

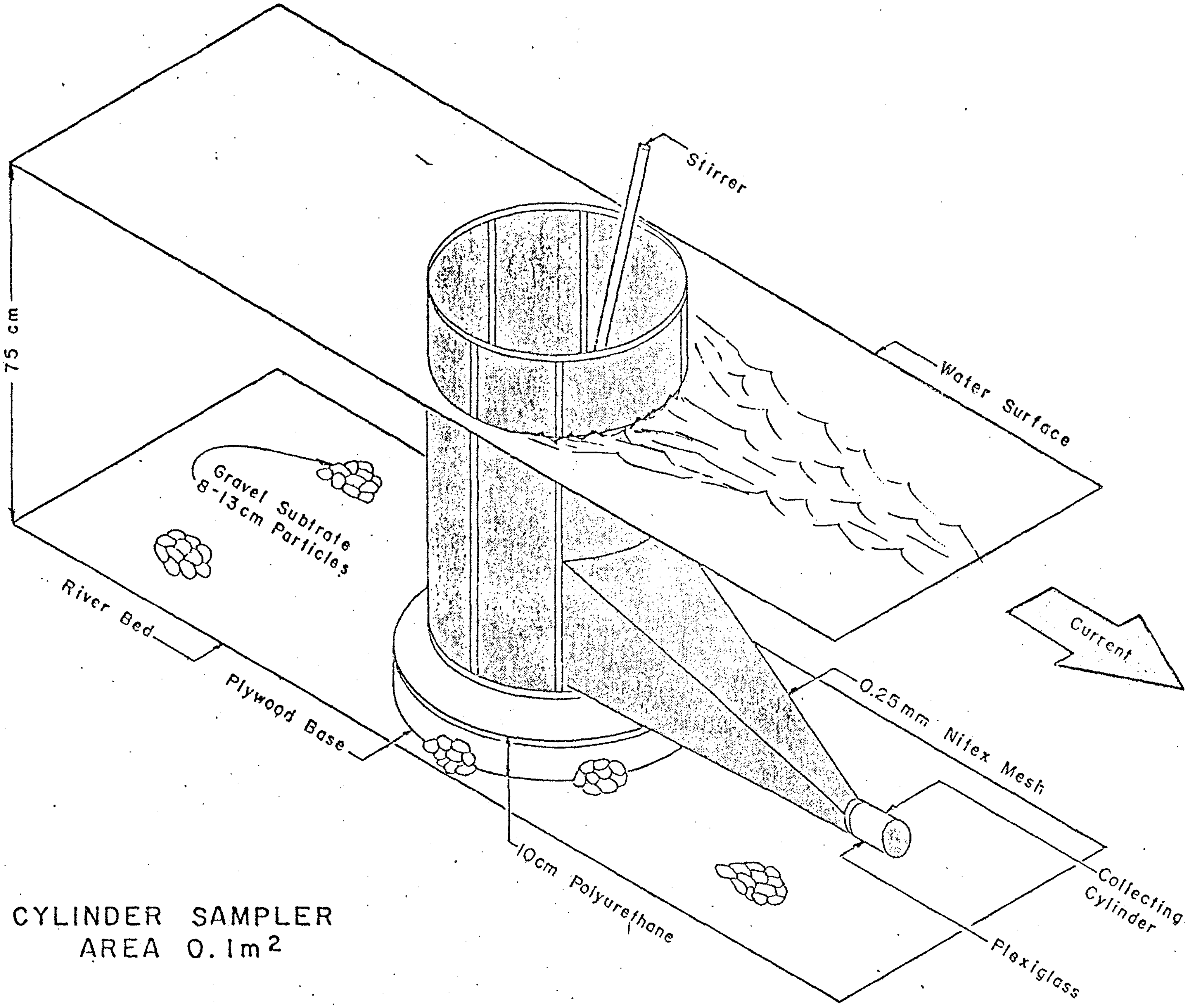

Figure 2. Cylinder sample used in the 1981 Athabasca survey.

downstream side of the cylinder terminated in a plexiglass collecting bucket the bottom of which was also covered with 250 mm Nitex mesh. The collecting bucket could be unscrewed from the collecting bag, thus making it easy to wash organisms from the bucket into a 250 mL collecting jar.

All samples were collected from a depth of 50 to 75 cm. Each of the two people operating the sampler placed one foot on the plywood collar. This compressed the foam and produced a tight seal between the bottom and the sampler. The sediment enclosed by the cylinder was then disturbed by a metal rod having a 15 cm metal spike welded to its bottom. The spike, which had a much smaller diameter than the rod, made it easier to stir up the sediment, and also ensured that the sediment was always disturbed to the same depth (i.e., 15 cm). While one person stirred up the sediment, the other person pushed water into the upstream end of the sampler with a paddle. This ensured that any organisms dislodged from the sediment were quickly swept into the collecting bag on the downstream side. As a result of the paddling, the flow of water through the cylinder was kept at 30 cm/s, even in areas of slow flow. Stirring and paddling was continued for 3 min. Several field trials with the sampler in the Bow River at Calgary showed that this mode of operation removed in excess of 90% of the organisms in the area enclosed by the sampler.

At each station, three replicate samples were collected, with the distance between samples being approximately 10 m. After the samples were placed in the collecting jar, they were examined for uniformity of sample volume. If the volume of detritus in the jars differed by more than 50%, more samples were collected and the three most similar ones chosen. This procedure was based on the correlation between detritus and density of organisms which has been frequently reported in the literature (cf. Rabeni and Minshall 1977). Such a selection procedure should reduce the variability between samples without biasing the sample mean, since there was no selection for either high or low volumes of detritus, but only for a uniform amount of detritus. Bias was furthermore prevented by the inability to see the stream bottom in the turbid water, and by not being able to determine the number of organisms in the sample by simple visual inspection.

The 16 stations were sampled in an upstream order. It required 2 days to sample all stations, with Sites 1 to 4 being sampled on the first day and Sites 5 to 8 on the next day. It required approximately 1 hour to collect three replicate samples from one station. Samples were collected at two-week intervals: May 13 and 14, May 28 and 29, June 9 and 10, June 23 and 24, July 7 and 8, July 21 and 22, August 4, and August 18 and 19. Sampling on August 4 was terminated after completion of Site 2 because of mechanical problems with the outboard motor. Sampling dates were the same as those on which water samples for chemical analysis were collected by Dr. M. Akena.

3.2 SORTING AND IDENTIFICATION

All samples had been preserved in the field with 10% formalin. In the laboratory, samples were washed through a set of nested sieves with mesh sizes 2, 1, 0.5, and 0.25 mm. The 2 mm and 1 mm fractions were examined completely and all organisms removed. The 0.5 mm and 0.25 mm fractions were each poured into a separate beaker to which water was added to make a volume of 200 mL. The sample was then vigorously stirred and a 40 mL subsample was quickly poured into a smaller beaker. Several trials showed that, at the concentrations encountered in the laboratory (up to 500 organisms/200 mL), the sub-sampling procedure was unbiased (i.e., a chi-squared test showed no significant differences in the number of animals in the five subsamples possible from a single sample).

Animals were removed from the samples by placing small amounts of substrate into a Petri dish and examining it under the low power (x60) of a binocular dissection microscope. The animals collected from each size fraction were placed in a separate plastic 4 dram pharmaceutical vial with a snap cap. Once organisms had been sorted from the sediment, the sediment was returned to a jar and kept for future reference.

Sorting was done by six undergraduate students having varying degrees of prior experience. The first three samples sorted by a student, as well as random samples thereafter, were re-examined by the author to determine sorting efficiency. After the first three samples, the sorting efficiency of the students was always greater than 95%. Average sorting time per sample was 45 min.

All identifications were done by the author. Identifications were based on the following keys: Edmunds et al. (1976) for Ephemeroptera; Wiggins (1977) for Trichoptera; Pennak (1978); and Merritt and Cummins (1978) for other groups. Identifications of larval fish were verified by Carl Dietz, Edmonton. Taxonomic work on some of the groups, especially the Oligochaeta and Chironomidae is still in progress and will be reported at a later stage. All specimens are being kept by the author. Average identification time was 70 min per sample.

3.3 STATISTICAL ANALYSIS

The Shannon-Wiener diversity index was used to summarize the species-abundance data from each station into a single number which could then be compared with indices for other stations. The advantages of this index over others are:

1) It has been widely used in aquatic ecology (Hellawell 1978).
2) Indices for two stations can be compared statistically with a modified t-text (Poole 1974).
3) The index is less affected by changes in sample size than other indices (Edwards et al. 1975).

A two-dimensional community ordination, originally described by Bray and Curtis (1957), was used to provide a graphical representation of the similarity of the 16 stations to each other. This ordination technique is both one of the simplest and most effective (Gauch and Whittaker 1972; Rabeni and Gibbs 1980. The first step is to produce a community matrix in which each station is compared with every other station with the use of a suitable community similarity coefficient. A Raabe coefficient (Raabe 1932) was used mainly because of its simplicity of calculation. The coefficient is simply the sum of the minimum percentage abundance of the species common to both sites. The coefficient varies from 0% (no species in common between the two stations being compared) to 100% (all species present in the same proportion at the two stations being compared). The similarity coefficients are then subtracted from 100 to convert them to dissimilarity coefficients. Next, the two stations most dissimilar to each other are determined and used to define the end points of the x-axis. The remaining stations are then arranged along the x-axis with regard to the end points based on Euclidean distance. Next, the station with the poorest fit on the x-axis is determined. This station, together with the station most dissimilar to it, are then used as end points for the y-axis. The remaining stands are then positioned along the y-axis relative to the end points as was done for the x-axis.

The final result is a two-dimensional plot in which each station is represented by a point. The distance between the points is proportional to the dissimilarity between stations. Points located close together indicate stations which are similar to each other, while points located far apart indicate dissimilar stations. Further details regarding the technique are described in Cox (1980).

4. RESULTS

4.1 TAXONOMIC COMPOSITION AND RELATIVE ABUNDANCE

Detailed species abundance lists of each of the 348 samples collected are given in Appendix 7.2. The total of 27 229 organisms which were identified (all of the 2 mm and 1 mm fractions and one fifth of the 0.5 mm and 0.25 mm fractions) were classified into 68 taxonomic categories (Table 2). Ephemeroptera made up 21% of the total organisms. It is likely the 32 mayfly taxa listed in Table 2 represent separate species. Only 5 taxa (*Ametropus*, *Caenis*, *Cloeon*, *Heptagenia* and *Tricorythodes*) contributed more than 1% to the mean density. *Heptagenia* was by far the most abundant mayfly nymph.

Plecoptera comprised only 2% of the total organisms collected, with the majority of the nymphs belonging to the family Perlodidae. Nymphs identified to more specific levels keyed out to *Isogenoides* and *Isoperla*. The majority of the stonefly nymphs lacked any distinguishing characteristic noticeable under the dissecting microscope, and it was not practical to identify them as to genus on a routine basis with the use of the dissecting microscope.

Trichoptera made up only 1% of the organisms collected and the majority belonged to the family Hydropsychidae. Larvae of both *Hydropsyche* and *Cheumatopsyche* were identified, but the characteristic separating the two genera (presence or absence of a pair of sclerotized plates posterior to the prosternal plate) was not suitable for routine separation of large numbers of often very small larvae.

Diptera made up 53% of the total organisms collected and all except 1% of this percentage was comprised of Chironomidae. Unfortunately, more specific identification of this group requires mounting the larvae on microscope slides and examining them with a compound microscope. Some of the samples examined so far in this manner have already yielded 24 larval types.

All of the other insect orders collected (Odonata, Collembola, Hemiptera, Coleoptera) comprised less than 1% of the total

Table 2. Density and relative abundance of macrobenthos in the Athabasca River near Fort McMurray. Values are means based on all 7 dates and 16 stations.

Taxon	Density ind/m²	%	Taxon	Density ind/m²	%
Ephemeroptera			*Metretopus*	8.67	0.54
Ameletus	5.16	0.32	*Pseudocloeon*	6.30	0.39
Ametropus	20.03	1.25	*Rhithrogena*	0.87	0.05
Aneletris	0.45	0.03	*Siphlonurus*	1.66	0.10
Aneletris 2	0.09	0.01	*Siphloplecton*	0.54	0.03
Baetis A	10.65	0.67	*Stenonema*	0.12	0.01
Baetis B	1.53	0.10	*Tricorythodes*	39.83	2.49
Baetis C	1.86	0.12	Plecoptera		
Baetis D	0.12	0.01	Perlodidae	34.90	2.18
Baetis E	0.06	0.00	*Pteronarcella*	0.06	0.00
Baetis X	10.87	0.68	*Pteronarcys*	0.13	0.01
Baetisca	0.30	0.02	Trichoptera		
Brachycerus	2.14	0.13	*Brachycentrus*	0.87	0.05
Caenis	28.94	1.81	Hydropsychidae	14.67	0.92
Centroptilum	2.21	0.14	Hydroptilidae	0.21	0.01
Centroptilum 2	0.03	0.00	*Neureclepsis*	1.02	0.06
Cloeon	47.72	2.67	*Oecetis*	0.64	0.04
Cloeon 2	0.46	0.03	Diptera		
Epeorus	0.06	0.00	Ceratopogonidae	9.80	0.61
Ephemera	0.15	0.09	Chaoboridae (*Chaoborus*)	0.03	0.00
Ephemerella	4.61	0.29			
Ephoron	0.03	0.00	Chironomidae	829.66	51.86
Heptagenia	137.71	8.61	Empididae (*Hemerodromia*)	4.17	0.26
Hexagenia	0.18	0.01	Muscidae (*Limnophora*)	0.03	0.00
Isonychia	11.01	0.69			
Leptophlebia	2.77	0.17	Rhagionidae (*Atherix*)	0.03	0.00

continued ...

Table 2. Concluded.

Taxon	Density ind/m^2	%
Simuliidae (*Simulium*)	8.80	0.55
Tipulidae (*Hexatoma*)	0.03	0.00
Collembola	4.59	0.29
Odonata (*Ophiogomphus*)	10.77	0.67
Hemiptera (Corixidae)	0.78	0.05
Coleoptera		
Dytiscidae	0.03	0.00
Elmidae	0.13	0.01
Hydracarina	1.49	0.09
Cladocera	17.40	1.09
Ostracoda	6.46	0.40
Copepoda	0.96	0.06
Amphipoda	0.03	0.00
Hirudinoidea (*Nephelopsis*)	0.06	0.00
Oligochaeta	295.11	18.45
Nematomorpha	10.44	0.65
Hydroida	0.93	0.06
Pelecypoda (Sphaeriidae)	0.60	0.00
Gastropoda (*Lymnaea*)	0.03	0.00
Pisces		
Catastromus	1.57	0.10
Cottus	1.07	0.07
Stizostedion	0.03	0.00

organisms. Among the Crustacea, only the Cladocera contributed more than 1% to the total density. Among the non-arthropods, all groups made up less than 1% except the Oligochaeta, which had a relative abundance of 18%. Again, the Oligochaeta is a group for which more specific identification requires the larvae to be mounted on microscope slides and examined with a compound microscope. A sample of larvae examined by Dr. A. Anderson, Water Quality Branch, Alberta Environment, yielded 7 species (Naididae: *Nais behningi, Nais communis, Uncinais uncinais, Pristina foreli;* Tubificidae: *Ilyodrilus templetoni, Limnodrilus hoffmeisteri, Limnodrilus profundicola*).

4.2 DIFFERENCES BETWEEN STATIONS

Table 3 shows the densities of the 68 taxa at each of the 16 stations. Each density is a mean based on all 21 samples collected at that station (7 dates x 3 replicates per date). All species comprising more than 0.1% of the collection were widely distributed, being recorded at most of the stations. The number of taxa per station varied from 27 to 45, with Site 8E having the lowest number of species. The stations along the east side of the river had a somewhat higher number of taxa (37.3) than those on the west side (34.8). This lateral difference was most pronounced at the three sites below the junction of the Clearwater River (Sites 5E, 6E, and 7E).

Total densities for individual stations (botton of Table 3) averaged 1 590 ind/m^2. Average density for the eight stations downstream from Suncor (1E to 4W) was 1 281 ind/m^2, while the average density for the eight control stations upstream of Suncor (5E to 8W) was 1 881 ind/m^2. Density of Station 7W, located 5.5 km downstream from the Fort McMurray Sewage Treatment Plant, was 41% higher than that of the next highest station. If this station is excluded from the calculations, then the average density of the remaining 7 control stations is 1 682 ind/m^2, or 31% higher than the average density for the eight stations downstream from Suncor. A t-text performed on log transformed data showed this difference to be statistically significant at the 5% level.

Table 3. Mean density (ind/m^2) of macroinvertebrates and fish collected within a 0.1 m^2 cylinder sampler at 16 stations in the Athabasca River, 1981 May 13 to August 18. Densities for each station are based on 21 samples (7 dates, 3 replicates per date).

Taxon	Station															
	1E	1W	2E	2W	3E	3W	4E	4W	5E	5W	6E	6W	7E	7W	8E	8W
Ephemeroptera																
Ameletus	0.5	2.9	0.5	2.9	0.5	16.2	5.2	20.5	13.8	0.5	1.0	5.2	6.2	6.2		0.5
Ametropus	0.5	11.4	219.9	39.0	12.9	2.9	12.4		7.1	1.0	1.0		3.3			9.0
Aneletris	2.4											4.8				
Aneletris 2			1.0	0.5												
Baetis A	9.5	16.2	4.3	4.8	33.3	22.8	31.4	5.2	11.9	3.8	8.1	4.8	7.1	5.7	0.5	1.0
Baetis B	13.8	1.9	0.5	1.0	0.5		3.8				0.5	1.0		1.4		
Baetis C	0.5	4.3	2.4	1.0		4.8	3.3	3.8	1.0	0.5	0.5		4.3	2.9		0.5
Baetis D							0.5							1.4		
Baetis E	1.0															
Baetis X	7.1	23.3	5.2	7.1	10.0	11.9	19.0	10.9	5.7	0.5	10.9	9.5	21.9	29.5	1.0	0.5
Baetisca	1.9	2.4		0.5									0.5			
Brachycercus	2.4	3.3	1.0		1.4	0.5	5.2		6.2		5.7	3.3	3.3	1.4		0.5
Caenis	7.1	6.9	41.4	9.5	39.5	14.3	2.9	14.8	78.1	0.5	86.2	11.9	123.8	17.6	1.9	6.7
Centroptilum		4.3		2.4	4.3	4.2	2.4	3.8	1.0	0.5	5.7		2.9	1.9		1.0
Centroptilum 2											0.5					
Cloeon	29.5	2.9	42.8	42.8	69.0	27.6	46.2	19.0	64.3	18.6	88.5	11.4	210.4	4.3	1.9	2.4
Cloeon 2	0.5	0.5			2.9				1.0	0.5		0.5	0.5	0.5	0.5	
Epeorus										1.0						
Ephemera		1.4											1.0			
Ephemerella	2.4	1.4	2.9	3.8	9.0	4.8	8.1	8.1	7.6	5.7	6.2	5.2	1.4	3.3	3.3	0.5
Ephoron													0.5			
Heptagenia	158.5	62.8	100.9	65.2	159.0	231.3	170.9	174.2	143.8	152.8	110.4	251.8	197.1	176.6	7.1	40.9
Hexagenia		2.9														
Isonychia	26.2	5.2	7.1	1.0	10.0	42.8	26.2	10.5	21.9	8.6	10.0	4.3	1.9	0.5		
Leptophlebia		0.5	6.2	3.3	3.8	5.7			2.4		5.2	1.0	11.9	4.3		
Metretopus	1.9	2.4	6.2	5.7	10.0	6.2	6.7	4.8	16.7	4.8	40.0	18.1	10.9	1.9	2.4	

continued ...

Table 3. Continued.

Taxon	Station															
	1E	1W	2E	2W	3E	3W	4E	4W	5E	5W	6E	6W	7E	7W	8E	8W
Pseudocloeon	1.0	3.3	7.1	10.5	2.9	10.0	7.6	9.5	19.5	5.7	9.5		9.5	3.3		1.4
Rhithrogena	1.4		0.5				1.4	1.4		2.9		0.5	0.5	1.0	3.8	0.5
Siphlonurus	0.5	1.0	2.9	4.3		2.9			6.2	3.3		0.5	2.4	1.0	1.0	0.5
Siphloplecton				1.0					1.4		1.0	2.9			2.4	
Stenonema							0.5		1.4							
Tricorythodes	23.3	36.7	46.2	19.0	53.3	30.5	55.2	46.2	115.2	6.7	62.8	22.8	76.6	35.7	1.9	5.2
Plecoptera																
Perlodidae	53.3	35.2	30.5	34.7	34.3	87.1	49.5	52.8	7.6	29.5	11.4	52.4	12.4	28.6	10.5	28.6
Pteronarcella						0.5							0.5			
Pteronarcys						1.0						1.0				
Trichoptera																
Brachycentrus						1.0	0.5		0.5	1.0		1.4		4.3	1.4	3.8
Hydropsychidae	33.8	13.8	9.5	0.5	15.2	7.1	41.4	9.5	7.6	14.3	19.5	12.9	3.8	26.7	1.0	18.1
Hydroptilidae							2.9					0.5				
Neureclepsis	0.5	0.5	0.5	1.4		1.4			0.5	1.0	5.2	0.5	4.8			
Oecetis	0.5		0.5	0.5		4.3					1.0	0.5	1.4	0.5		1.0
Diptera																
Ceratopogonidae	14.3	15.2	8.6	50.5	11.9	10.0	12.4	4.3	4.8	4.3	3.8	6.7	7.6		1.0	1.4
Chaoboridae											0.5					
Chironomidae	528.5	387.2	632.0	573.2	410.0	582.5	697.9	680.7	1171.4	329.4	568.4	1159.5	1091.0	1975.4	1739.3	747.8
Empididae	2.9	5.7	1.9	1.9	2.9	6.2	6.7		1.9	5.2	8.6	15.2	0.5	0.5	1.9	4.8
Muscidae											0.5					
Rhagionidae								0.5								
Simuliidae	1.4	9.5	1.9	0.5	1.9	1.0	9.5	1.4	6.2	19.0	5.7	3.8	2.9	6.2	3.3	66.6
Tipulidae		0.5														
Collembola	2.4	21.9	4.3	2.4	7.6	5.2	2.4	3.3	14.3		0.5	0.5	2.9	5.7		
Odonata																
Ophiogomphus	10.5	19.0	16.2	10.5	4.3	23.8	7.1	9.0	13.3	6.7	16.2	4.8	19.5	9.5		1.9

continued ...

Table 3. Concluded.

Taxon	1E	1W	2E	2W	3E	3W	4E	4W	5E	5W	6E	6W	7E	7W	8E	8W
	Station															
Hemiptera																
Corixidae	1.4	1.0	0.5						1.9		1.9	1.0	2.9		1.9	
Coleoptera																
Dytiscidae								0.5								
Elmidae				0.5		0.5	0.5		0.5							
Hydracarina	0.5	1.0	3.8	2.9		4.4	0.5	0.5	1.4		0.5	2.4	7.1			
Cladocera	1.0	4.8	6.2	10.9	29.5	19.0	10.0		29.5	3.8	66.6	5.2	89.0	0.5	2.4	
Ostracoda			20.0	2.4	2.4		10.0	2.4	12.9	0.5	7.1	9.5	17.1	4.8	1.9	2.4
Copepoda						7.1			2.4		0.5		0.5		4.8	
Amphipoda						0.5										
Hirudinoidea																
Nephelopsis								0.5			0.5					
Oligochaeta	493.6	277.5	167.6	158.0	69.0	193.3	260.4	222.8	479.8	135.7	178.5	221.0	220.3	887.1	488.6	268.5
Nematomorpha	20.5	4.8	9.5	6.7	4.3	11.7	6.2	8.6	8.1	7.1	23.3	9.0	18.1	16.2	6.7	6.2
Hydroida							0.5				4.8		9.5			
Pelecypoda																
Sphaeriidae	2.9								0.5				5.7	0.5		
Gastropoda																
Lymnaea					0.5											
Pisces																
Catastomus	.5	0.5	0.5	1.4	0.5	5.2	1.4	3.8	0.5	1.9	1.4	1.4	1.4	1.0	2.4	1.4
Cottus	0.5					0.5	0.5		3.8				3.3	2.9	5.2	0.5
Stizostedion													0.5			
Totals (to nearest whole number)	1461	996	1415	1084	1017	1413	1514	1348	2296	778	1380	1569	2220	3271	2310	1224
Shannon-Wiener Diversity Index	2.29	2.52	2.33	2.49	3.19	2.59	2.66	2.42	2.29	2.52	2.73	1.73	2.36	1.49	0.76	1.53
Number of Taxa	39	38	36	37	31	39	38	29	41	32	41	38	45	36	27	29

If Site 7W, located downstream of the sewage treatment plant, is excluded, then the density on the east side is higher than on the west side. As with total species, this lateral difference is most pronounced at Sites 5, 6, and 8 (east stations = 1 995 ind/m^2; west stations = 1 190 ind/m^2) than at Stations 1, 2, 3, and 4 (east stations = 1 352 ind/m^2; west stations = 1 210 ind/m^2). A t-test indicated that the differences were not significant ($P > .5$).

Shannon-Wiener diversity indices (bottom of Table 3) varied from 0.76 (Station 8E) to 3.19 (Station 3E). There was no difference between stations on the east and west sides of the river. Average diversity at the eight stations downstream from Suncor (H' = 2.56) was 33% higher than at the eight upstream control stations (H' = 1.93). A t-test indicated that the difference was not statistically significant.

Figure 3 shows the results of the two-dimensional community ordination. Three clusters of stations may be recognized: one cluster consisting of stations 8E, 8W, and 7W; a second cluster consisting of stations 1E, 1W, and 5W; and a third cluster containing the remaining stations. Stations 4E and 4W, the first stations downstream of the Suncor plant, are shown to be similar to (ie., near to) some of the upstream control stations (6W and 6E). For the four sites downstream from Suncor (1 to 4), the average distance between stations on the east and west sides was 20.5 units, while for the upstream sites the average was 55.5 units. In other words, lateral differences between east and west sides of the river were greater at the upstream sites than the downstream sites.

4.3 SEASONAL CHANGES IN MACROBENTHOS

Average densities of the total benthic community (Table 4) declined from May 13 to May 28, then increased steadily to a peak on July 7, and then declined again. Seasonal changes in the abundance of the four size classes based on sieving are shown in Table 5. The percentage of specimens belonging to the largest size class (> 2 mm) were over two times more abundant on June 9 than on any other date.

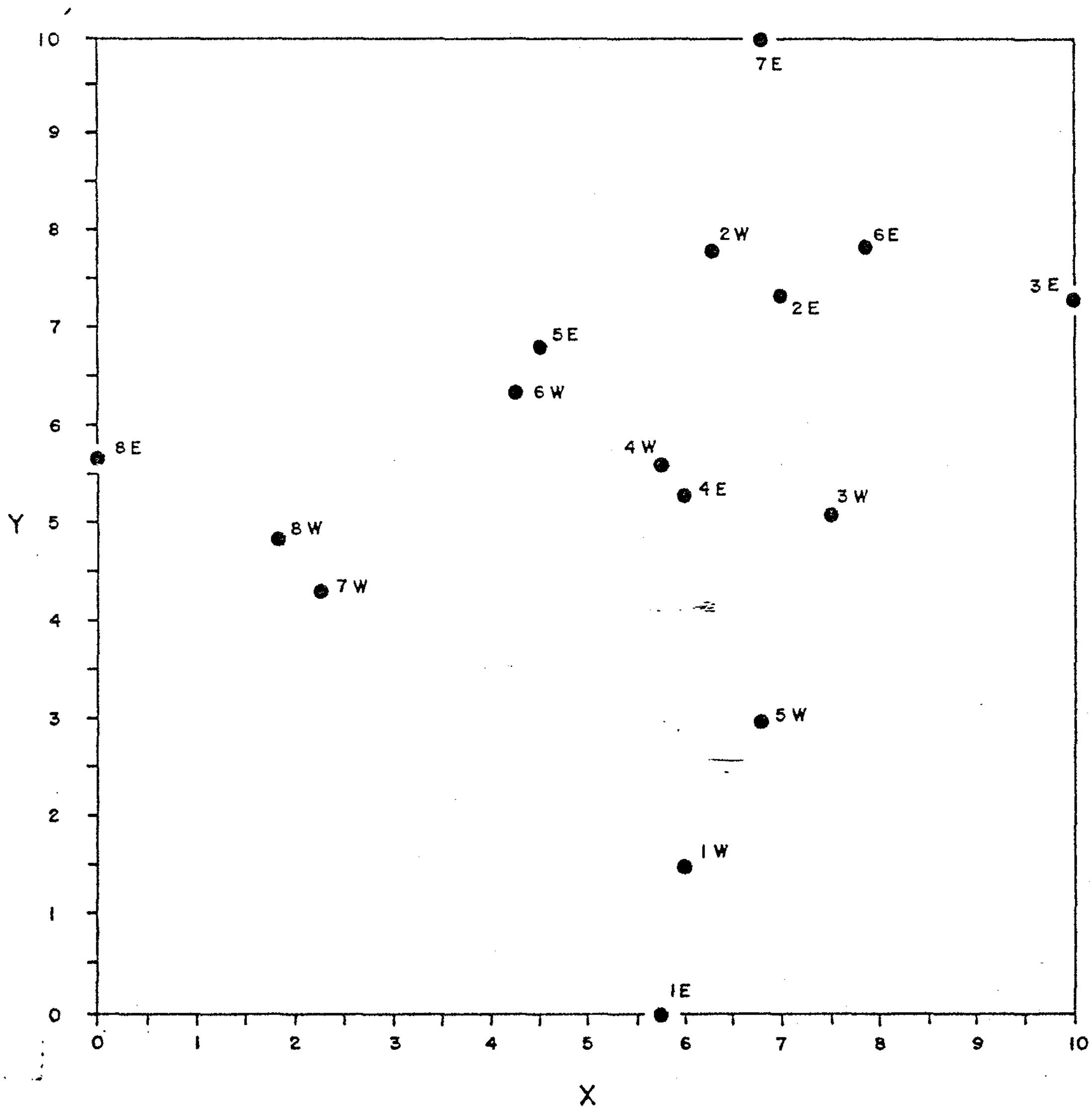

Figure 3. Two-dimensional ordination of the 16 stations sampled in the Athabasca River. Ordination is based on data in Table 3. Values along x and y axes are arbitrary units. Similar stations (points) are located close together, while dissimilar stations are located far apart.

Table 4. Seasonal changes in density (individuals/m^2) of total benthos in Athabasca River, 1981. Each value based on three replicate cylinder samples.

Station	May 13	May 28	June 9	June 23	July 7	July 21	August 18
1E	700	170	223	1540	3993	1313	2287
1W	300	153	227	1887	2337	1530	540
2E	733	173	210	1857	3310	1410	2213
2W	440	233	307	1460	1663	1230	2257
3E	393	207	303	1113	2257	1527	1317
3W	570	133	740	1267	3907	1823	1453
4E	410	180	753	1340	3493	1987	2433
4W	367	130	213	2037	3097	1433	2160
5E	653	1593	587	3553	6717	1060	1910
5W	337	253	203	1553	833	1450	820
6E	333	567	553	2220	2320	1883	1787
6W	520	437	390	1907	4413	2390	3023
7E	307	233	527	1183	4237	4773	4280
7W	417	313	413	2350	6283	11333	1787
8E	223	83	186	973	2317	5537	6850
8W	367	610	97	1537	1533	2787	1637
Mean	442	276	371	1736	3294	2717	2297

Table 5. Seasonal changes in the size distribution of macroinvertebrates in the Athabasca River. Percentages for dates except August 4 based on combined data from all 16 stations. Percentages for August 4 based on stations 1E, 1W, 2E, and 2W only.

Date	Total Organisms Collected	Percentage of organisms in sieves			
		> 2 mm	1-2 mm	0.5-1.0 mm	0.25-0.5 mm
May 13	2 225	16	32	35	17
May 28	1 640	20	20	41	19
June 9	1 734	47	21	23	9
June 23	8 333	15	19	50	16
July 7	15 822	16	22	53	9
July 21	13 021	13	19	54	14
August 4	1 996	11	16	39	34
August 18	11 026	15	17	43	25
TOTAL	55 797	16	20	48	16

The 1 to 2 mm size class was most abundant on May 13. Except on June 9, the 0.5 to 1.0 mm size class was the most abundant, generally including about half of the organisms in the collections. The smallest size category was most abundant in August.

5. DISCUSSION

The main objective of this study was to determine if the Suncor operation has had a significant impact on the macrobenthos of the Athabasca River. Average densities of macrobenthos at the stations downstream of the Suncor plant were 31% lower than at upstream control stations. This difference was statistically significant and would have been even greater if results for Station 7, located downstream of the Fort McMurray Sewage Treatment Plant, had been included in the analysis. The number of taxa, as well as the Shannon-Wiener diversity indices, were similar at upstream and downstream sites. Furthermore, the two-dimensional community ordination showed that the sites below the plant were not markedly different from some of the upstream sites.

The effect of toxic substances on macrobenthic communities is different from the effect of sewage and usually involves a reduction in both density and number of species (Warren 1971:328). That only the density has so far been reduced below the Suncor plant may suggest that the river is still capable of assimilating the effluents, but that the biological processes of assimilation are using energy which could otherwise have been used in the production of more biomass. Assimilation and degradation of toxic chemicals may occur through biological processes (Martin 1970; Colwell and Sayler 1978; McKnight and Morel 1979; Atlas 1981) as well as through physical and chemical processes such as photochemical oxidation (Zepp 1981), absorption onto clay minerals and humic substances (Ogura et al. 1981), and burial through the downstream movement of sandbars. Many organisms have also been shown to develop tolerance to sublethal levels of toxic materials (Salibu and Krzyz 1976; Houba and Remacle 1980; Duncan and Klaverkamp 1980; Weis et al. 1981)

Two other factors were found to influence the macrobenthic communities in the Athabasca River. The effluent from the Fort McMurray Sewage Treatment Plant increased the density of macrobenthos at Station 7W, located 5.5 km downstream. Buoys anchored on the west side of the river for 30 km below the outfall were covered at the water line with filamentous algae which were lacking on buoys on the east side of the river. The Clearwater River, which may account for up to 29% of the flow of the Athabasca River below the confluence, influenced the macrobenthos along the east side both by changing the chemical composition of the water and by carrying downstream taxa not normally found in the Athabasca River. Fragments of pondweed (*Potamogeton*), not found growing in the swift, turbid waters of the Athabasca River but common in the Clearwater River, were frequently seen suspended on buoys on the east side of the river as far downstream as the Suncor dyke. Examination of the maps in Appendix 7.1 shows that the river flows fairly straight from Fort McMurray until the Suncor dyke. It then makes almost a 90% turn around the dyke.

The lateral differences upstream of the Suncor dyke make it difficult to select control stations because those on the east side will be affected by the Clearwater River, while those on the west side will be affected by the sewage effluent. After the mixing of the river water at the Suncor dyke, the next gravel bar in a downstream direction is at Station 4E, although on the east side of the river, it is already 6 km below the Suncor discharge.

The lack of suitable control stations upstream of the Suncor dyke could be overcome by sampling sandy substrates which are much more abundant than gravel in the Athabasca River. Samples collected in sandy substrates in 1980 suggest that densities of organisms are much lower and that the community is dominated to an even higher degree by oligochaetes and chironomids, two taxonomic groups which are difficult to identify. Furthermore, because much more of the lighter sand is swept into the collecting bucket of the cylinder sampler, the time required for sorting is increased.

Another procedure would be to abandon the use of control stations, and instead, monitor a number of sites downstream of the Suncor facility and compare year-to-year changes. Sampling would, however, have to be on a yearly basis in order to be able to determine the degree of natural fluctuation in the macrobenthic community.

Examination of the data in Appendix 7.2 indicates that there was as much as a ten-fold difference in the number of organisms in the three replicate samples collected at a station. Stream substrates are very heterogeneous and these substrate differences are one of the major determinants of the composition and abundance of macrobenthic stream communities (Rabeni and Minshall 1977).

Samples collected on artificial substrates of known composition have much less variability (Hellawell 1978). This increase in sample precision frequently outweighs the disadvantages of artificial substrate samplers. Furthermore, artificial substrate samplers are generally selectively colonized by taxa such as Ephemeroptera, Plecoptera, and Trichoptera which are easier to identify than groups such as Oligochaeta and Chironomidae.

6. REFERENCES CITED

Akena, A.M. and L.L. Christian. 1981. Water quality of the Athabasca oil sands area. Vol. IV: An interim compilation of non-AOSERP water quality data. Prep. for Alberta Environment, Alberta Oil Sands Environmental Research Program. AOSERP Report L-74. 242 pp.

Atlas, R.M. 1981. Microbial degradation of petroleum hydrocarbons: an environmental perspective. Microbiol. Rev. 45:180-209.

Barton, D.R. and M.A. Lock. 1979. Numerical abundance and biomass of bacteria, algae and macrobenthos of a large northern river; the Athabasca. Int. Revue Ges. Hydrobiol. 64:345-359.

Beltaos, S. 1978. Transverse mixing in natural streams. Alberta Research Council. Report SWE 78-1.

Beltaos, S. 1979. Mixing characteristics of the Athabasca River below Fort McMurray - winter conditions. Prep. for Alberta Oil Sands Environmental Research Program. AOSERP Report 40.

Benner, A. 1980. A report on sewage composite sampling and flow - monitoring at the city of Fort McMurray, July 1980. Prep. by Municipal Engineering Branch, Pollution Control Division, Department of Alberta Environment.

Bray, J.R. and J.T. Curtis. 1957. An ordination of the upland forests of Southern Wisconsin. Ecol. Monogr. 27:325-349.

Colwell, R.R. and G.S. Sayler. 1978. Microbial degradation of industrial chemicals. In Water Pollution Microbiology: Vol. II; ed. R. Mitchell. Toronto: J. Wiley and Sons. pp. 111-134.

Cox, G.W. 1980. Laboratory manual of general ecology (4th edition). Dubuque: W.C. Brown.

Doyle, P.F. 1977. Hydrologic and hydraulic characteristics of the Athabasca River from Fort McMurray to Embarras. Prep. by Alberta Research Council. Report SWE 77/02.

Duncan, D.A. and J.K. Klaverkamp. 1980. Induced tolerance in white suckers (*Catastomus commersoni* Lacepede) by exposure to sublethal concentrations of heavy metals. In Proccedings of the Sixth Annual Aquatic Toxicity Workshop; ed. J.K. Klaverkamp. Can. Tech. Rep. Fish. Aq. Sci. 975:108-109.

Edmunds, G.F. et al. 1976. The mayflies of North and Central America. Minneapolis: University Minnesota Press.

Edwards, R.W. et al. 1975. Biological survey in the detection and assessment of pollution. Symp. Brit. Ecol. Soc. 15:139-156.

Flannagan, J.F. 1976. Life cycles of some common aquatic insects of the Athabasca River, Alberta. Prep. for Alberta Oil Sands Environmental Research Program. AOSERP Report 11.

Flannagan, J.F. et al. 1979. The effects of an experimental injection of methoxychlor on aquatic invertebrates: accumulation, standing crop and drift. Can. Ent. III:73-89.

Gauch, H.G. and R.H. Whittaker. 1972. Comparison of ordination techniques. Ecology 53:863-875.

Geesey, G.G. and J.W. Costerton. 1979. Microbiology of a northern river: bacterial distribution and relationship to suspended sediment and organic carbon. Can. J. Microbiol. 25:1058-1062.

Hellawell, J.M. 1978. Biological surveillance of rivers. Stevenage, England: Water Research Centre.

Houba, C. and J. Remacle. 1980. Composition of saprophytic bacterial communities in freshwater systems contaminated by heavy metals. Microb. Ecol. 6:55-69.

Kellerhals, R., C.R. Neill, and D.I. Bray. 1972. Hydraulic and geomorphic characteristics of rivers in Alberta. Alberta Research Council. River Engineering and Surface Hydrology Report 72-1.

Lipsett, A.W. and S. Beltaos. 1978. Tributary mixing characteristics using water quality parameters. Prep. by Alberta Research Council. Report 78-4.

Martin, J.H. 1970. The possible transport of trace metals via moulted copepod exoskeletons. Limnol. Oceanogr. 15:756-761.

McCart, P. et al. 1977. Baseline studies of aquatic environments in the Athabasca River near Lease 17. Environmental Research Monographs 1977-2. Syncrude Canada Ltd.

McKnight, D.M. and F.M. Morel. 1979. Release of weak and strong copper complexing agents by algae. Limnol. Oceanogr. 25:160-165.

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

Nix, P.G. et al. 1979. A preliminary study of chemical and microbial characteristics in the Athabasca River in the Athabasca oil sands area of northeastern Alberta. Prep. for Alberta Oil Sands Environmental Research Program. AOSERP Report 54.

Ogura, K. et al. 1981. The role of clay minerals and humic substances on the behaviour of organic and inorganic compounds in freshwater. Verh. internat. Verein. Limnol. 21:545-549.

Pennak, R.W. 1978. Freshwater invertebrates of the United States, 2nd edition. Toronto, Ontario: John Wiley.

Poole, R.W. 1974. An introduction to quantitative ecology. Toronto, Ontario: McGraw-Hill.

Raabe, H. 1932. Uber den 'Affinitatswert' in der Planzensoziologie. Vegetatio, Haag. 4:53-68.

Rabeni, C.F. and K.E. Gibbs. 1980. Ordination of deep river invertebrate communities in relation to environmental variables. Hydrobiologia 74:67-76.

Rabeni, C.F. and G.W. Minshall. 1977. Factors affecting microdistribution of stream benthic insects. Oikos. 29:33-43.

Salibu, L.J. and R.M. Krzyz. 1976. Acclimation and tolerance of *Artemia salina* to copper salts. Mar. Biol. 38:231-238.

Strosher, M.T. and E. Peake. 1978. Characterization of organic constituents in waters and wastewaters of the Athabasca oil sands mining area. Prep. for Alberta Oil Sands Environmental Research Program. AOSERP Report No. 20.

Tripp, D.B. and P.J. McCart. 1979. Investigations of the spring spawning fish populations in the Athabasca and Clearwater rivers upstream of Fort McMurray. Prep. for Alberta Oil Sands Environmental Research Program. AOSERP Report No. 84.

Warren, C.E. 1971. Biology and water pollution control. Toronto, Ontario: W.B. Saunders Co.

Weis, J.S. et al. 1981. Methyl mercury tolerance of Killifish (*Fundulus heteroclitus*) embryos from a polluted vs. unpolluted environment. Mar. Biol. 65:283-287.

Wiggins, G.D. 1977. Larvae of the North American caddisfly genera (Trichoptera). Toronto, Ontario: University of Toronto Press.

Zapp, R.G. et. al. 1981. Comparison of photochemical behaviour of various humic substances in water. Vol. I: Sunlight induced reactions of aquatic pollutants photosensitized by humic substances. Chemosphere 10:109-112.

7. APPENDICES

7.1 LOCATION OF 16 SAMPLE STATIONS

Location of 16 sample stations (dark circles) in the Athabasca River sampled in 1981. Maps copied from Canadian Hydrograph Service, Chart 6301: Athabasca and Slave rivers, 1973 edition. River flow and north is towards the top of each page. Numbers in circles indicate river miles. Dotted line in river indicates navigation channel. Dark triangles indicate locations of emergence traps (not discussed in this report).

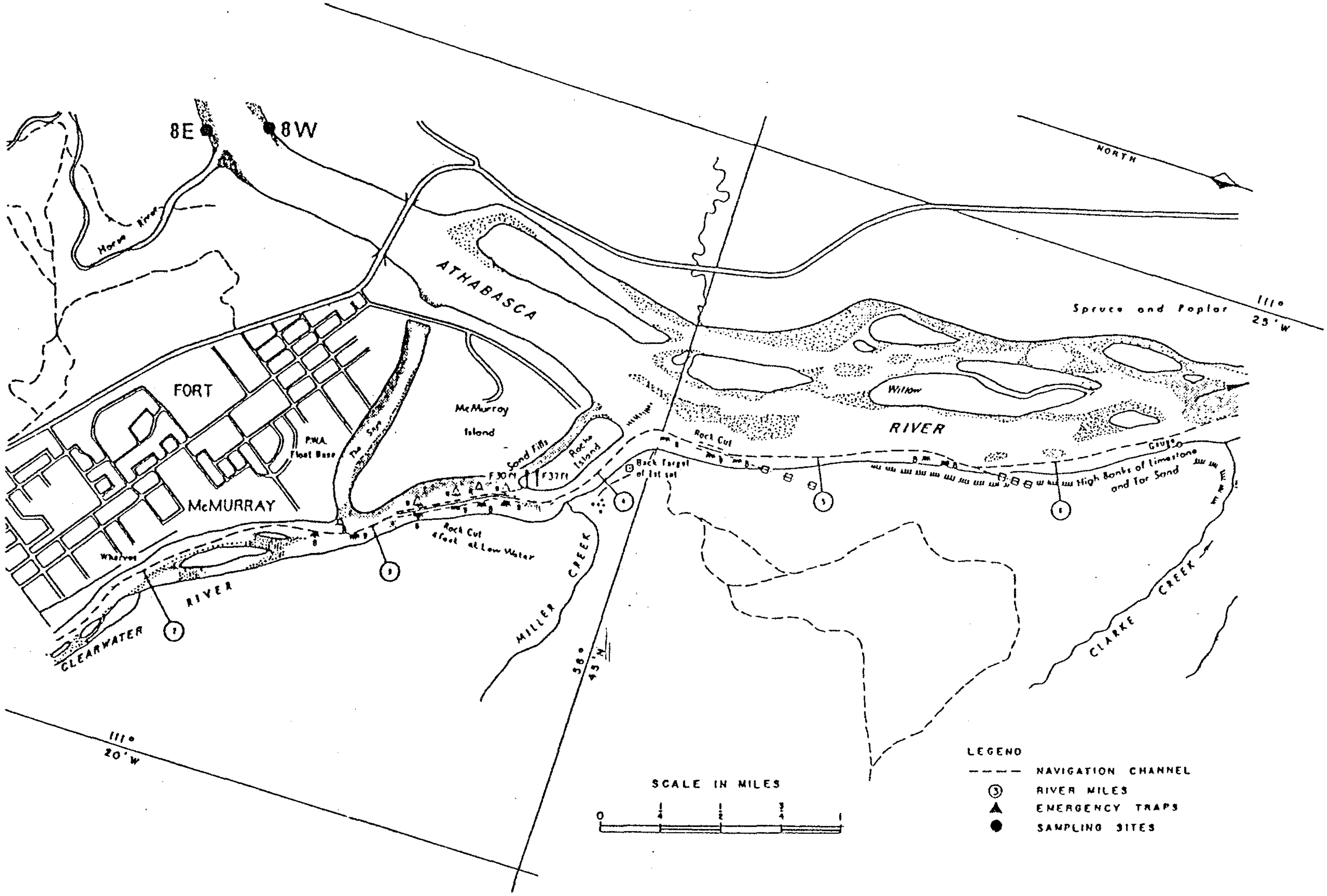

Figure 4. Athabasca River at Fort McMurray.

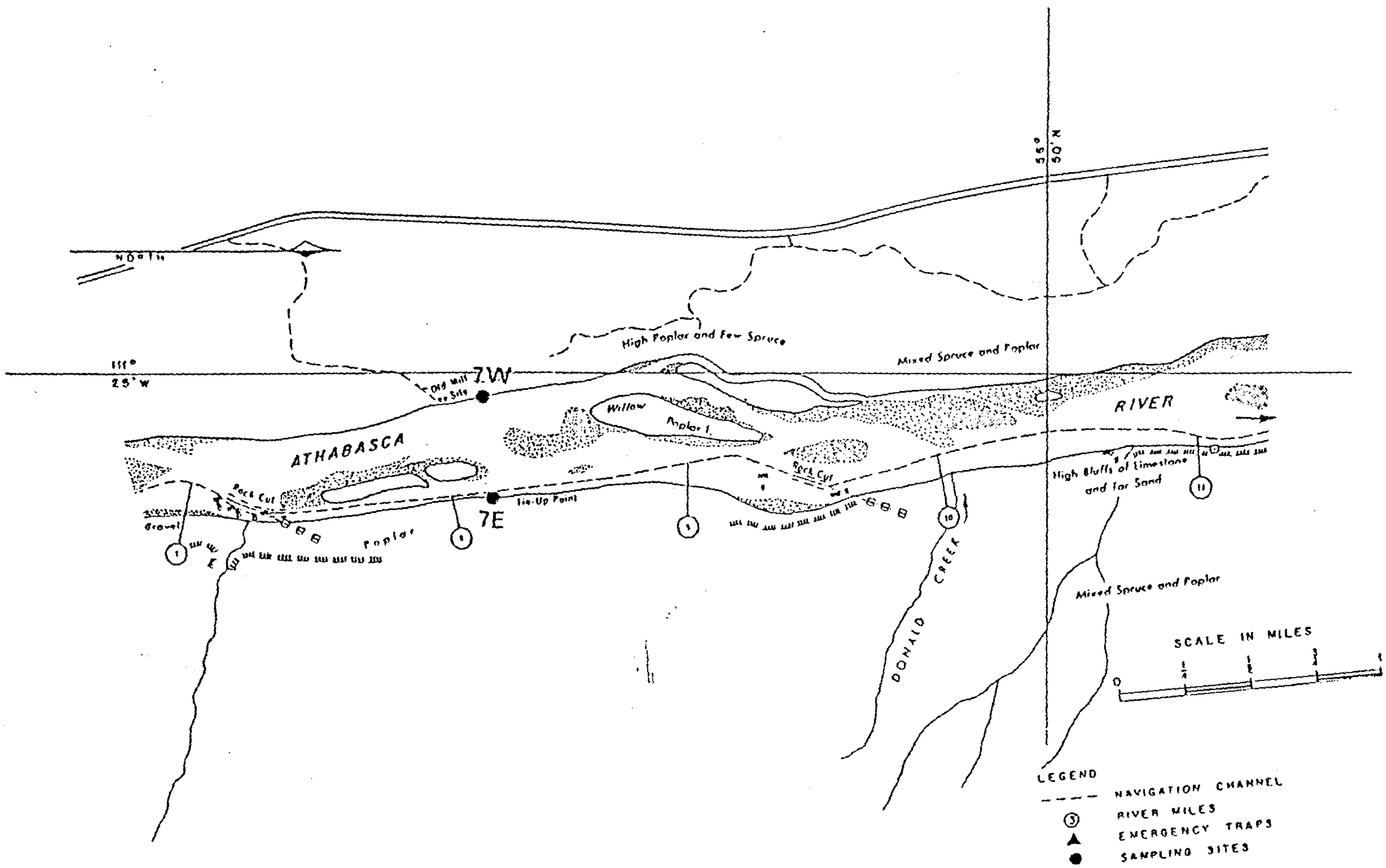

Figure 5. Athabasca River, river miles 7 to 11.

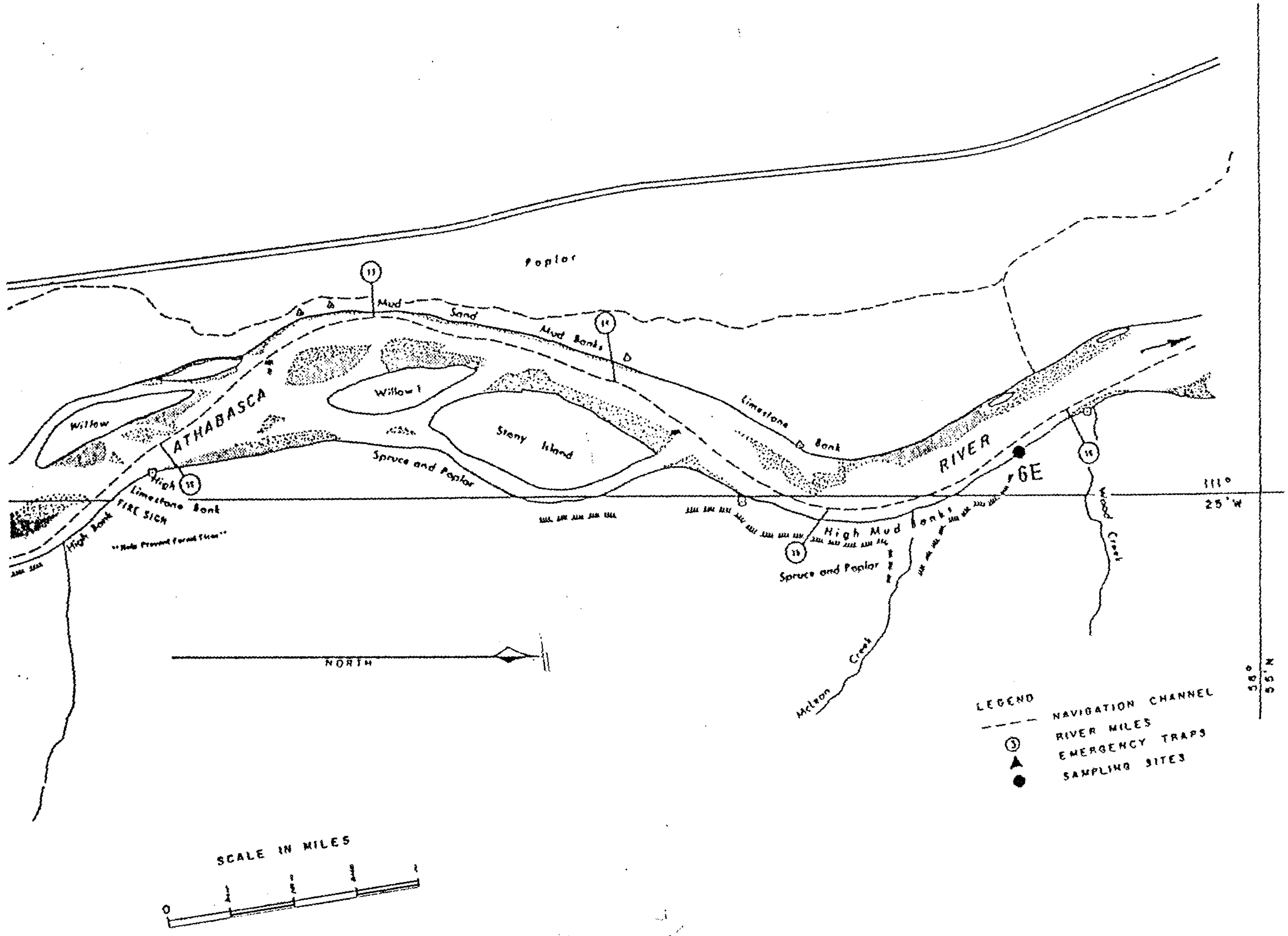

Figure 6. Athabasca River, river miles 12 to 16.

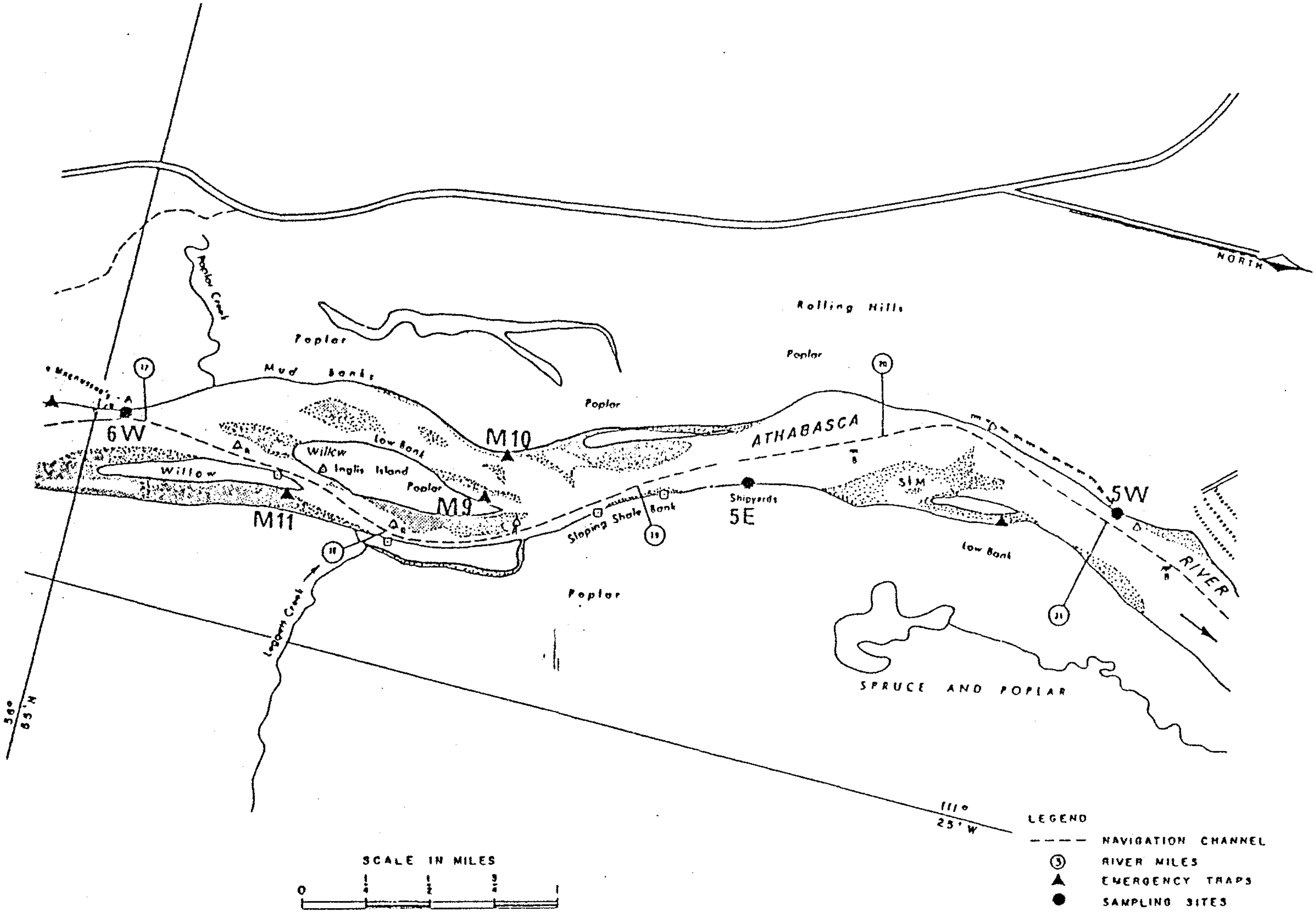

Figure 7. Athabasca River, river miles 17 to 21.

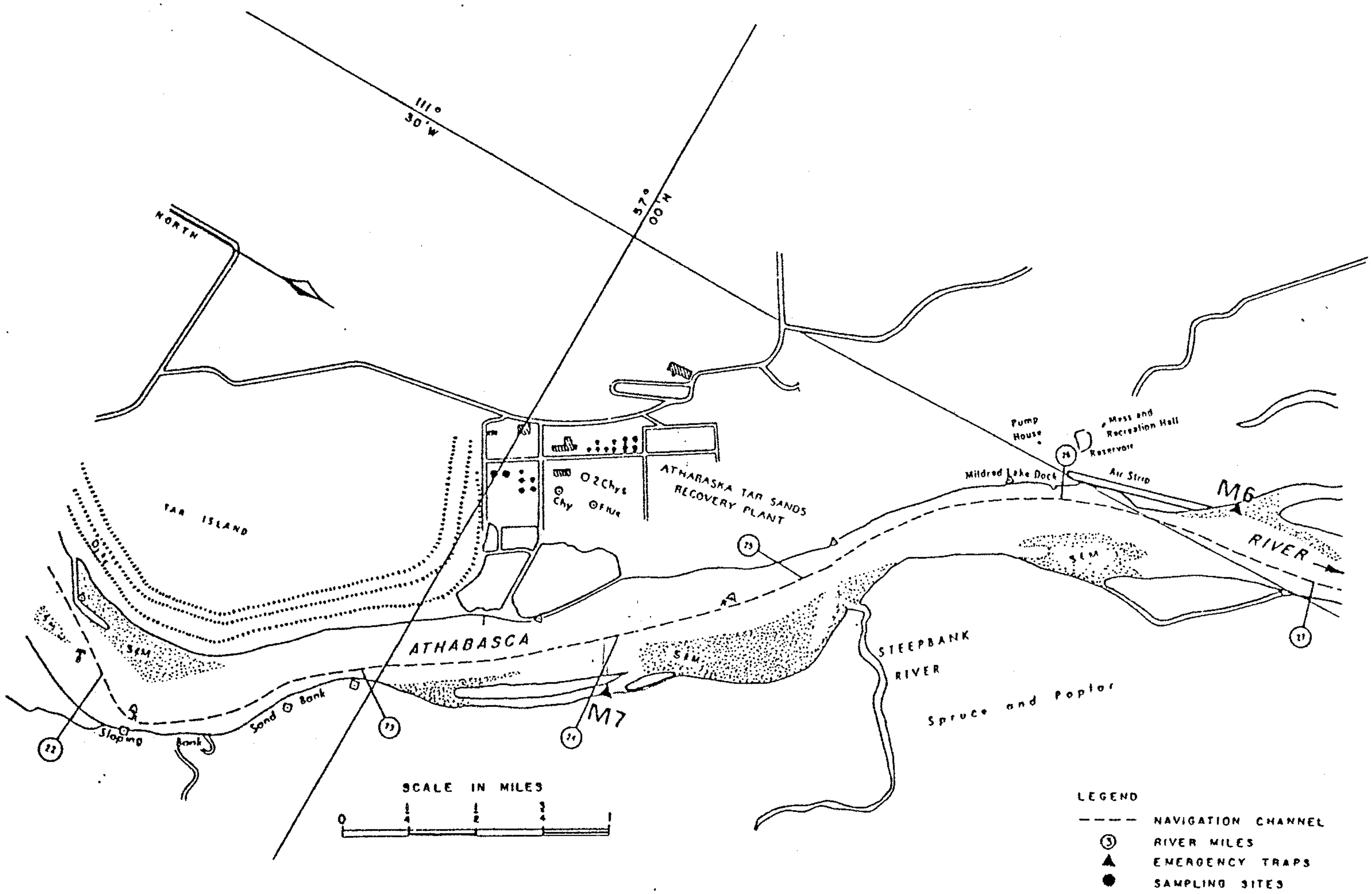

Figure 8. Athabasca River, river miles 22 to 27.

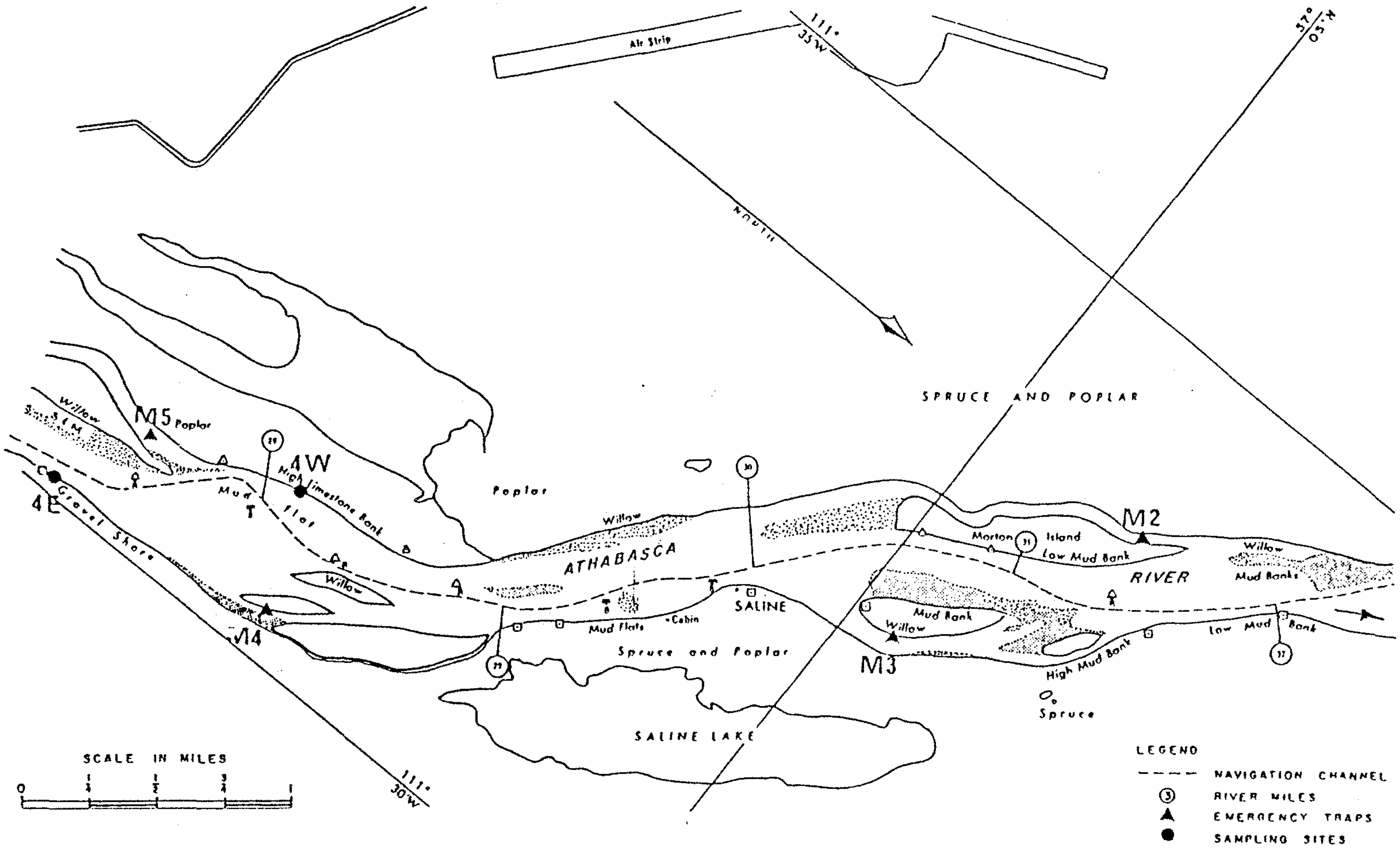

Figure 9. Athabasca River, river miles 28 to 32.

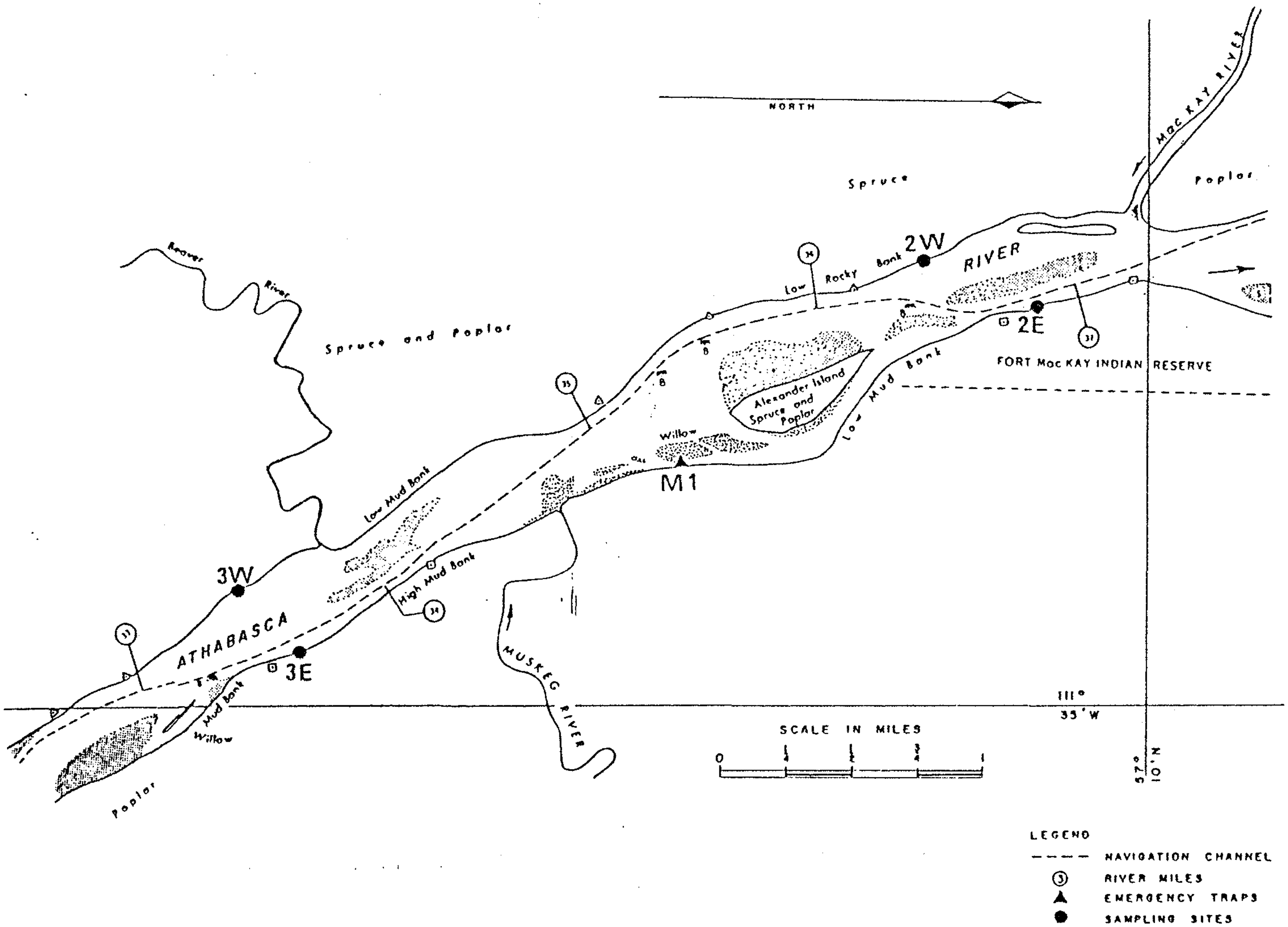

Figure 10. Athabasca River, river miles 33 to 37.

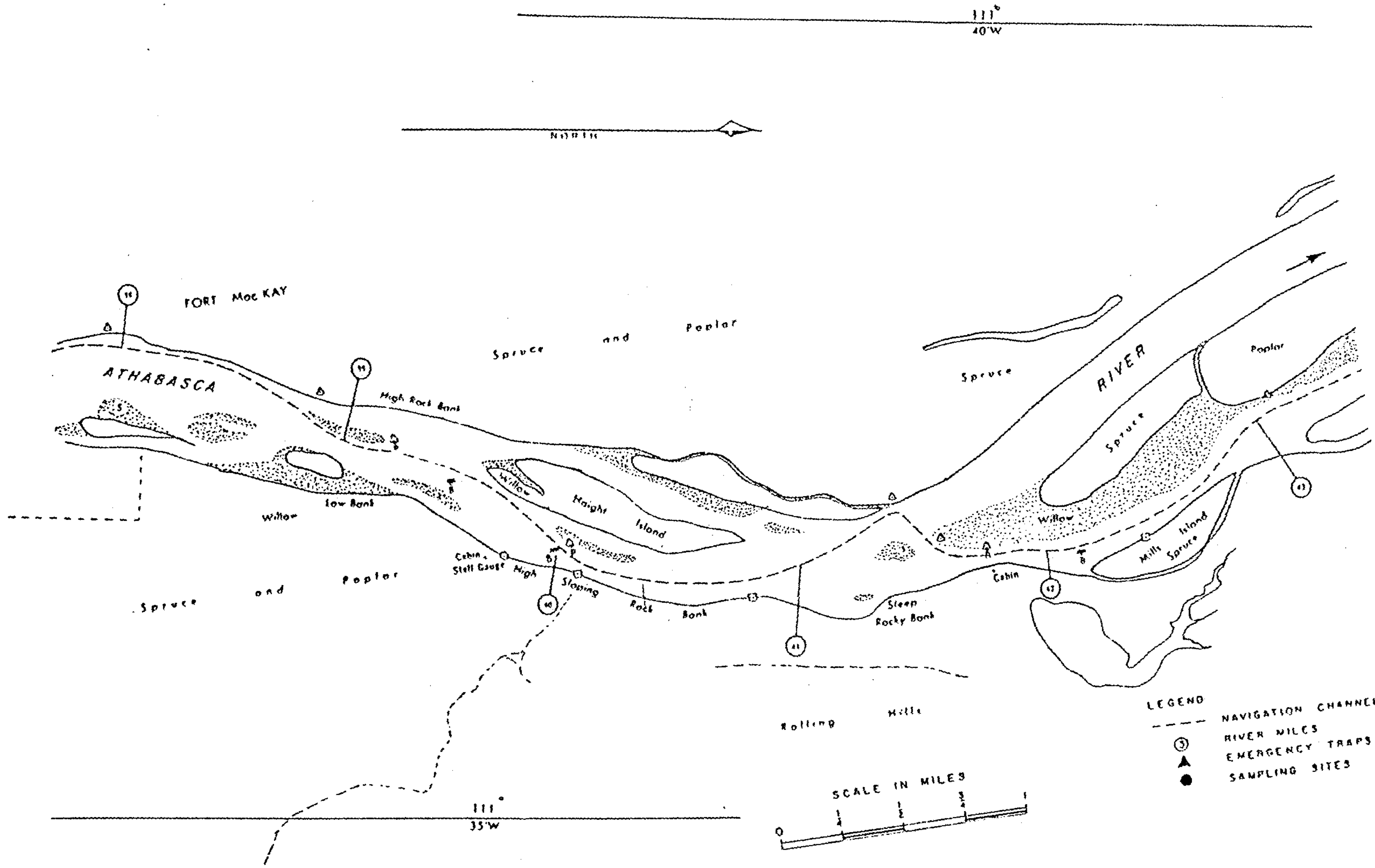

Figure 11. Athabasca River, river miles 38 to 43.

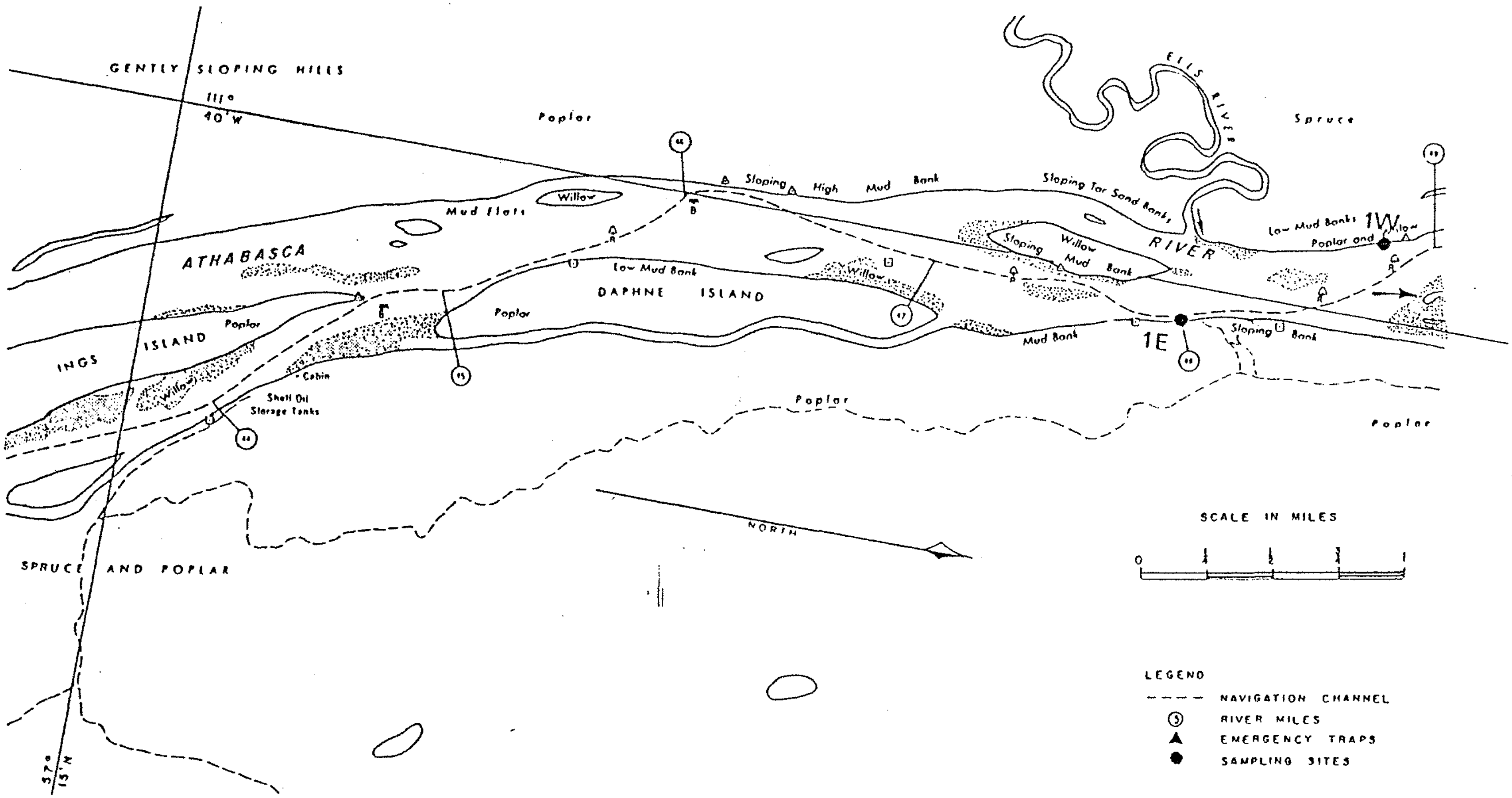

Figure 12. Athabasca River, river miles 44 to 49.

7.2 DENSITIES OF MACROBENTHOS SPECIES

Densities (ind/m^2) of macrobenthic species at 16 stations in the Athabasca River. A, B, and C represent replicate samples.

Table 6. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 1E, river Mile 48.0. A, B, and C represent replicate samples.

Taxon	May 13 A	May 13 B	May 13 C	May 28 A	May 28 B	May 28 C	June 9 A	June 9 B	June 9 C	June 23 A	June 23 B	June 23 C	July 7 A	July 7 B	July 7 C	July 21 A	July 21 B	July 21 C	Aug. 18 A	Aug. 18 B	Aug. 18 C
Ephemeroptera																					
Ameletus																1					
Ametropus																					1
Aneletris							5														
Baetis A													6	7	7						
Baetis B			4										1	2	2						20
Baetis C																				1	
Baetis E																			2		
Baetis X													1				4		8		2
Baetisca	1	1	2																		
Brachycerus							4	1													
Caenis													2	7	6						
Cloeon														3	8	13	4	26	3	5	
Cloeon 2														1							
Evhemerella																					5
Heptagenia	4	3	54	1							6		31	81	48	3	5	9	21	30	37
Isonychia													5	33	13		3				1
Metretopus									2		2										
Pseudocloeon																	1	1			
Rhithrogena	1		2																		
Siphlonurus				1																	
Tricorythodes			1										17	10	18			1		2	

continued ...

Table 6. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Plecoptera																					
Perlodidae	9	3	30	2	1	6	1												11	25	24
Trichoptera																					
Hydropsyche			1										6	28	3		1	1	2	12	17
Neureclepsis			1																		
Oecetis																			1		
Diptera																					
Ceratopogonidae							2	2	4	2									16		2
Chironomidae	4	12	64	18	11	5		16	12	1	49	44	130	121	214	48	13	33	133	75	107
Empididae																				1	5
Simuliidae									1								1	1			
Collembola																			5		
Odonata																					
Ophiogomphus	1									1		1	4	5	2	4				3	1
Hemiptera																					
Corixidae			3																		
Hydracrina																				1	
Cladocera																1		1			
Oligochaeta	5	2			1	4	6	4	7	78	25	248	77	122	148	72	73	77	16	37	45
Nematomorpha		2										3	12	13	3	2			1	7	
Pelecypoda Sphaeriidae																			5	1	
Pisces																					
Coregonus					1																
Cottus															1						
Total	25	23	162	22	14	15	18	23	26	80	86	296	292	433	473	144	105	145	224	195	267

Table 7. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 1W, river mile 48.8. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus							5										1				
Ametropus											16	2				1	1	3		1	
Baetis A									12	2			8	11	1						
Baetis B	1			1													1				1
Baetis C								4	1							3	1				
Baetis X	2							1					4	6		17		11		8	
Baetisca			4	1																	
Brachycerus													1								
Caenis													3	1	8	1					
Centroptilum														1					3	5	
Cloeon																1	2	1		1	1
Cloeon 2																	1				
Ephemera													1			1				1	
Ephemerella	1		1					1													
Heptagenia	3	1	1				1	1			2	1	23	28	12	18	6	7	8	13	7
Hexagenia																				6	
Isonychia													1	6	1			1			2
Leptophlebia																1					
Metretopus		1				1	2											1			
Pseudocloeon																2	2	3			
Siphlonurus					2																
Tricorythodes													9	37	29		1	1			

continued ...

Table 7. Concluded.

Taxon	May 13 A	May 13 B	May 13 C	May 28 A	May 28 B	May 28 C	June 9 A	June 9 B	June 9 C	June 23 A	June 23 B	June 23 C	July 7 A	July 7 B	July 7 C	July 21 A	July 21 B	July 21 C	Aug. 18 A	Aug. 18 B	Aug. 18 C
Plecoptera																					
Perlodidae	3		9	3	3	7	2	5	2	1	14								7	6	12
Trichoptera																					
Hydropsyche	1	1														6	1		1		19
Neureclepsis																			1		
Diptera																					
Ceratopogonidae					1	1		1	9	2	9		2	1	2	2		1			1
Chironomidae	39	13	4	6	2	7		4	3	62	34	24	80	103	106	154	76	65	9	12	11
Empididae					3	1			1							1					6
Simuliidae										4	1	1						14			
Tipulidae														1							
Collembola														13	33						
Odonata																					
Ophiogomphus			1		2			1	2	3	2	5	3	4	3		1	1	2	3	7
Hemiptera																					
Corixidae		1	1																		
Hydracarina													1		1						
Cladocera							1				1						1		1	1	5
Oligochaeta			2			4			9	180	152	42	54	47	45	31	5	4	3	2	3
Nematomorpha													2		8						
Pisces																					
Coregonus						1															
Total	50	17	23	11	13	22	11	18	39	260	231	75	192	260	249	240	101	118	34	38	70

Table 8. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 2E, river mile 36.8. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus			1																		
Ametropus							4	4					278	168	58						1
Analetris 2																1			1		
Baetis A								5	4												
Baetis B													1								
Baetis C								1		2						1					1
Baetis X	2													1					5	3	
Brachycerus										2											
Caenis		1	1							40	19		8	11	2	1	3	1			
Cloeon								1		12		5		6		35	12	20		1	2
Ephemerella	1	1	2		1									1							
Heptagenia	5	3	3	1				3	1	7	5	2	45	7	3	12	40	11	45	7	12
Isonychia											10		3		2						
Leptophlebia																	6		7		
Metretopus				2	2	5	2		1										1		
Pseudocloeon												1	2			5	5	2			
Rhithrogena	1																				
Siphlonurus				1	1	4															
Tricorythodes											10	15	32	15	4	1	7	8			5

continued ...

Table 8. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Plecoptera																					
Perlodidae	21	7	12	4	9	1	1	1	1										6	1	
Trichoptera																					
Hydropsyche														1	1		1		17		
Neureclepsis																					1
Oecetis																					1
Diptera																					
Ceratopogonidae							2			3	2	2		1	1				5	2	
Chironomidae	55	31	59	9		7		3	6	62	66	78	161	69	73	45	42	92	392	23	54
Empididae	2		2																		
Simuliidae			1							2	1										
Collembola											3	5		1							
Odonata																					
Ophiogomphus				1						5	3		5	3	4	1	4	1	2	3	2
Hemiptera																					
Corixidae																			1		
Hydracarina								1	1	1								5			
Cladocera										6		1	5		1						
Ostracoda										10	7	5							20		
Oligochaeta	1		1	1		2	15	3	3	95	57	13	42	15	5	2	50	9	34		4
Nematomorpha	7												1	6	1				5		
Pisces																					
Coregonus				1																	
Total	95	43	82	20	13	19	24	22	17	247	183	127	533	305	155	104	170	149	541	40	83

Table 9. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 2W, river 36.5
A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus														6							
Ametropus	1								12	6	22	8	7	10	15					1	
Aneletris 2																1					
Baetis A							8	2													
Baetis B	1	1																			
Baetis C									2												
Baetis X	1												1	5	2				5	1	
Baetisca	1																				
Caenis		1											6		10			2		1	
Centroptilum																2			3		
Cloeon														6	1	20	13	33	13		4
Ephemerella	2						2	2	2												
Heptagenia							6		5	1	1	5	19	30	27	3	2	11	9	7	10
Isonychia													2								
Leptophlebia																		5	2		
Metretopus				3	1	1		4				1								2	
Pseudocloeon											1						10	11			
Siphlonurus				1		8															
Siphloplecton																				2	
Tricorythodes										2			12	3	15		5	2		1	

continued ...

Table 9. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Plecoptera																					
Perlodidae	6	12	16		9	11	8	4	6			6							2	3	
Trichoptera																					
Hydropsyche												1									
Neureclepsis																			1	2	
Oecetis																				1	
Diptera																					
Ceratopogonidae				10			2	1	7		1	1					1		27	30	26
Chironomidae	49	12	24	7		1	1	6	5	60	54	44	134	91	61	49	85	60	141	160	160
Empididae	1		2																	1	
Simuliidae											1										
Collembola																		5			
Odonata																					
Ophiogomphus	1		1			1							6	2	2	1			2	2	4
Hemiptera																					
Corixidae																					
Coleoptera																					
Elmidae					1																
Hydracarina	1		5																		
Cladocera															1	1	5	11	5		
Ostracoda																			5		
Oligochaeta	2			13		1	2	1	1	43	74	99	8	13	4	7	9	12	15	22	6
Nematomorpha			1			1	1			5	1	1						3	1		
Pisces																					
Coregonus					2			1													
Total	66	27	39	34	13	23	31	21	40	117	155	166	95	166	138	84	130	155	231	236	210

Table 10. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 3E, river mile 33.5. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus		1																			
Ametropus			1					5	9										3	6	3
Baetis A								4	2	37	16	5	1	5							
Baetis B		1																			
Baetis X															1				10	6	4
Brachycercus								1		1		1									
Caenis									2				7	18	6	10	16	22		1	1
Centroptilum								1				4				2	1			1	
Cloeon			3				5				4			12	6	21	35	49	7		3
Cloeon 2																				6	
Ephemerella	1	1						1					5	11							
Heptagenia	2	12	1				3	5	6	33	17	7	24	35	25	36	34	32	29	9	24
Isonychia											1	1	5	9	4			1			
Leptophlebia																5	2			1	
Metretopus				8	2	2	3		3	1									1	1	
Pseudocloeon			1					1	1								1	2			
Tricorythodes											4		21	51	28	1			6	1	

continued ...

Table 10. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Plecoptera																					
Perlodidae	3	6	10	5	2	5	4	7	6	1	2	2		5		1			6	6	1
Trichoptera																					
Hydropsyche													4	5					15	5	3
Diptera																					
Ceratopogonidae							2	4	3	1	5	1							9		
Chironomidae	3	33	16	22		7	1	1	3	50	60	33	97	182	65	33	37	41	133	13	31
Empididae																1			5		
Simuliidae											4										
Collembola			1														5	10			
Odonata																					
Ophiogomphus							1			1		1				1	1	1		1	2
Cladocera														5		15	19	23			
Ostracoda																			5		
Oligochaeta	20			1		6	1	2	4	20	18	2		32	2				31		6
Nematomorpha			1	1							1			6							
Gastropoda																					
Lymnaea				1																	
Pisces																					
Coregonus			1																		
Total	29	54	35	38	4	20	20	32	39	145	132	57	164	376	137	126	151	181	260	57	78

Table 11. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 3W, river mile 33.4. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus		5											5	14	10						
Ametropus											4								2		
Baetis A							16	13	9	9			1								
Baetis C																2		6	2		
Baetis X												1			6				7	8	3
Brachycerus										1											
Caenis												8	11			9	1	1			
Centroptilum											2		7			2					
Cloeon													12	1		21	7	17			
Ephemerella		1					1	1	1		1				5						
Heptagenia		2	3		1		16	30	45	38	20	20	23	100	18	15	8	33	26	59	29
Isonychia										8	4	3		11	63	1					
Leptophlebia															5					5	2
Metretopus				1	2	4	1	1		2	1	1									
Pseudocloeon													2		1	6		11			1
Rhithrogena	2		1									1									
Siphlonurus				4	2																
Tricorythodes										15	13		17	6	6	3	2		2		

continued ...

Table 11. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Plecoptera																					
Perlodidae	9	52	27	3	7	4	9	8	7	1	4	2						5	13	10	22
Pteronarcella																				1	
Pteronarcys		1	1																		
Trichoptera																					
Brachycentrus																			2		
Hydropsyche	1									1				6	2				5		
Neureclepsis																			2		1
Oecetis																			7	1	1
Diptera																					
Ceratopogonidae							1	1				3					2		3	11	
Chironomidae	10	24	13	1		1	20	11	2	29	23	18	223	137	221	96	111	106	73	53	42
Empididae		8														1	3		1		
Simuliidae										1		1									
Collembola																5		6			
Odonata																					
Ophiogomphus	1	2	3		1			1	1	3	6	3	2	4	3	5		4	2	3	4
Coleoptera																					
Elmidae																				1	
Hydracarina							5	2													
Cladocera										1			22			7	5			5	
Copepoda										5			5								
Amphipoda																			1		
Oligochaeta					4		10	6	2	20	85	16	61	62	77	22	16	1	17		7
Nematomorpha													15	1			6	1	2		
Pisces																					
Coregonus				1		2		1	1				1	3	2						
Cottus										1	1										
Total	23	100	48	10	17	13	79	75	68	134	169	77	408	345	419	195	161	191	167	157	118

Table 12. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 4E, river mile 27.2. A, B, and C represent replicate samples.

Taxon	May 13 A	May 13 B	May 13 C	May 28 A	May 28 B	May 28 C	June 9 A	June 9 B	June 9 C	June 23 A	June 23 B	June 23 C	July 7 A	July 7 B	July 7 C	July 21 A	July 21 B	July 21 C	Aug. 18 A	Aug. 18 B	Aug. 18 C
Ephemeroptera																					
Ameletus	1									10											
Ametropus		2															1		6	13	4
Baetis A							8	42	10			1	3	2							
Baetis B			1	1	5											1					
Baetis C							4	1			1					1					
Baetis D								1													
Baetis X											5			1					15	8	11
Brachycerus									1				3	5	2						
Caenis									1									1	3	1	
Centroptilum																3				1	1
Cloeon	1	2											4	1	2	29	24	13	7	13	1
Ephemerella		1		1	1	2		5			1	1	2		3						
Heptagenia	5	2	3			2	23	8	2	41	89	20	19	11	26	6	6	4	31	24	53
Isonychia								5		3	3		3	6	2						
Metretopus				2		1			2											2	3
Pseudocloeon		1					8	8													
Rhithrogena								1		1		1									
Stenonema							1														
Tricorythodes										5	7	5	16	21	32	8	8		10	1	3
Plecoptera																					
Perlodidae	6	2	3	3	1	1	10	19	20	4	2	2	1	3	1				3	15	8

continued ...

Table 12. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Trichoptera																					
Brachycentrus											1										
Hydropsyche										3	2	2		2	3				41	12	20
Hydroptilidae						1	5														
Diptera																					
Ceratopogonidae				1				1			1	2							3	13	5
Chironomidae	10	21	12	6	17	2	14	3	1	15	97	56	131	264	229	84	76	172	112	42	98
Empididae																1	1	1	3	6	2
Muscidae						1															
Simuliidae										3	6	8				1	2				
Collembola																5					
Odonata																					
Ophiogomphus	1			1			2	2									2	1	3	1	2
Coleoptera																					
Elmidae																	1				
Hydracarina											1										
Cladocera															5	6			10		
Ostracoda																5	1	15			
Hydroida																		1			
Oligochaeta	11	28	9	2	2		6	3	6	7	2	3	67	83	92	41	42	23	61	23	36
Nematomorpha								1	1				2		1	2	5	2			
Pisces																					
Coregonus			1	1												1					
Cottus									1												
Total	35	59	29	18	26	10	81	100	45	92	209	101	251	399	398	194	169	233	298	185	247

Table 13. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 4W, river mile 28.2. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus	2		1							10			13	7	10						
Baetis A							5	1	3	1				1							
Baetis C								1		4	2									1	
Baetis X													2	4					6	2	9
Caenis										19			3	1	6	1	1				
Centroptilum														2	5	1					
Cloeon												1	4	3	5	5	10	12			
Ephemerella			1			1	2	4	2	1		1	4	1							
Heptagenia	1	2				1		3	5	80	32	30	39	18	31	7	2	5	31	49	23
Isonychia										2	3		23	9	18						
Metretopus				1					1	2		10									
Pseudocloeon							1			6	1	1		2		5	1		2	1	
Rhithrogena	1	1														1					
Tricorythodes										25	36	12	6	5	9	1	1		1		1
Plecoptera																					
Perlodidae	13	21	7		4	6	2	3	11	1	1								25	3	14

continued ...

Table 13. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Trichoptera																					
Hydropsyche		1									1	5	2	1				5	1	3	1
Diptera																					
Ceratopogonidae																		1	2	5	1
Chironomidae	31	14	10	7	6	3	1	8	2	89	84	29	244	146	103	104	87	93	55	186	128
Rhagionidae					1																
Simuliidae					1	2															
Collembola												5						2			
Odonata																					
Ophiogomphus	3		1								3	1	1	4	1				1	1	3
Coleoptera																					
Dytiscidae						1															
Hydracarina										1											
Ostracoda												5									
Hirudinoidea																					
Nephelopsis										1											
Oligochaeta				1			2	2	4	5	38	52	83	58	9	1	36	48	13	49	27
Nematomorpha											1		3	1	9					1	3
Pisces																					
Coregonus				2	2		1						2		1						
Total	51	39	20	11	14	14	14	22	28	257	202	152	429	263	237	126	138	166	137	301	210

Table 14. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 5E, river mile 19.5. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus														1	28						
Ametropus								7	6					1						1	
Baetis A							20	1			1	2					1				
Baetis C									1										1		
Baetis X																			6	6	
Brachycerus											6	3			4						
Caenis							1			25	30	46	15	23	24						
Centroptilum								1											1		
Cloeon								2		12	4		10	7	18	22	27	20	6	2	5
Cloeon 2						1													1		
Ephemerella							4	4	2					5	1						
Heptagenia							3			46	37	19	22	26	78	1		1	13	25	31
Isonychia										12	2	11	4	1	9				5	1	1
Leptophlebia		2																	2		1
Metretopus				12		3	9	2	6							3					
Pseudocloeon							10	6	2	1	2		1	1	13				3	1	1
Siphlonurus				5	1	6											1				
Siphloplecton																	3				
Stenonema								1	2												
Tricorythodes										33	100		20	30	49				1	1	8
Plecoptera																					
Perlodidae	1				4		5	2			1									2	1

continued ...

Table 14. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Trichoptera																					
Brachycentrus				1																	
Hydropsyche														5						5	6
Neureclepsis																					1
Diptera																					
Ceratopogonidae									1	1	2		1	1					1	2	1
Chironomidae	66	25	84	99	89	209	20	18	25	103	158	52	494	230	403	14	29	15	98	158	72
Empididae		1	2	1																	
Simuliidae				2		5						1					5				
Collembola					5	5							15		5						
Odonata																					
Ophiogomphus			1				1	1	1	2	1	1	1	3	4		1	1	4	3	3
Coleoptera																					
Elmidae									1												
Hemiptera																					
Corixidae				2	1	1															
Hydracarina						1	1	1													
Cladocera													1	1	18	17	15	10			
Copepoda											5										
Ostracoda										10	2	5			10						
Oligochaeta	3	6	2	6		10	5	2	2	88	169	72	135	89	207	24	57	45	24	56	6
Nematomorpha	1	2									1		1				1	5	6		
Sphaeriidae																					1
Pisces																					
Coregonus				1																	
Cottus				3	4	1															
Total	71	36	89	132	104	242	79	48	48	333	521	212	720	424	871	81	140	97	172	263	138

Table 15. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 5W, river mile 21.0. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus																		1			
Ametropus																		1			1
Baetis A							1	2			1	1				2	1				
Baetis C																			1		
Baetis X													1								
Caenis														1							
Centroptilum																			1		
Cloeon	2	1	1								1			2		1	1	12		18	
Cloeon 2						1															
Ephemerella	1		2		1	1	1	3	3		1	1									
Epeorus											1	1									
Heptagenia		1			6	3	4	9	3	91	34	72	25	16	15	3		9	15	9	6
Isonychia										2		10	1	5							
Metretopus		1		5		1				1									1	1	
Pseudocloeon								1			5		5		1						
Rhithrogena										1		5									
Siphlonurus				7																	
Tricorythodes										5				1		3			5		
Plecoptera																					
Perlodidae	7	12	5	5	8	7	1	13	4									1			5
Trichoptera																					
Brachycentrus				1			1														
Hydropsyche	2				1	1	1			1	5								7	6	6
Neureclepsis																				1	1

continued ...

Table 15. Concluded.

Taxon	May 13 A	May 13 B	May 13 C	May 28 A	May 28 B	May 28 C	June 9 A	June 9 B	June 9 C	June 23 A	June 23 B	June 23 C	July 7 A	July 7 B	July 7 C	July 21 A	July 21 B	July 21 C	Aug. 18 A	Aug. 18 B	Aug. 18 C
Diptera																					
Ceratopogonidae			1		1			1		1		2					1			1	1
Chironomidae	13	21	16	5	1	6		1	7	46	22	61	32	75	20	106	87	25	43	86	19
Empididae	1	2	1													2				5	
Simuliidae				3	1	3				6	1	3				22	1				
Odonata																					
Ophiogomphus								2			1	1		1	1				2	4	2
Cladocera																	6	2			
Ostracoda												1									
Oligochaeta	3	5	2		6	1			3	35	9	37	1	44	4	78	4	53			
Nematomorpha			1									2					5	7			
Pisces																					
Coregonus					2						1							1			
Total	29	43	29	26	27	23	9	32	20	189	81	196	65	144	41	217	106	112	75	131	40

Table 16. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 6E, river mile 15.7. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus											1		1								
Ametropus							2														
Baetis A							2	6	6		1						1	1			
Baetis B																			1		
Baetis C																				1	
Baetis X														5	8					8	2
Brachycerus							2	2	3	2	2	1									
Caenis							1	2	2	28	47	47	10	20	20	3	1	1			
Centroptilum							1							1		9			1		
Centroptilum 2																1					
Cloeon							4			2	4	1	2	21	6	58	50	35		2	1
Ephemerella					1	1	3	2											1	5	
Heptagenia					2		5	16	3	30	74	21	8	14	2	2	5		18	23	9
Isonychia							1	1	1	1	14	3									
Leptophlebia	1																			8	2
Metretopus				19	17	23	12	6	4		1						2				
Pseudocloeon								5			1	6								7	1
Siphloplecton																2					
Tricorythodes											80		2	22	15		7	1	1	3	1
Plecoptera																					
Perlodidae	2			1		3	5	7	1	2	1	2								2	
Trichoptera																					
Hydropsyche										5	10		6							12	2
Neureclepsis																			5	6	
Oecetis																				2	

continued ...

Table 16. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Diptera																					
Ceratopogonidae							1					1							4	1	1
Chaoboridae	1																				
Chironomidae	19	10	58	24	6	51	22	11	4	46	111	62	139	110	191	22	30	39	108	91	39
Empididae			5																6	7	
Simuliidae										1	1		5					5			
Collembola																1					
Odonata																					
Ophiogomphus		1					1	2		3	3	4			5	4	1	1	2	7	
Hemiptera																					
Corixidae	1												1			1	1				
Hydracarina							1														
Cladocera						5							1	5	1	25	42	56		5	
Copepoda						5															
Ostracoda																10			5		
Hydroida																5	5				
Hirudinoidea																					
Nephelopsis				1																	
Oligochaeta	1				6	5	5	6	3	5	33	7	16	21	39	52	25	34	45	71	1
Nematomorpha			1					5								15	3	7	3	15	
Pisces																					
Coregonus									1								2				
Total	25	11	64	45	32	93	68	70	28	127	384	155	190	219	287	210	175	180	200	276	60

Table 17. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 6W, river mile 16.9. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus							4		4	1					1		1				
Analetris														5		5					
Baetis A					10																
Baetis B														2							
Baetis X										1			6	8		4			1		
Brachycerus									2	2			2	1							
Caenis										7		1	5	6	2	4					
Cloeon	5									2	2		4						9	1	1
Cloeon 2							1														
Ephemerella		3					2	3						5							
Heptagenia	1			2			22	5	21	10	3	4	73	181	76	29	6		62	26	8
Isonychia										1			4	1	3						
Leptophlebia																				1	1
Metretopus	1			20	8	1		3		1	1							2		1	
Rhithrogena							1														
Siphlonurus											1										
Siphloplecton																6					
Tricorythodes										6		1	24	11	3	1	1	1			
Plecoptera																					
Perlodidae	10	45	17	3	1	5	19	1		1									7	1	
Pteronarcys		1													1						

continued ...

Table 17. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Trichoptera																					
Brachycentrus														1	2						
Hydropsyche		1	1				1							13	1				10		
Hydroptilidae														1							
Neureclepsis																			1		
Oecetis																			1		
Diptera																					
Ceratopogonidae		1											1			1	1		5	2	3
Chironomidae	13	15	21	19	18	10	6	11	8	167	69	222	172	405	178	125	172	125	192	60	418
Empididae	2	4																	14	1	11
Simuliidae				2		6															
Collembola														1							
Odonata																					
Ophiogomphus				1			1						4	1	1				2		
Hemiptera																					
Corixidae			1							1											
Hydracarina																			5		
Cladocera					5								5	1							
Ostracoda					5							5		5				5			
Oligochaeta	5	7			7	1			2	15	5	44	44	46	16	66	85	64	25		28
Nematomorpha	1			5													3				10
Pisces																					
Coregonus					1	1								1							
Total	38	78	40	52	55	24	57	23	37	215	80	277	344	695	284	241	269	207	334	93	480

Table 18. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 7E, river mile 8.5. A, B, and C represent replicate samples.

Taxon	May 13 A	May 13 B	May 13 C	May 28 A	May 28 B	May 28 C	June 9 A	June 9 B	June 9 C	June 23 A	June 23 B	June 23 C	July 7 A	July 7 B	July 7 C	July 21 A	July 21 B	July 21 C	Aug. 18 A	Aug. 18 B	Aug. 18 C
Ephemeroptera																					
Ameletus												2		2	1			5	2	1	
Ametropus													5		2						
Baetis A							4	5	5							1					
Baetis C																		9			
Baetis X														4			17		9	5	11
Baetisca		1																			
Brachycerus								2	1	2		1	1								
Caenis										34	3	26	100	40	25	7	8	17			
Centroptilum											2		3				1				
Cloeon							8			3	9	15	41	14	9	60	139	92	5	34	13
Cloeon 2																	1				
Ephemera																2					
Ephemerella				1				1						1							
Ephoron													1								
Heptagenia	7	4	2			1	5	33	3	15	10	24	77	13	20	33	26	25	33	42	41
Isonychia							1						1		1		1				
Leptophlebia														1		5			1	10	8
Metrotopus				1			7	4	9			1					1				
Pseudocloeon							1	2	1	1	6	2	1			3		1	2		
Rhithrogena																	1				
Siphlonurus						5															
Tricorythodes											6	2	92	15	6	9	8	5	2	9	7
Plecoptera																					
Perlodidae	3	1	2	1		7	8	2	1		1										
Pteronarcella																	1				

continued ...

Table 18. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Trichoptera																					
Hydropsyche													6	1						1	
Neureclepsis			1															1	2	2	4
Oecetis																					3
Diptera																					
Ceratopogonidae							1	1		2	2				1				1	4	4
Chironomidae	28	5	31	10	7	3	6	13	4	67	31	73	364	132	151	158	194	129	190	338	358
Empididae																					1
Simuliidae						5												1			
Collembola													1			5					
Odonata																					
Ophiogomphus			1	1				1		1	2	3	2		1	3	4	2	8	8	4
Hemiptera																					
Corixidae															6						
Hydracarina											5									5	5
Cladocera					5								2	18	10	25	74	32		11	10
Copepoda														5							
Ostracoda														5	1			10		15	5
Hydroida																	17			1	2
Oligochaeta	6			7	7	5	13	5	4	3			38	22	10	247	8	24		43	23
Nematomorpha									3				7	9		5	7	6	1		
Pelecypoda																					
Sphaeriidae															2	1			5	4	
Pisces																					
Coregonus					1	1		1													
Cottus					1	1	1	1	1	1				1							
Stizostedion																	1				
Total	44	11	37	21	21	28	55	71	32	129	77	149	742	283	246	564	509	359	261	524	499

Table 19. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 7W, river mile 8.4. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus									1		2		10								
Baetis A							2	2		7	1										
Baetis B													2	1							
Baetis C											1						5				
Baetis D														2		1					
Baetis X														4		1		21	12	12	12
Brachycerus										2			1								
Caenis											8		7	5	7	4	2	4			
Centroptilum														1		2		1			
Cloeon										1						6	1		1		
Cloeon 2																	1				
Ephemerella		5																	2		
Heptagenia		3	1	6			10	7	5	26	28	8	31	58	34	64	11	43	27	7	2
Isonychia							1														
Leptophlebia																1	5			3	
Metretopus							2			1					1						
Psedocloeon																5		1	1		
Rhithrogena											2										
Siphlonurus						2															
Tricorythodes													13	8	21	24	2	7			
Plecoptera																					
Perlodidae	1	9	6	13	4	2	2	3	3	2	1					10			2	1	1

continued ...

Table 19. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Trichoptera																					
Brachycerus														4			5				
Hydropsyche								1		3	2		7	6	7		10		12	5	3
Oecetis																			1		
Diptera																					
Chironomidae	14	41	25	17		5	14	11	10	144	122	302	819	175	347	674	422	585	111	135	177
Empididae		1																			
Simuliidae				7	6																
Collembola						2							5			5					
Odonata																					
Ophiogomphus				1				1		2					1	3	1	4	4		3
Cladocera																1					
Ostracoda																	10				
Oligochaeta		3	4	2	8	16	5	27	13	4	8	28	145	127	35	632	625	179			2
Nematomorpha		11											1			15	7				
Pelecypoda																					
Sphaeriidae		1																			
Pisces																					
Coregonus				1				1													
Cottus						2	1	1	1					1							
Total	15	74	36	47	18	29	37	54	33	192	175	338	1041	391	453	1448	1107	845	173	163	200

Table 20. Density (ind/0.1 m^2) of macroinvertebrates amd fish collected at Station 8E, just upstream of Horse River. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Baetis A								1													
Baetis X														1							1
Caenis										1	1		1	1							
Cloeon												1	1	1	1						
Cloeon 2															5						
Ephemerella	1	1			1					1		3									
Heptagenia		1		1			1			1		2	1	2	2	2	1		1		
Metretopus																	5				
Rithrogena			8																		
Siphlonurus				2																	
Siphloplecton																5					
Tricorythodes													1	1		2					
Plecoptera																					
Perlodidae	4	10	6	2																	
Trichoptera																					
Brachycentrus										1		2									
Hydropsyche	1			1																	

continued ...

Table 20. Concluded.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Diptera																					
Ceratopogonidae											1								1		
Chironomidae	11	1	21				7	9	3	42	108	35	130	208	214	330	162	582	422	713	656
Empididae		1	1					2													
Simuliidae					1			5	1												
Hemiptera																					
Corixidae					2											1				1	
Cladocera													5								
Copepoda													10								
Ostracoda													15		5	5					
Oligochaeta				1			6	17	3	13	70	10	38	26	17	148	158	253	4	82	172
Nematomorpha													5				5	2		2	
Pisces																					
Coregonus					3				1						1						
Cottus				6	5																
Total	17	14	36	13	12	0	14	34	8	59	180	53	207	240	248	494	330	837	428	797	830

Table 21. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 8W, just upstream of the Horse River. A, B, and C represent replicate samples.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera																					
Ameletus	1																				
Ametropus						1				5	3	8						1		1	
Baetis A								1									1				
Baetis C																				1	
Baetis X																					1
Brachycerus										1											
Caenis										13	1										
Centroptilum								1		1											
Cloeon																					5
Ephemerella			1																		
Heptagenia	1	2	3						2	6		3	20	7	2	3		2	17	9	9
Pseudocloeon										2								1			
Rhithrogena			1																		
Siphlonurus					1																
Tricoruthodes										2	1	2		2	1	2		1			
Plecoptera																					
Perlodidae	3	9	21	4	3	1	1		7						5	1				2	3

continued ...

Table 21. Continued.

Taxon	May 13			May 28			June 9			June 23			July 7			July 21			Aug. 18		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Trichoptera																					
Brachycentrus													1	4	1				2		
Hydropsyche				5		1				5		1	5		3					13	5
Oecetis																			1		1
Diptera																					
Ceratopogonidae											3										
Chironomidae	28	6	18		6	17	1	1	2	75	147	58	82	153	101	222	197	136	116	60	145
Empididae			5			2	1												1		1
Simuliidae				6	7	119					6				1					1	
Odonata																					
Ophiogomphus		1												1					1		1
Ostracoda																		5			
Oligochaeta			5	5	2	1	7	1	3	20	91	5	18	38	14	103	129	28	15	41	38
Nematomorpha			5									1				5	1				1
Pisces																					
Coregonus				1		1	1														
Cottus												1									
Total	33	18	59	21	19	143	11	4	14	130	252	79	126	210	124	335	328	173	153	128	210

continued ...

Table 22. Density (ind/0.1 m^2) of macroinvertebrates and fish collected at Station 1E, 1W, 2E, and 2W on August 4, 1981. A, B, and C represents replicate samples.

Taxon	1E			1W			2E			2W		
	A	B	C	A	B	C	A	B	C	A	B	C
Ephemeroptera												
Ametropus						1		1	1			
Analetris sp. 2.		2				2		4				
Baetis X				2	1							3
Baetis C						3				4	16	
Caenis						1			5			
Centroptilum		1		1	1					1		
Cloeon		4		5	5	25	20		7	4	9	8
Heptagenia				1	1	2	1	2	1	53	65	14
Leptophlebia					1							5
Metretopus						1						
Pseudocloeon											10	11
Siphloplecton					2				1			
Tricorythodes										1		5
Plecoptera												
Perlodidae						1				16	26	10
Trichoptera												
Hydropsyche										15		5

continued ...

Table 22. Concluded.

Taxon	1E			1W			2E			2W		
	A	B	C	A	B	C	A	B	C	A	B	C
Diptera												
Ceratopogonidae			1			1	1	2				1
Chironomidae	31	115	134	78	135	114	177	93	74	144	106	62
Empididae								1		1		
Tipulidae												1
Odonata												
Ophiogomphus					1	1	1	2		1	2	2
Hydracarina								5		5		
Cladocera	5	10		1	1	5						
Ostracoda		5		10			5	10		5		
Oligochaeta	41	30	4	43	15	17	23	26	20	14	4	21
Nematomorpha		1						1				
Total	77	168	139	141	163	174	228	147	109	264	238	148