ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

The Ecology of Macrobenthic Invertebrate Communities in Hartley Creek, Northeastern Alberta

WS 1.3.3

March 1979

Sponsored jointly by

Alberta ENVIRONMENT

Environment Canada

Environnement Canada

15th Floor, Oxbridge Place
9820 - 106 Street
Edmonton, Alberta, Canada
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ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

RESEARCH REPORTS

These research reports describe the results of investigations funded under the Alberta Oil Sands Environmental Research Program, which was established by agreement between the Governments of Alberta and Canada in February 1975 (amended September 1977). The 10-year program is designed to direct and co-ordinate research projects concerned with the environmental effects of development of the Athabasca Oil Sands in Alberta.

A list of research reports published to date is included at the end of this report.

Enquiries pertaining to the Canada-Alberta Agreement or other reports in the series should be directed to:

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The Ecology of Macrobenthic Invertebrate Communities in Hartley Creek, Northeastern Alberta

Project WS 1.3.3

AOSERP Report 49

This report may be cited as:

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The Hon. J.W. (Jack) Cookson
Minister of the Environment
222 Legislative Building
Edmonton, Alberta

and

The Hon. John Fraser
Minister of the Environment
Environment Canada
Ottawa, Ontario

Sirs:

Enclosed is the report "The Ecology of Macrobenthic Invertebrate Communities in Hartley Creek, Northeastern Alberta".

This report was prepared for the Alberta Oil Sands Environmental Research Program, through its Water System, under the Canada-Alberta Agreement 1975 (amended September 1977).

Respectfully,

W. Solodzuk, P.Eng.
Chairman, Steering Committee, AOSERP
Deputy Minister, Alberta Environment

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Member, Steering Committee, AOSERP
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THE ECOLOGY OF MACROBENTHIC INVERTEBRATE COMMUNITIES IN HARTLEY CREEK, NORTHEASTERN ALBERTA

DESCRIPTIVE SUMMARY

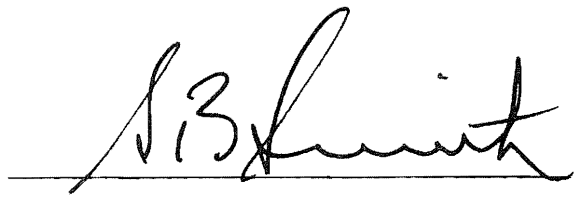
BACKGROUND

This project was initiated in early 1976 by the Aquatic Fauna Technical Research Committee of AOSERP with the general goal of assessing invertebrate production and the factors that affect it in a small watershed in the oil sands area. Objectives were grouped within two broad areas, life cycle studies and community studies. Details of the objectives can be found in the Introduction Section of the report. Ultimately the baseline information accumulated by this project was to be related to effects of oil sands developments. The project continued into early 1978 when the numbering was changed from AF 2.5.1 to WS 1.3.3

ASSESSMENT

A number of scientists in Environment Canada, Alberta Environment, and AOSERP reviewed a draft of the report and it is the impression of AOSERP that the authors have taken into consideration the review comments. In addition to this final report, a Ph.D. thesis was produced by one of the researchers at the University of Calgary (R. Crowther). The conclusions from the project whether in this report or in the Ph.D. thesis are the authors' and do not necessarily reflect the views of Alberta Environment or Environment Canada, and the mention of trade names does not constitute an endorsement for use. The Alberta Oil Sands Environmental Research Program is satisfied

with the efforts put forth by the researchers in this project and accepts their report, "The Ecology of Macrobenthic Invertebrate Communities in Hartley Creek, Northeastern Alberta", as an important and valid document.



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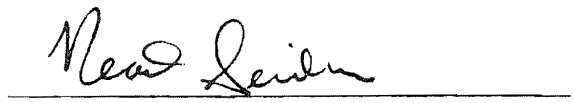

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THE ECOLOGY OF MACROBENTHIC INVERTEBRATE COMMUNITIES IN HARTLEY CREEK, NORTHEASTERN ALBERTA

by

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ALBERTA OIL SANDS ENVIRONMENTAL
RESEARCH PROGRAM

WS 1.3.3

March 1979

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ABSTRACT

Hartley Creek, a tributary of the Muskeg River in the Athabasca Oil Sands area of northeastern Alberta, has a discharge ranging between 0.5 and 7 $m^3.s^{-1}$, experiences temperatures ranging between 0° and about 18°C, and has high oxygen concentrations at all seasons. The benthic fauna is rich and diverse and is dominated numerically by Chironomidae but by Trichoptera in terms of biomass. Each of the four principal substrate types found in the pools has a distinctly different benthic community. The riffle benthic communities are different from the benthic communities of the pools. The "single-rock" sampling technique has shown that the microdistribution of trichopteran larvae is influenced by both rock size and the presence or absence of moss cover. Most of the aquatic insects are univoltine (producing only one brood per year) with spring or summer emergence. A few species (some Chironomidae, Baetinae) may be multivoltine and at least one species takes at least three years. Invertebrate drift displays a typical diel cycle with morning and evening peaks. Predominant benthic components include Baetinae and Chironomidae but Cladocera and Copepoda are also abundant and are derived from pools.

Temperature and discharge both exert profound effects on structure and composition of the benthic communities but none of the chemical factors measured appears to be a signficant influence. The benthic communities of the riffles are different from those of the pools.

ACKNOWLEDGEMENTS

We are indebted to the following for their assistance in the field: Dr. D.R. Barton, Dr. M.A. Lock, Dr. R.W. Wallace, Ms. Shirley Charleton, Ms. Judy Buchanan, Ms. Donna McCullough, Mr. J. Culp, Mr. M. O'Connell, Mr. M. Psutka, and Mr. F. Wrona.

We also benefited from discussions with Dr. Barton, Dr. Lock, and Dr. Wallace, and are indebted to Dr. J.W. Costerton for his advice and aid with the electron microscope.

The Hydrology Section of AOSERP kindly provided data on water chemistry and discharge rates in 1976 and 1977, and Dr. A. Nimmo and Dr. G.B. Wiggins provided confirmation and identifications of Trichoptera.

This research project WS 1.3.3 was funded by the Alberta Oil Sands Environmental Research Program, a joint Alberta-Canada research program established to fund, direct, and co-ordinate environmental research in the Athabasca Oil Sands area of northeastern Alberta.

1. INTRODUCTION

The work described in this report has been undertaken to meet eight principal objectives which together constitute a baseline study of the aquatic benthic invertebrate fauna of Hartley Creek, a tributary of the Muskeg River which flows into the Athabasca River from the east side. The eight objectives were:

1. To identify the aquatic invertebrate species of Hartley Creek;
2. To determine the temporal and spatial distribution and abundance of the principal aquatic invertebrate species of the creek;
3. To determine the life-cycles of the principal aquatic invertebrate species of the creek;
4. To determine the species composition, significance and variability of aquatic invertebrate drift in Hartley Creek on a diel and seasonal basis;
5. To define, quantitatively, the aquatic invertebrate community structure of pools and riffles in Hartley Creek;
6. To determine the microdistribution of the principal aquatic invertebrates of each community;
7. To define, quantitatively, the principal aquatic invertebrates as components of the communities; and
8. To define and assess the principal interactions between these components of the community and the effects of primary environmental factors.

Although these objectives are listed as discrete entities it was evident that careful experimental design would obviate duplication of effort both in the field and in the laboratory since the same material could be used towards more than one objective. The report which follows describes the manner in which the work was conducted and the results which were obtained.

The value of baseline data on benthic invertebrate communities lies in the fact that benthic invertebrates are very

good indicators of stress or change in aquatic ecosystems. If assessments are to be made of the impact of oil sands development, it is essential to understand the nature of the communities prior to development. However it must be realized that a baseline study alone does not generally permit predictive assessments or models to be produced. It is thus regretted that all manipulative experiments proposed by the authors were eliminated and that such a strong emphasis was placed on baseline studies. The results of carefully designed manipulative experiments would make it possible to directly predict the effects of different aspects of oil sands exploitation and development on Hartley Creek and other similar systems in the AOSERP study area.

2. RESUME OF CURRENT STATE OF KNOWLEDGE

Knowledge of the benthic invertebrate communities of rivers varies widely between different parts of the world. At one extreme we find that there is a very large body of literature on the faunas of European rivers, and at the opposite extreme there is a great paucity of information on neotropical rivers. Western North American rivers, and especially those at high latitudes fall somewhere between these two extremes. Although nearctic river faunas have much in common with those of palearctic rivers the detailed structure of benthic communities has been neglected in studies of northern rivers. Work on Russian rivers at latitudes similar to those of the Athabasca River makes little mention of aquatic invertebrates and no mention of their ecology (e.g., Lastochin 1943; Greze 1953; Shadin 1956, 1964).

In North America the work of Wiens, Rosenberg and Snow (1975) has given taxonomic information on the aquatic flora and fauna of the Mackenzie and Porcupine watersheds of northern Canada, but their study did not include analysis of the structure or function of the communities. Clifford (1969) has provided a valuable introduction to the biology of aquatic invertebrates in the Bigoray River, a brown water stream in west-central Alberta; however this river is significantly different from Hartley Creek in many important limnological and climatic aspects and hence Clifford's findings are not all applicable to Hartley Creek.

Two of the earliest studies in the AOSERP study area were those of Dames and Moore (1973) on Hartley Creek and Syncrude (1975a) on Beaver Creek. In both cases the results are of limited relevance to the present study since the data were not quantitative and the identifications made only to family level. Another study by Syncrude (1975b) on Poplar Creek attempted to provide some quantitative data on benthic invertebrates but unfortunately the sieve mesh used for sample concentration (0.6 mm) was so coarse that many small invertebrates must have been lost, leading to data which are almost certainly misleading.

Flannagan (1975, 1977) has reported some preliminary

life-cycle data for some aquatic insect species from the Athabasca River, and more recently Barton and Wallace (in prep.) have published valuable data on benthic invertebrates of a number of streams and rivers in the AOSERP study area. In addition, a recent report (Syncrude Ltd. 1978) describes the water quality and aquatic resources of the Beaver Creek Diversion System.

3. STUDY AREA

The Alberta Oil Sands Environmental Research Program (AOSERP) study area covers an area of seven million acres (2.83 million hectares) in northeastern Alberta (Figure 1). The climate of this region is continental, with hot, dry summers and very cold winters, with the rivers generally ice covered from November through to the end of April. The mean annual precipitation is 46 cm.

Hartley Creek is a second order tributary of the Athabasca River. The stream flows from its source at an altitude of 505 m approximately 45 km northwards to its confluence with the Muskeg River at an elevation of 290 m. It is situated within the Alberta Oil Sands Research Program study area in Townships 94 and 95, Range 9, between 57°16'N, 111°29'W and 56°58'N, 111°14'W. This is approximately 75 km northeast of Fort McMurray, and 15 km east of the Athabasca River - map reference Zone 12, 74E; universal transverse mercator grid (Figure 2).

Hartley Creek is an alkaline brown water stream with an average stream gradient of 20% over its length. The mean stream discharge in 1976 was 0.765 $m^3.s^{-1}$ with an annual discharge of 24 176 281 m^3. The maximum and minimum discharge rates for 1976 were 5.3 $m^3.s^{-1}$ and 0.0085 $m^3.s^{-1}$ respectively.

The substrate of the stream is composed of limestone pavement, limestone and granite boulders and mixed granite, limestone and shale tills of glacial or deltaic origin (Gallup 1974).

The till or overburden in the southern section of the study area is 36.6 m thick (Page 1974) and overlies the oil-bearing McMurray sandstone formation. Within Townships 94 and 95, this formation contains more than 10% bitumen making it a prime location for oil sands extraction (Gallup 1974).

Geologically, Hartley Creek can be broken down into three sections to show the local stratigraphy. The lower Hartley, near its confluence with the Muskeg River, is exposed McMurray Sandstone. This exposure decreases upstream until at

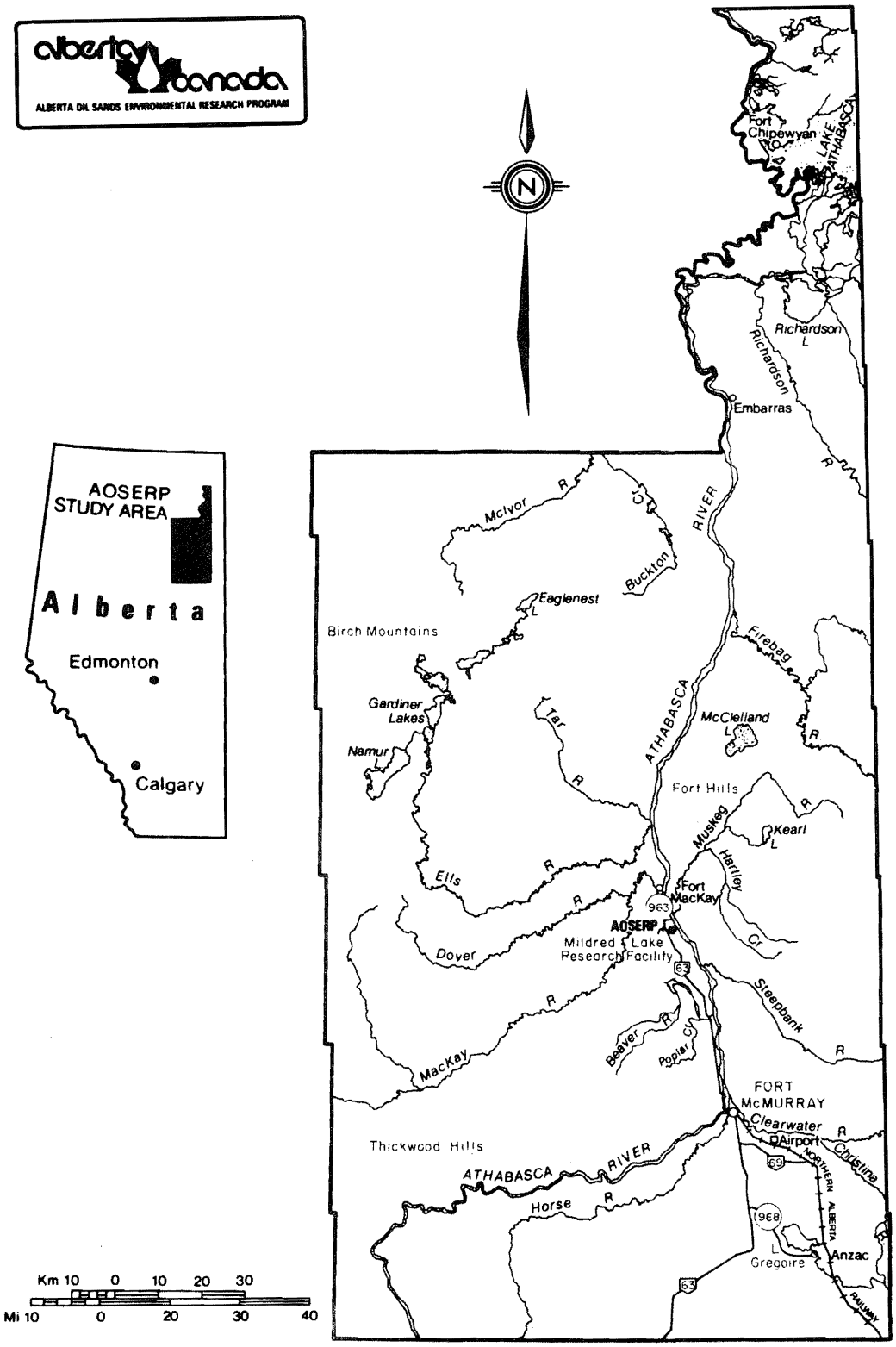


Figure 1. The AOSERP study area.

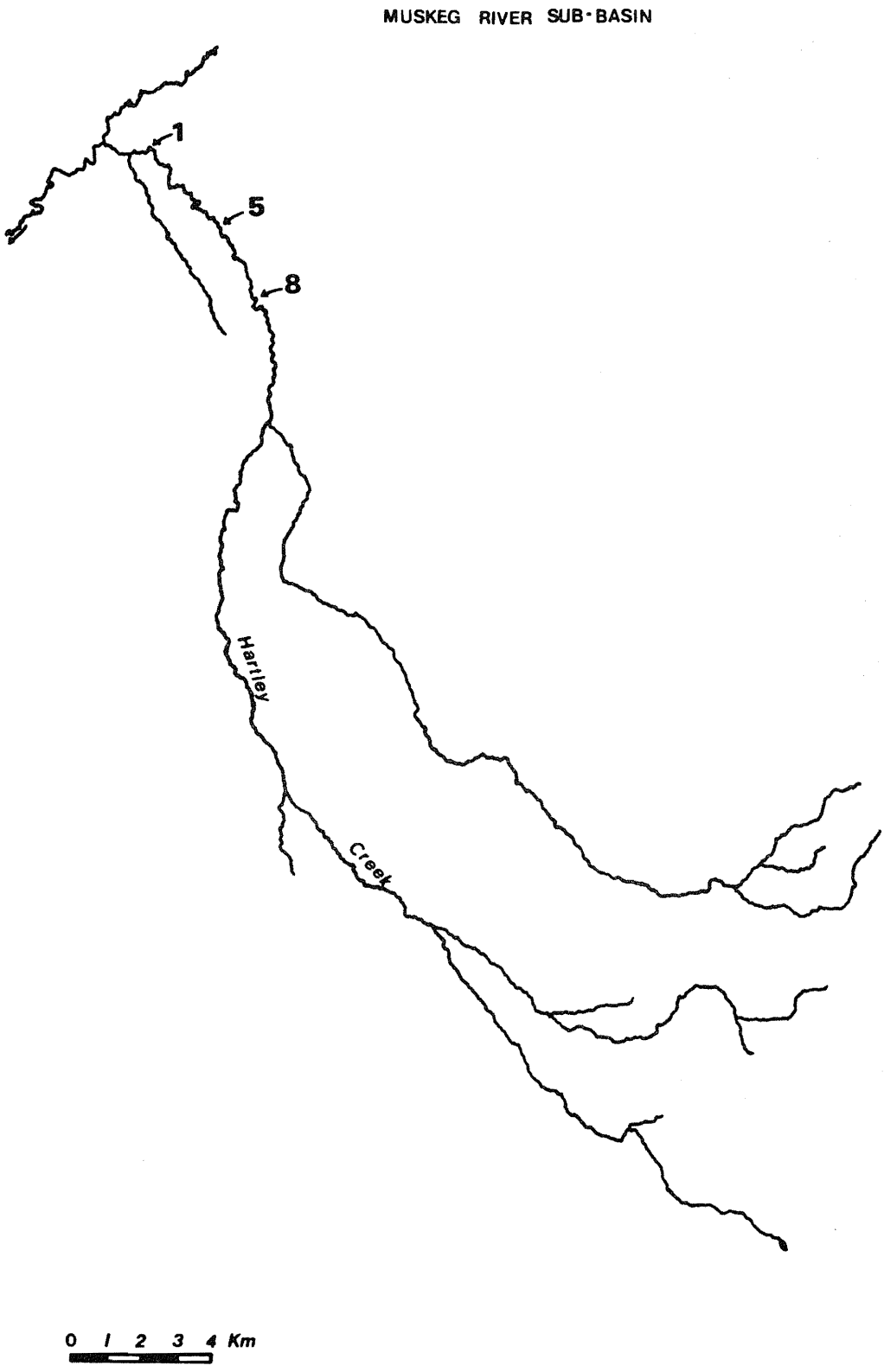


Figure 2. Map of Hartley Creek showing locations of sampling sites 1, 5 and 8. Sites 5(a), 5(b) and 5(c) are 200,350 and 370 m respectively downstream of Site 5.

385 m contour line the sandstone is overlain by the Clearwater shale formation. The headwaters of Hartley Creek cut through the modern Grand Rapids formation Buff Beach complex.

The McMurray sandstone formation was deposited during the Cretaceous period and in the oil sands region often caps salt lenses of Devonian age. The sandstone is overlain by the marine Clearwater shales which were formed from the transgressive Clearwater Sea (Gallup 1974). Overlying this formation is overburden composed of eroded glacial deposits from the Cratonic shield, Athabasca formation and lacustrine tills from Clearwater shales, exposed McMurray sandstone and Waterways limestone.

It has been suggested that the east bank tributaries of the Athabasca River from the Clearwater north to the Firebag River were at one time part of a delta system draining glacial Lake Athabasca into the transgressive sea (Kidd 1951; Gallup 1974; Page 1974). This delta deposited the Grand Rapids formation which consists of sands and silts. As the sea receded many terrace benches and dunes were isolated and these benches and stabilized dunes represent the low relief hills in the Hartley Creek area.

The geology of the region is reflected in the substrate types found in Hartley Creek. These substrates are characterized by large limestone boulders 250 - 1000 mm in size, granite tills of sizes ranging from boulders to gravels, shales, and fine quartz sands. The extensive calcareous deposits also cause the water to be alkaline despite the heavy humic acid input from upland muskegs.

The vegetation surrounding the creek is characterized by stands of *Populus tremuloides* (Michx.), with mixed *Salix*, *Alnus*, and *Picea mariana* (Min.) in low-lying areas. The principal aquatic macrophytes are *Potamogeton richardsonii* (Benn.) and *Sparganium fluctuans* (Morong); both are scarce except in slow stretches of water.

3.1 STUDY SITES

Locations of all study sites are shown in Figure 2. These sites were chosen after an initial survey of the whole length of Hartley Creek because they were representative of the major habitat types present.

3.1.1 Site 1.

Site 1 was located 1.6 km south of the confluence of Hartley Creek and the Muskeg River at 57°15'40"N, 111°27'W. The substrate of the riffle, from which the benthic samples were taken, consisted of outcrops of granite and sandstone and boulders of slate. There were no macrophytes present and very little epilithic algae. The surrounding vegetation consisted of grasses and low shrubs typically associated with a disturbed environment.

3.1.2 Site 5.

Site 5 was located approximately 4 km south of the confluence at 57°12'30"N, 111°24'W. The riffle was characterized by large boulders (250 mm diameter) of limestone and granite, limestone pavement, and mixed cobbles and gravels of granite and shale. The 53% gradient at this site resulted in extremely turbulent flow. Algal growth was dense and many of the rocks were also thickly matted with mosses. The most conspicuous alga present was *Cladophora glomerata* (L.). The vegetation on the left bank was open *Picea* parkland with scattered *Alnus* thickets at the water's edge, while that on the right bank was dense *Picea*, *Alnus*, and low shrubs. Three sub-sites were chosen for intensive sampling based upon the range of rock sizes in the riffle and the amount of vegetation on the rocks.

3.1.2.1 Site 5(a). This site is located approximately 200 m downstream of Site 5. At this point, the Creek is surrounded by dense growths of shrubs, *Alnus* and *Picea*. The main

distinguishing character of the site is that a large proportion of the rocks are covered by a thick layer of the moss *Hydroamblystegium* (Figure 3). Rocks without moss cover comprise approximately 30% of the total and are mainly found in deeper parts of the riffle beneath other rocks. There is a large variety of rock sizes in this riffle ranging from 3 cm - 49 cm in maximum diameter (Figure 4). Clearly, the most numerous rocks are in the 3 - 7 cm size range.

The depth of the water in a cross-section of this riffle ranges from 1 - 29 cm (Figure 5).

3.1.2.2 Site 5(b). This site is located 150 m downstream from Site 5 (a). It is also surrounded by dense vegetation but, because of the angle of the main axis of the creek to the direction of the sun's path, it receives more sunlight. This may contribute to the greater coverage of *Nostoc* found on the rock surfaces. The site includes a large range of rock sizes (Figure 6) whose frequency distribution is similar to that found at Site 5.

The water depth at this site ranges from 10 - 24 cm with a modal depth of 18 cm (Figure 7).

3.1.2.3 Site 5(c). This site is located about 20 m downstream from Site 5 (b). The distinguishing feature of this riffle is its comparative homogeneity in rock size and depth. Rocks with a maximum diameter greater than 18 cm were not found and most rocks had a maximum diameter of 3 - 5 cm (Figure 8). The depth of the riffle ranged from 8 - 21 cm with a mode at 10 - 12 cm (Figure 9).

3.1.3 Site 8.

This site was located at 57°12'N; 111°24'W about 1.5 km south of Site 5. It consisted of two riffles and two adjoining pools.

The upstream riffle was designated 8 Head or 8 H. The substrates in this riffle consisted of assorted

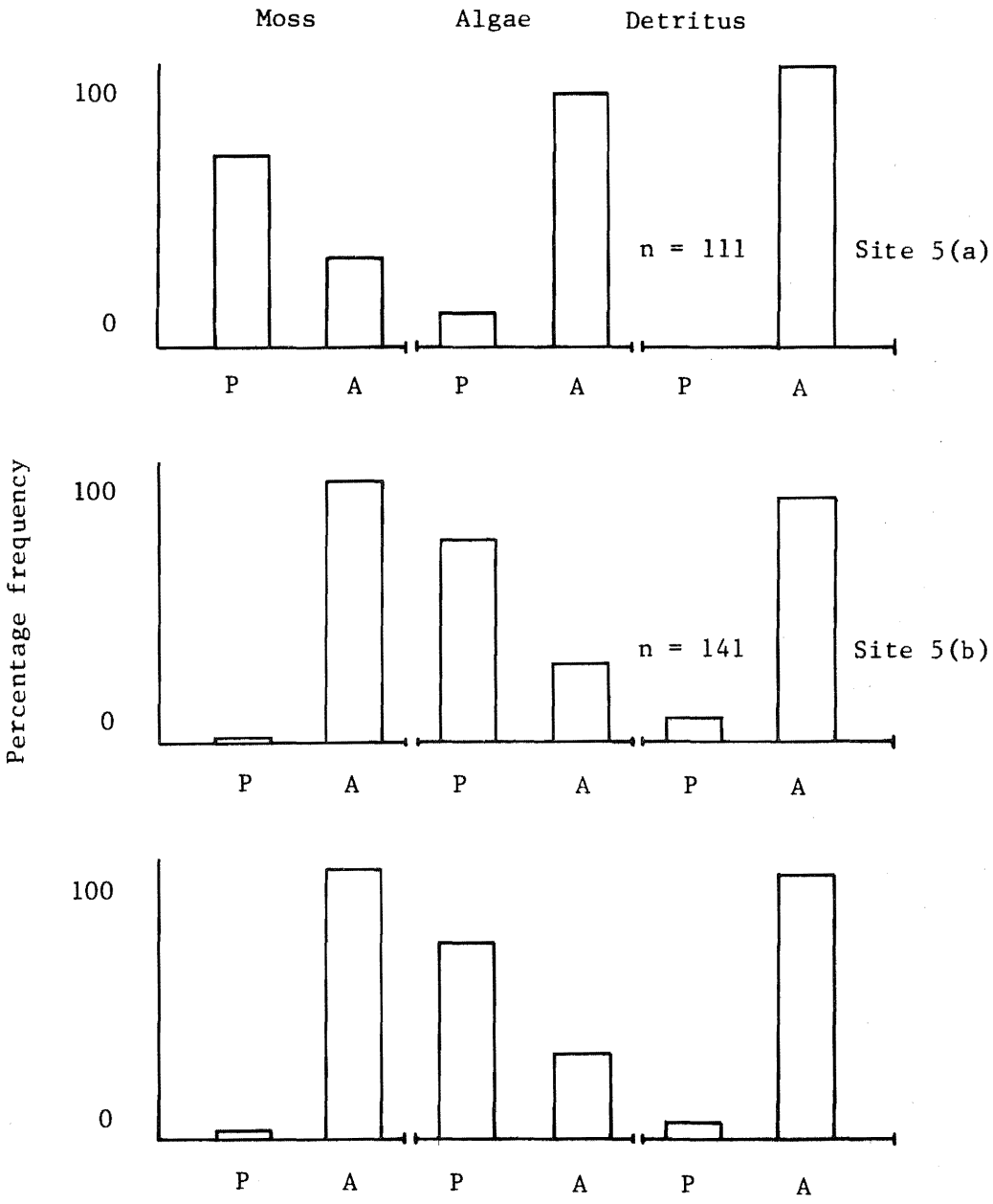


Figure 3. Frequency distributions of the presence (P) or absence (A) of moss, algae, or detritus cover at Sites 5(a), 5(b), and 5(c).

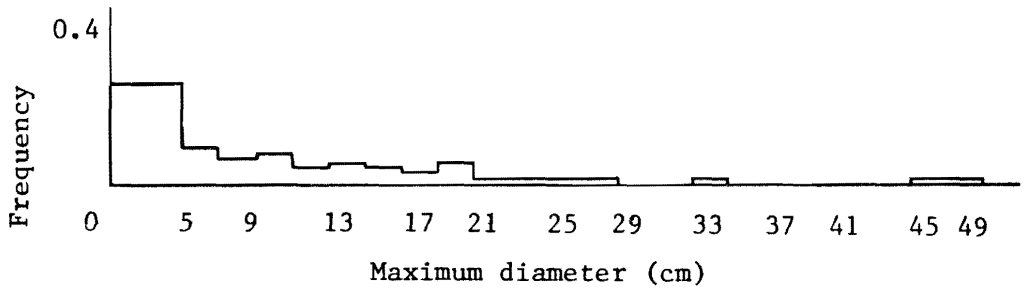


Figure 4. Frequency distribution of the maximum diameters of the rocks from Site 5(a).

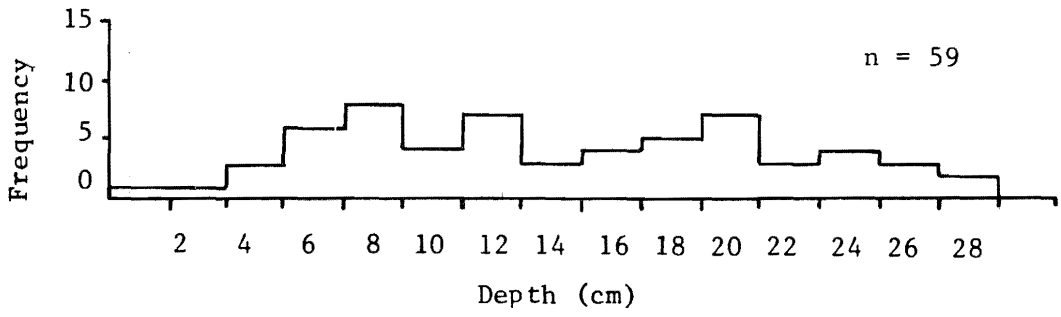


Figure 5. The frequency distribution of depth measurements at Site 5(a), September 1976.

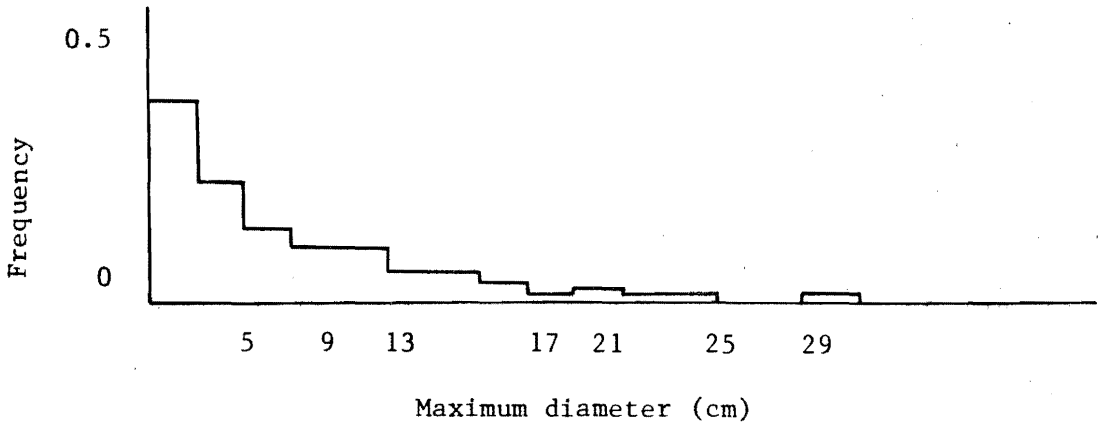


Figure 6. Frequency distribution of the maximum diameters of the rocks from Site 5(b).

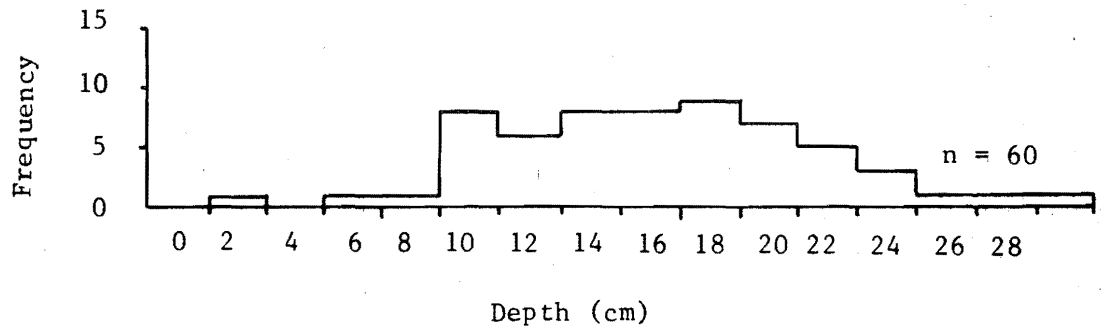


Figure 7. The frequency distribution of depth measurements at Site 5(b), September 1976.

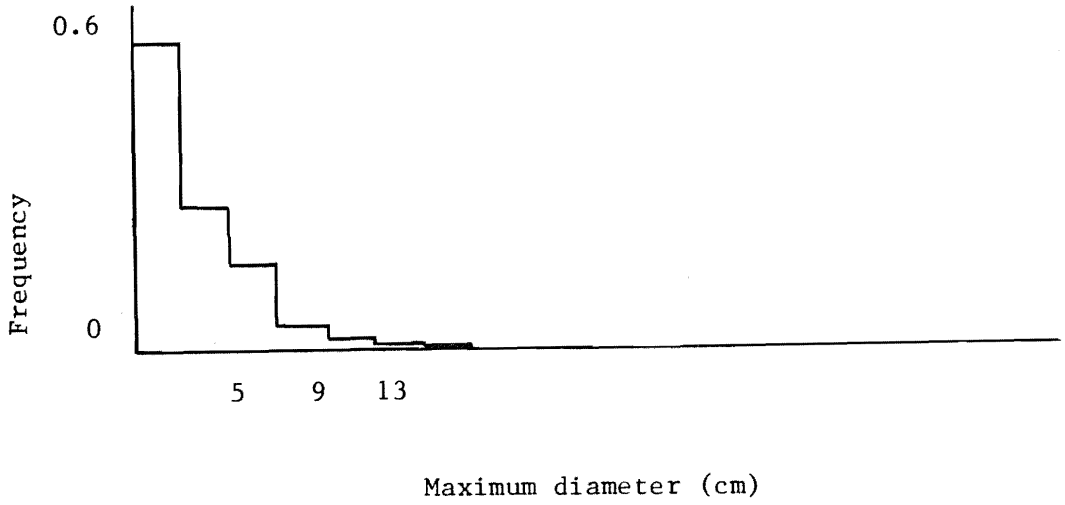


Figure 8. The frequency distribution of the maximum diameters of the rocks from Site 5(c).

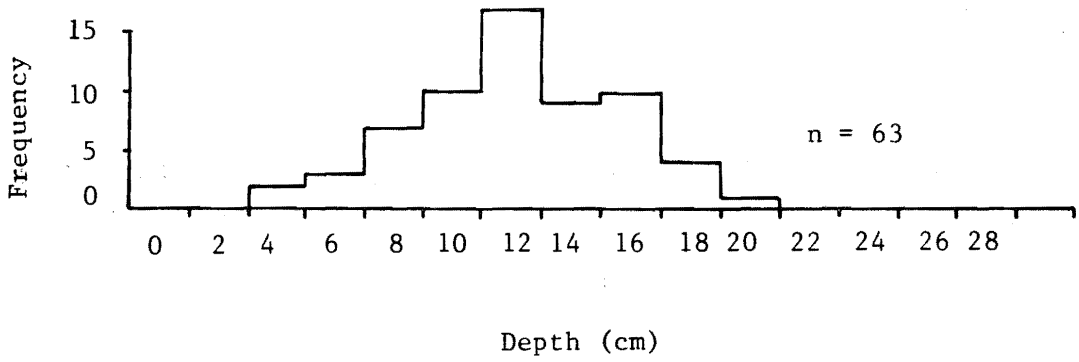


Figure 9. The frequency distribution of depth measurements at Site 5(c), September 1976.

rocks with diameters in the range of 100 - 250 mm. The rocks were thickly coated with *Nostoc* sp. and the moss *Hygroamblystegium tenax* (Hedw.) Jenn., and there were scattered patches of *Sparganium fluctuans*.

Directly downstream of the 8 H riffle the river opened up into a large pool, 8 Hp. The pool had a maximum depth of 2.0 m and its substrate was completely uniform, consisting of the fine quartz sands covered patchily with fine organic detritus.

A second, lower pool (Site 8 Tp) was separated from the upper pool by a ridge of limestone slabs which traversed a 90° bend in the river. The maximum depth in Site 8 Tp was 2.1 m and the substrate was highly diverse and included areas of dense macrophytic growth dominated by *Potamogeton richardsonii*, with patches of *Sparganium fluctuans*, and occasionally *Cladophora glomerata*. The mineral substrates included areas of granite and limestone boulders 250 - 2000 mm in diameter, cobbles 64 - 250 mm in diameter, quartz sands covered by thick deposits of organic detritus, and coarse gravels.

The lower pool discharged into the riffle designated Site 8 Tail or Site 8 T (Figure 10). The substrate consisted of cobble mixed with granite, slate, and limestone boulders 250 - 500 mm in diameter, coarse gravels and sands. Isolated areas of *Sparganium* occurred towards the right bank while the mid-section was characterized by rocks covered thickly with the moss *Hygroamblystegium tenax* and *Cladophora glomerata*.

At Site 8 Tail the left bank, a stabilized sand dune, rose 10 m above the stream and was covered by *Picea mariana* and shrubs. Between Sites 8 Tp and 8 Hp a large sand spit projected into the stream and formed the shore of the upper pool for some 10 m, while the remaining shoreline was covered by *Alnus* and grasses. The right bank was low and densely covered by *Picea mariana*, *Populus tremuloides*, *Alnus*, and tall grasses.

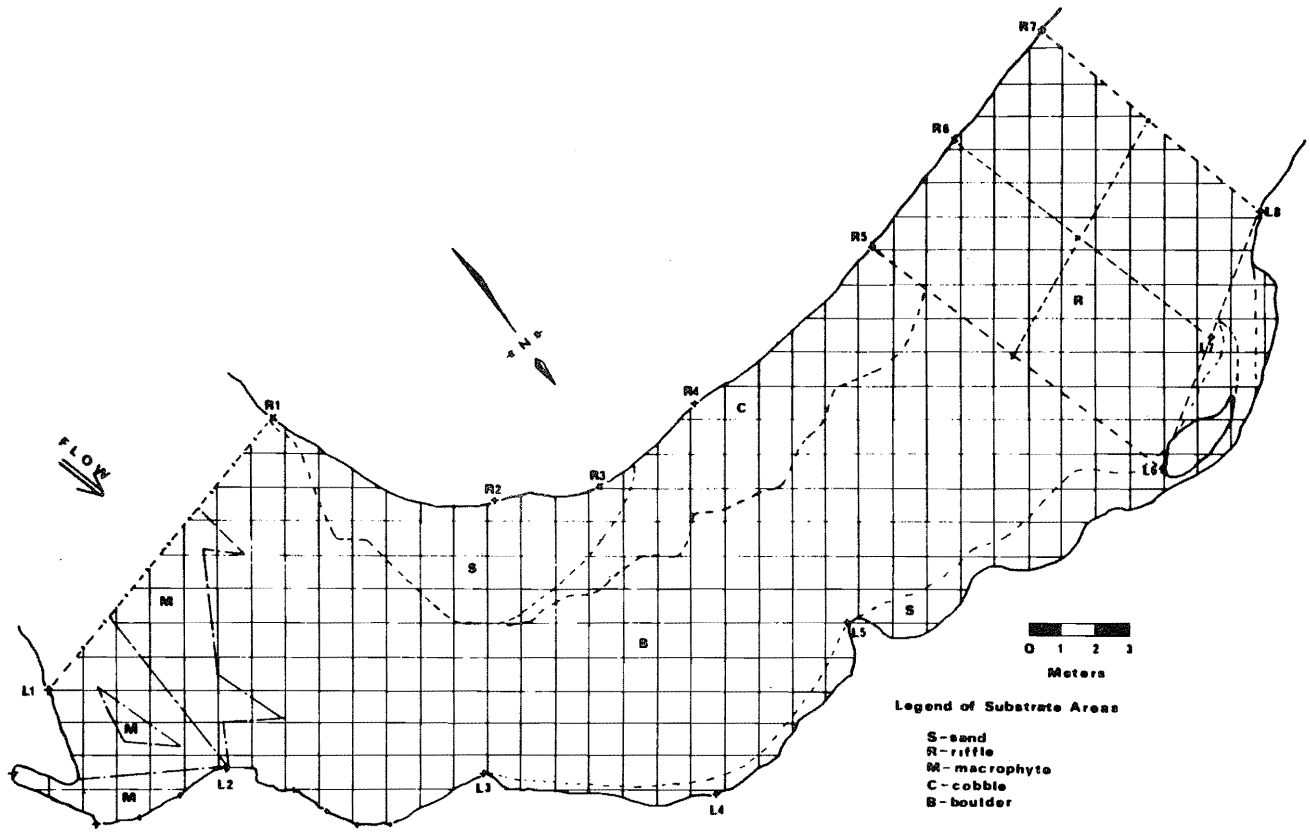


Figure 10. Map of the substrate groupings at Site 8T.

4. MATERIALS AND METHODS

4.1 BIOLOGICAL COLLECTIONS

The dates, types of benthic samples collected and the numbers of replicates taken over the period are shown in Table 1. Five benthic sampling techniques were used:

4.1.1 Surber Sampler (Surber 1934).

The Surber sampler was covered with 250 µm mesh Nitrex and defined a sampling area of 0.093 m^2. Sample locations within the riffle were selected randomly. The sampler was laid over the section of the substrate to be sampled and firmly held down with its opening facing upstream. The large rocks (>16.0 mm in diameter) enclosed within the sampling quadrat were removed, placed in a bucket, picked clean of attached algae, mosses, and invertebrates, scrubbed with a nylon brush, and washed. The remaining substrates enclosed by the sampler were stirred vigorously so that materials and organisms dislodged from the substrate were carried by the stream current into the Nitex collection net. The contents of the Surber collection net were also washed into a bucket, stirred, and emptied into a 180 µm mesh Standard seive. Stirring and decanting was repeated until all the detritus was removed. After decanting, the heavier substrates contained in the bucket were hand-picked, and any Trichoptera with stone cases and Gastropoda present removed. The sieved sample plus the hand-picked invertebrates were preserved with 10% Formalin and stored in labelled 500 ml. screw-top jars.

4.1.2 Neil Cylinder Sampler (Neil 1938).

The modified Neil cylinder sampler (Davies et al. 1977) consisted of a 250 µm Nitrex mesh cylinder fastened to a frame 30 cm in diameter enclosing an area of 707 cm^2. The height of the cylinder was adjustable from 30 to 60 cm.

The technique for sampling depended on the depth of water at the sample location. At depths up to 30 cm the standard

Table 1. Schedule of benthic sampling 1976-1977: numbers of replicates taken and methods used.
a = Neil cylinder sampler; b = Ekman Dredge sampler.

DATES & NOS.																
LOCATIONS	M	Jn	Jy	Ag	S	O	N	F	M	Jn	Jy	Ag	S	O	N	METHODS USED
SITE 1	5	5	5	3	3	5[a]	5[a]	-	-	-	-	-	-	-	-	Surber, Neil[a]
SITE 5	5	5	5	3	3	5[a]	8[a]	-	-	-	-	-	-	-	-	Surber, Neil[a]
SITE 5 (a)	-	-	-	-	-	-	-	-	-	-	-	-	55	-	-	Single Rock
SITE 5 (b)	-	-	-	-	-	-	-	-	-	-	-	-	86	97	-	Single Rock
SITE 5 (c)	-	-	-	-	-	-	-	-	-	-	-	-	101	84	-	Single Rock
SITE 8 Tr	-	5	5	3	3	5[a]	-	-	5[a]	9[a]	9[a]	9[a]	9[a]	-	9[a]	Surber, Neil[a]
SITE 8 Tm	-	-	-	-	-	-	-	-	2	4	4	4	4	-	-	Extension Neil
SITE 8 Tc	-	-	-	-	-	-	-	-	2	4	4	4	4	-	-	Neil & Extension
SITE 8 Ts	-	-	-	-	-	-	-	-	2	4	4	4	4	-		Neil & Extension
SITE 8 Tb	-	-	5	5	5	5	-	-	2	4	4	4	4	-	4	Air Lift
SITE 8 Hp	5[b]	-	5	5	5	5	-	-	-	-	-	-	-	-	-	Air Lift, Ekman[b]
SITE 8 Hr	5	5	5	3	3	5[a]	8[a]	-	-	-	-	-	-	-	-	Surber, Neil[a]

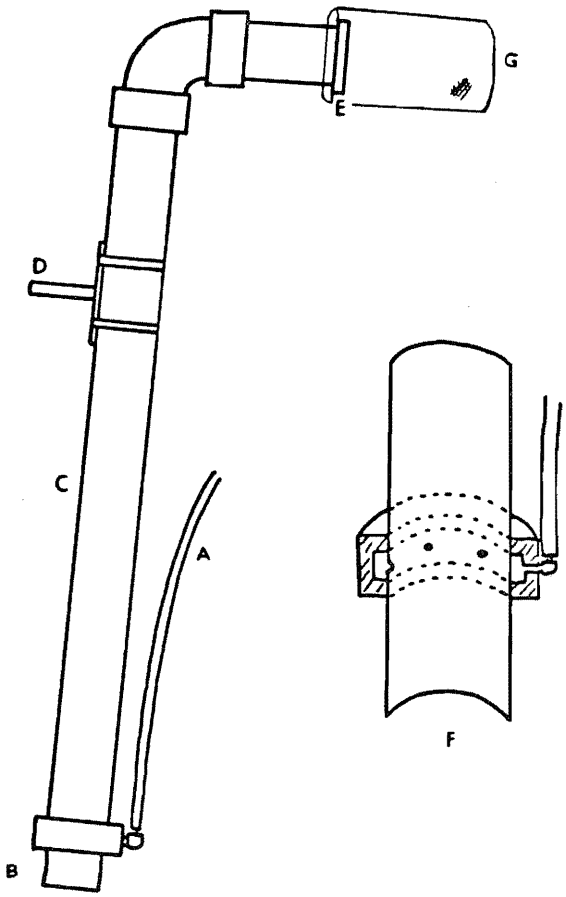
Neil cylinder was used, however, at greater depths (>30 cm but ≤ 60 cm) the extended cylinder was used. During sampling, the Neil cylinder was placed over the substrate and forced into the substrate to a depth of 5-10 cm. The large rocks (>16.0 mm in diameter) were removed and placed in a bucket, picked, scrubbed, and washed. The substrates remaining in the sample area were agitated to dislodge materials and organisms which were retained in the collection net. After this, the sampling technique was the same as that employed while using the Surber sampler except for modifications designed to provide information relating to the distribution and abundance of *Brachycentrus americanus*, *Lepidostoma pluviale*, and *Psychomyia flavida* during 1977 (Section 4.1.8).

The Neil cylinder was substituted for the Surber sampler during the program because: 1. The Surber could not be used in water depths greater than 30 cm; 2. The Surber allowed organisms and detritus to escape sampling, either by being washed around the collection net or by going beneath the quadrat.

4.1.3 Air Lift Pump Sampler.

Samples from water depths greater than 60 cm were taken with a vacuum air lift pump fitted with a 250 µm Nitrex mesh collecting bag. The sampling area was enclosed by a 30 cm high cylinder of 250 µm mesh Nitrex (Figure 11). The sampling device operated from a diving cylinder which fed pressurized air (20.7 MPa) into a brass nozzle from which it escaped through several 1 mm diameter holes inside the barrel of the sampler. As the air rose up the barrel, the pressure dropped behind it causing water, rocks (up to 3 cm in diameter), organic material, and any organisms present to be sucked into the collection bag. Substrates larger than 3 cm diameter were placed in a bucket after sampling, picked, scrubbed, and washed.

The air lift pump was used only in waters deeper than 60 cm. In shallower water, it was not as efficient in terms of numbers of individuals collected as the Neil sampler because it could not develop sufficient lift.



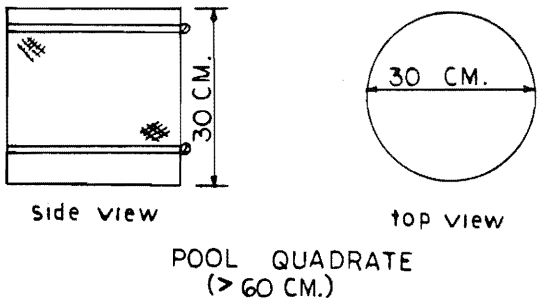


Figure 11. Airlift pump sampler and pool quadrate used in water of >60 cm depth. (A) low pressure hose from SCUBA tank. (B) nozzle. (C) 1.3 m length of 5 cm ID polyethylene pipe. (D) handle. (E) rim to hold drawstring of mesh collecting bag. (F) detail of nozzle. Air enters barrel of airlift via six 1 mm holes. (G) 250 µm collecting bag.

4.1.4 Ekman Dredge (Ekman 1911)

Samples from water depths greater than 60 cm from very soft substrates were taken during the initial survey only with an Ekman dredge (0.23 x 0.23 x 0.23 m) mounted on a pole. Penetration of the substrate was fixed at 10 cm. Because suitable soft substrates were rare and the air lift pump sampler worked efficiently on both soft and rock substrates in deeper waters, to standardize techniques the air lift pump sampler was used in all but the first month. The air lift pump also has the advantage of not producing a shock wave (as the Ekman dredge does) permitting more quantitative sampling.

4.1.5 Single Rock Samples.

To estimate the abundance of the benthic invertebrates on the rock surface, whole rock samples were taken from each of the riffles. The method employed was to select from the natural range of rock sizes in riffles a subsample of each size range. The method of sampling was similar for all rock sizes.

To sample each rock a large hand net was placed downstream of it. The net (mesh size 250 µm) was positioned such that as the rock was rolled into its mouth by gently lifting and pushing the rock downstream, the net could scoop both the rock and its surrounding water as it was lifted from the substrate. The sample was immediately taken to the shore and placed into a bucket.

In many cases, both the invertebrates on the surface and the rock itself were required for further analysis. In this case, each rock was individually placed into a strong plastic bag and the contents of the bag were preserved in 10% Formalin. It was impossible to bring back all rock samples from the field; the algae, detritus, and animals living on the surface of many rocks were therefore either picked off by hand or scraped off using a scrubbing brush. The invertebrates and algae were placed in screw top jars, preserved in 10% formalin solution, labelled, and transported back to the laboratory for sorting.

The maximum diameter, width and breadth of each rock as well as its weight and shape was recorded in the field and the rock returned to the riffle.

At each site, six kick samples were taken. The invertebrates in these samples were preserved in 10% formalin and used to estimate the biomass of individuals of each instar of each species.

4.1.6 Adult Collections.

4.1.6.1 Emergence traps. Mundie (1964) pyramid emergence traps were employed at Site 5 throughout the 1976 season to collect adult aquatic insects. The collections were preserved in a 10% formalin and 1% glycerin solution and returned to the laboratory for identification.

4.1.6.2 Light trapping. A light trapping technique was employed for adult collections at Sites 1, 5 and 8, during 1976, and at Site 8 in 1977. This technique consists simply of a bright light source (a Coleman lamp), above a collection tray that contained a solution of either 10% formalin or dilute detergent. The insects attracted to the light fell into the collection tray and were killed by the contained solution. Collections were transferred into vials containing 10% formalin and 1% glycerin, labelled, and returned to the laboratory for analysis.

4.1.6.3 Hand collections. Hand sweeps using a conical sweep and beating net were employed to augment the adult collections at all sites sampled during 1976/77. Specimens from these collections were preserved as noted, and identified in the laboratory.

4.1.6.4 Rearing. Several collections of live larval Trichoptera were returned to the laboratory and placed in rearing chambers consisting of 60 L glass aquaria in which aerated water and

rocks from Hartley Creek were placed; the top was covered with 250 µm mesh screening.

Emerging adults were collected off the screening using an aspirator containing 70% ethanol and preserved together with the associated larval cases and pupal sclerites taken from the aquarium.

4.1.7 Drift Samples

The drift of benthic invertebrates was sampled using 10.5 cm diameter nets of 250 µm Nitrex mesh arranged so as to sample the total water column at the centre of the stream and near both margins at Sites 8H and 8T. Nets were normally emptied every two hours through 24 h periods in July and in August 1976.

Since the flow of water through a net varies with the position of the net concurrent measurements of water flow were taken. This enables the drift data to be expressed in terms of numbers of organisms per unit volume (m^3) of water, thus avoiding anomalies arising from different flow rates through different nets.

4.1.8 Laboratory Analysis

4.1.8.1 Sub-sampling. Because of the extremely large numbers of animals collected, to save analysis time and money the 1977 benthic samples were divided into quarters using a sub-sampler. The sub-sampler (Figure 12) consisted of a 30 cm high lucite cylinder with an inside diameter of 19.0 cm. The bottom of the cylinder had 4 (3.5 cm diameter) equidistant holes. Each hole was stoppered with a rubber bung connected to a brass guide rod. The guide rods were connected at the top of the sampler by two yokes attached to a spring-loaded locking trigger device. By unlocking this trigger, all four bungs could be lifted out of the holes simultaneously. During sub-sampling the cylinder was sealed by locking the yolk which forced the bungs into place. The sample was poured into the cylinder and the cylinder filled through a 10 mm Tygon water ring located at the top of the cylinder. When

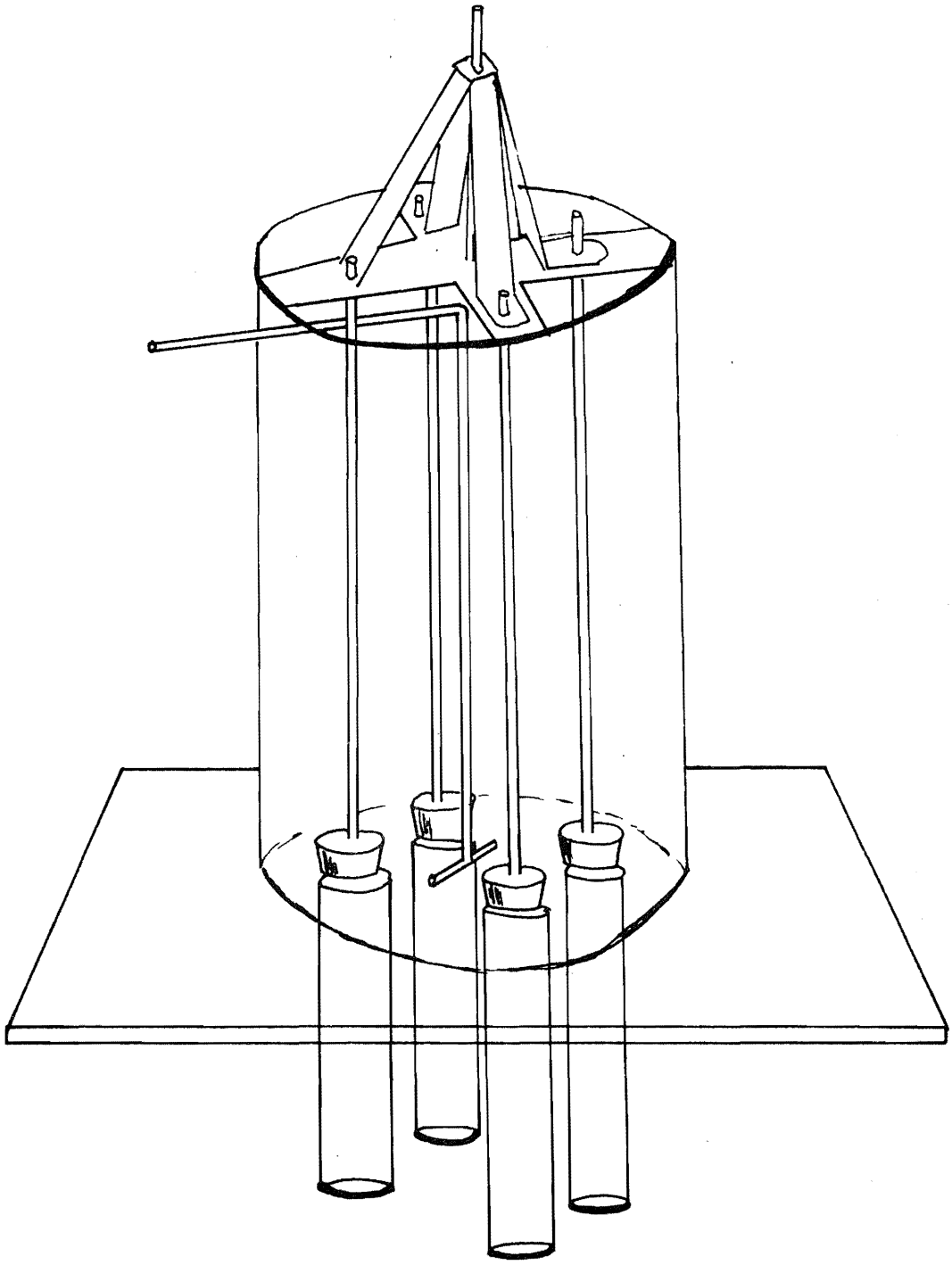


Figure 12. Construction of sub-sampling apparatus.

the cylinder was full, the water was shut off and the sample gently agitated by aeration provided by 5 air stones, to ensure complete randomization of the sample. After agitation for two minutes, the trigger was released and the sample flushed through the 4 holes at the bottom, into receiving bottles. The efficiency of this sub-sampling technique is described in detail in O'Connell (1978) who showed that there was no significant ($p < 0.001$) difference in the numbers of individuals between the four sub-samples collected.

4.1.8.2 Sorting and identification. Each sample was sorted and the organisms counted and identified under a dissecting microscope at 12X magnification. The references used for identifications are given in Appendix 10.2. Samples were stored in stoppered 2 dram vials containing 70% ethanol and 1% glycerin.

4.1.8.3 Cohort analysis. The head capsule widths of the numerically dominant Trichoptera larvae represented in the benthic samples were measured across the eyes using a dissecting microscope at 25X magnification, fitted with an ocular micrometer (accuracy ± 0.01 mm).

4.1.8.4 Gut content analysis. To determine the food range of the most abundant species of Trichoptera present at Site 8T gut content analysis was carried out. The quantification of food items was conducted using the method outlined by Mecom and Cummins (1964) and Resh (1976). Five larvae of each of *Brachycentrus americanus*, *Lepidostoma pluviale*, and *Psychomyia flavida* were preserved in Kahle's fluid (15 parts ethanol, 30 parts distilled water, 6 parts formalin and 1 part glacial acetic acid) (Beirne 1955). The guts of the preserved organisms were dissected and the contents suspended in 10 mL of distilled water. The suspension was filtered onto 0.45 µm gridded Millipore filters. The filters were cleared overnight in immersion oil and examined under a binocular microscope fitted

with an ocular micrometer at 100X magnification. Six grids on each slide were analyzed. The contents were categorized into mineral, detritus, diatom, vascular plant, filamentous algae, and animal. The size of all contents was measured with the micrometer.

Every month, five additional specimens of each species were fixed with a 10% glutaraldehyde and ruthenium red solution and the contents of all regions of the gut examined to determine if and where aquatic bacteria were used as food by these Trichoptera species. The fixative was replaced within two hours with a ruthenium red-cacodylate buffer solution, set at a pH of 6.6. After 20 min, the solution was changed and the specimens washed three more times at 20 min intervals, with the same solution. The larvae were then considered to have been stabilized and the guts excised. The dissected gut was divided into fore, mid, and hind regions and each section centrifuged separately at 5G for 5 min. The precipitants were placed in sealed snap-top plastic centrifuge tubes and returned to the laboratory for analysis. Both the gut contents and the tract wall were examined using a scanning electron microscope (AEI 801) to differentiate between bacteria utilized as food and the endemic flora of the gut. Ruthenium red stains carbohydrate fibrils with which endemic gut bacteria attach themselves to gut walls. Aquatic bacteria do not possess such fibrils, and on this basis, type separation was possible.

4.1.9 Modifications to Sampling Techniques During the 1977 Season.

During 1977, benthic samples were taken from five specific habitat areas at Site 8T: a) macrophytes (8Tm), b) cobble (8Tc), c) sand (8Ts), d) boulder (8Tb), and e) riffle (8Tr) (see Table 1 for methods, dates, and numbers).

The sample locations were selected using the proportional random sampling technique (Elliott 1977) and their positions triangulated prior to sampling.

Prior to taking a sample, the current velocity at that location was recorded from four depths. These were: below the top surface of the rocks, at the top surface of the rocks, at mid-water column, and at the water surface. A Pygmy Gurley Flow Meter was used (see Section 4.3.6 for details).

As rocks were removed from the sample quadrat, each was checked carefully for attached trichopteran larvae. When larvae of the species *Brachycentrus americanus*, *Lepidostoma pluviale*, and *Psychomyia flavida* were observed and their cases or tubes remained firmly attached to the rock, their locations with respect to each other and their position on that rock were recorded. Engineering calipers and compasses were used to take these measurements (accuracy ± 0.5 mm). These rocks were numbered for later classification (Section 4.3.4.1). All other rocks small enough to be removed from the quadrat were placed in a bucket, picked, scrubbed, washed, and classified. Those rocks which could not be removed were measured *in situ*.

In the deeper waters (>60 cm) it was not always possible to measure the spatial distribution of those species mentioned due to the nature of the sampling technique. In such cases, rocks were examined underwater, using snorkeling equipment; however, the clarity of the water seldom allowed this.

4.2 FIELD EXPERIMENTS

To estimate the biomass of periphyton and sessile bacteria, and to follow their colonization cycles, on 2 May 1977 20 granite discs (10 cm in diameter x 1 cm thick) were placed in Hartley Creek across a transect in the riffle at Site 8 Tail. Five replicates for each of the following tests were taken at two-week intervals, from 2 May until 12 November 1977: Total Chlorophyll, Chlorophyll ATP, Bacterial ATP, and Bacterial biomass determined by direct counts.

In 1977 at Site 8 Tail, five replicate water samples were taken every two weeks in conjunction with the other algal and bacterial work to estimate the biomass of suspended populations

of algae and bacteria.

4.2.1 Total Chlorophyll

To determine total chlorophyll, 4 x 1 cm^2 scrapes were taken from the discs, suspended in 10 mL of water, and filtered in the field using a Millipore tower with 0.45 µm Gilman Glass fiber filters. The filter was then sprinkled with magnesium carbonate, placed in a vial, wrapped in aluminum foil and frozen on dry ice and stored in a cooler. Samples were then returned to the laboratory and analyzed following the methods described by Vollenweider (1966), to determine algal biomass.

4.2.2 Chlorophyll and Bacterial ATP Biomass.

In the field, 4 cm^2 disc scrapes were suspended in 10 mL of boiling Tris buffer, for 10 min. The boiled solution was then placed into vials and stored frozen.

Further analysis consisted of thawing the samples, centrifuging them at 15G for 10 minutes, and determining the ATP concentration using the luciferinase reaction (Sorokin 1966).

Separate replicate series were used for bacterial and chlorophyll ATP.

4.2.3 Determination of Bacterial Numbers by Direct Counts.

Four x 1 cm^2 scrapes were fixed with 10% glutaraldehyde and cacodylate buffer (pH 7.8) and stored in vials containing this solution. In the laboratory, the scrapes were stained with acridine orange and examined under an ultra violet epifluorescence microscope following the methods described by Sorokin (1966), to determine the number of bacteria present.

4.2.4 Suspended Algal Biomass.

To determine the biomass of suspended algae, one liter of stream water was filtered through 0.45 µm Gilman Glass fiber filters. These filters were treated and analyzed as noted for periphyton total chlorophyll, and the biomass determined.

4.2.5 Suspended Bacterial Biomass.

The biomass of suspended bacteria was determined using the direct plate count methods previously described. The samples consisted of 3 mL of stream water which were filtered through 0.2 μm Nucleopore filters. These filters were placed onto a ball of cotton wool floating in a 10% glutaraldehyde solution in a small Petri plate. A top was put on the Petri plate and the container sealed and returned to the laboratory for analysis.

4.3 MEASUREMENT OF PHYSICAL PARAMETERS

4.3.1 Morphometry of Site 8 Tail Pool and Riffle.

A detailed map of the pool and riffle at Site 8 Tail was constructed in May 1977 using a surveyor's transom and fixed datum stakes (Figure 10). The major substrate types were plotted and the entire area gridded into 1 m^2 quadrats. The gridding system was used to: (a) permit the identification of a sample location; (b) permit the selection of random sample locations within each substrate group; and, (c) avoid repetitive sampling of the same location on successive months.

Depth profiles of each grid were recorded. A reference depth marker was installed so that the area and volume of the site could be determined easily and quickly at each subsequent visit (Figures 13 and 14).

4.3.2 Estimation of the Frequency Distribution of Rock Sizes at Sites 5(a), 5(b), and 5(c).

To estimate the density of each rock size category in each of the three riffles, between ten and twelve samples at sites 5(a), (b), and (c) were taken in September 1977. The method of sampling consisted of randomly selecting an area in the riffle and placing a 30 x 30 cm square quadrat on the surface of the substrate. All rocks within the delimited area were lifted from the substrate and their maximum diameter measured to the nearest cm. After each rock had been measured the presence or

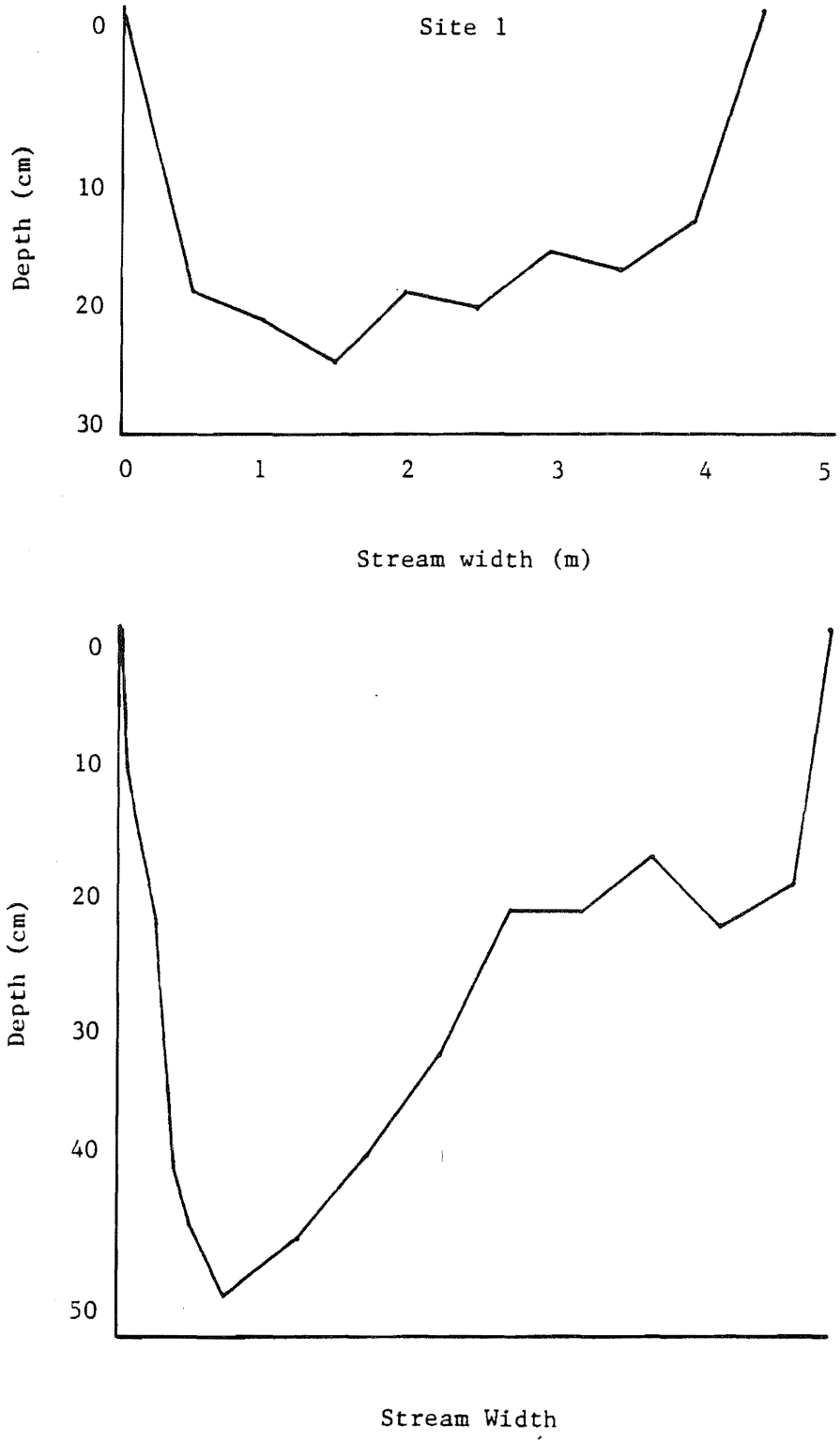
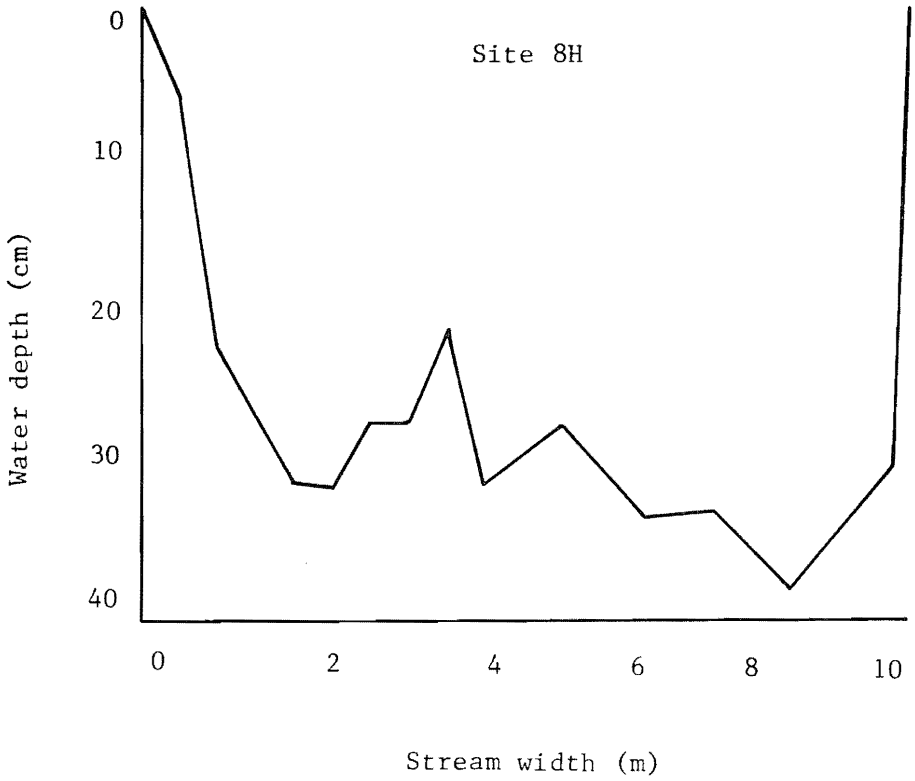


Figure 13. Stream profiles at Site 1 (top) and Site 5 (below).



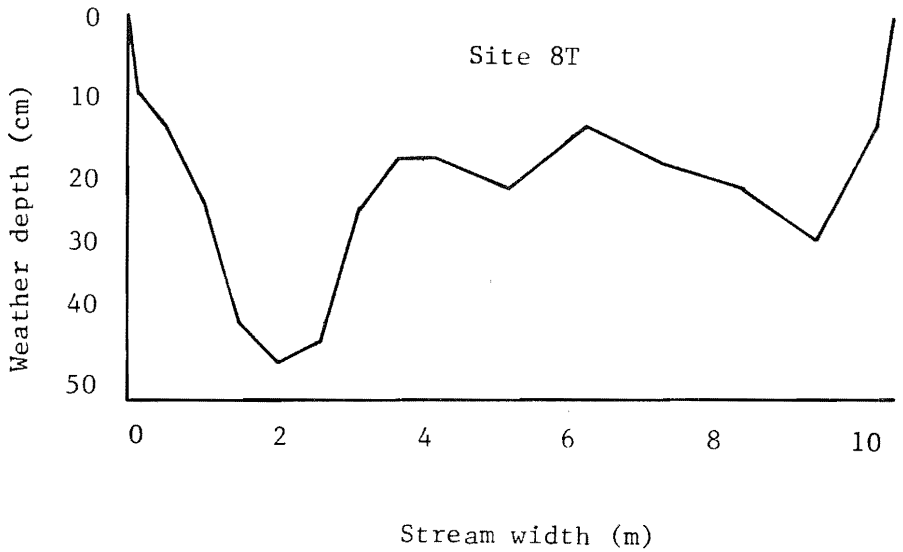


Figure 14. Stream profiles at Site 8H (top) and Site 8T (below).

absence of moss, *Nostoc*, and detritus was recorded. This was continued until all the rocks within the quadrat down to the sandy bottom had been measured and then a new area was selected.

The frequency distribution of the maximum diameters of the rocks in each of the riffles is given in Figures 4, 6, and 8.

4.3.3 Estimation of the Mean Depths of Sites 5(a), 5(b), and 5(c).

Depth measurements at each site were taken with a 50 cm ruler at a series of 60 randomly selected locations at each site in both September and October. The results obtained in September are presented graphically in Figures 5, 7, and 9.

4.3.4 Substrate Analysis.

4.3.4.1 Inorganic substrate classification. Inorganic substrates collected with the 1977 samples were sorted into size categories using the PHI scale system (Cummins 1962) (Table 2).

All rocks with a maximum dimension greater than 16 mm (PHI-4) were classified in the field. Classification consisted of measuring, weighing, and recording the shape and mineral class of each rock. Seven mineral types were recognized: limestone, granite, quartz, shale, tar sand, sandstone, and quartzite. Each rock was numbered so that information related to the spatial distribution of organisms could be catalogued. The mean density of each mineral type was calculated by volume displacement, using a graduated sedimentation cone. Using the weight and density, the volume (V) of the rock was calculated ($V = \frac{\text{Mass}}{\text{Density}}$). To calculate approximately the surface area of the rocks, the volume of an equivalent ellipsoid was assumed and the surface area calculated from the formulae:

$$\text{Ellipsoid Volume} = \frac{4}{3}\pi a\, b^2 \qquad (1)$$

$$\text{Ellipsoid Surface Area} = \frac{4}{3}\pi a\, b \qquad (2)$$

Table 2. Inorganic Substrate Classification.

Class	Maximum lineal dimension (mm)	PHI Scale Value
Boulder	256	-8
Cobble	64 - 256	-6, -7
Pebble A	32 - 64	-5
Pebble B	16 - 32	-4
Gravel Coarse	8 - 16	-3
Medium	4 - 8	-2
Fine	2 - 4	-1
Very Coarse Sand	1 - 2	0
Coarse Sand	0.5 - 1	1
Medium Sand	0.25 - 0.5	2
Fine Sand	0.125 - 0.25	3
Very Find Sand	0.625 - 0.125	4

where a = the major axis
b = the minor axis

Since 'a' was known from field measurements the equation (1) was solved for 'b', allowing the surface area to be calculated from equation (2).

The fine mineral substrates (<8 mm in size) were sorted in the laboratory using a standard sieving series and shaking tray. Each fraction was weighed dry and presented as a percentage of the total substrate weight.

4.3.4.2 Estimation of surface areas of rocks. To accurately calculate the surface areas of the rocks collected in the field the method of Calow (1972) was used (see also Minshall and Minshall 1977 and Kovalak 1978). It was necessary to obtain accurate estimates of rock surfaces in order to estimate the population densities of their inhabitants. Calow's method involves coating the dry rock surface with 3-4 layers of latex cement (Latex Compounding Co., Toronto). After the latex had dried it was peeled off and was cut into pieces. One side of each piece was inked and a print made on white typing paper. The prints were then cut out and weighed.

The surface area of each rock was determined by measuring the weight of inked paper corresponding to the whole surface area of the rock and comparing this value to the weight of inked paper of known surface area.

Both the weight and the maximum length of rocks were found to be good predictors of surface area, based on the following equations derived from measurements of 40 rocks of all size classes collected at Site 5.

$$\text{Surface area } (cm^2) = 2.319\ W^{0.7044} = 3.769\ L^{1.71}$$

where W = weight in g
L = maximum length in cm

These relationships could therefore be used to determine the surface areas of rocks for which only weight or maximum length data had been taken in the field.

4.3.5 Organic Substrate Analysis.

The organic fractions of the substrate collected with the 1977 benthic samples taken at Site 8 Tail, were separated from the benthic samples when sorting and counting. The organic substrates were placed into a rough classification as to type [macrophyte, mosses, algae (filamentous and *Nostoc*), twigs, bark, needles, and fine detritus]. Each fraction was analyzed for loss of weight upon ignition in a muffle furnace and presented as a percentage weight of each component.

4.3.6 Current Velocity and Discharge.

During 1976, monthly discharge was calculated at each site using a Gurley Pygmy Flow meter (accuracy ± 0.19 m^3/sec). In May 1976 the stream profiles at each riffle site were measured across fixed transects to an accuracy of ± 1.0 cm at intervals of 50 cm from bank to bank (Figures 13, 14). Three replicate velocity readings were taken at each transect interval from 0.6 of the total depth and the mean used to represent the velocity at those positions. The number of revolutions of the meter's propeller were recorded over 50-second periods. These readings were correlated to velocity using a rating chart (Gurley Meters) and from these data, a standard curve was prepared. This graph was used in subsequent months with velocity readings taken at 0.6 depths at 50 cm intervals.

The velocity recordings taken in 1977 at Site 8 T at each sample location were obtained in a similar manner.

Daily discharge data were received from the Alberta Research Council's gauging station near Site 1.

4.3.7 Flow Patterns.

The flow patterns at Site 8 T were investigated in May and June 1977 using a marker dye (sodium fluoroscein). The dye was applied at the upstream end of the sample area and followed by snorkeling and timed so that scour and depositional areas could be located and the turnover time of the water in the pool calculated.

4.3.8 Temperature.

Continually recording thermographs (Rikosha Twin Probes) were monitored from May to November 1976 at Sites 1, 5, and 8. Additional data was obtained from the Alberta Research Council gauging station.

During May and June 1977, continual recordings from the substrate water interface were taken at Site 8 Tail pool and riffle. From July to November maximum-minimum thermometers were placed at the substrate-water interface and checked every two weeks.

4.3.9 Light Penetration.

Monthly turbidity measurements were taken at all sites from May to November 1976. 125 ml samples of unfiltered stream water were kept in the dark and cold until returned to the laboratory for analysis. Prior to analysis, samples were agitated vigorously to ensure the resuspension of all particles. Analysis was carried out with a Hach model #2100 turbidimeter, giving readings in Formazin Turbidity Units (FTU's) with a precision of ± 2.0% of full scale.

In 1977, a light profile was taken at each sample date at Site 8 Tail, at depth intervals of 5 cm to the maximum depth in the pool and riffle, with an underwater light meter (Li-Cor model #L1-185 Quantum/Radiometer/Photometer) which had an accuracy of ± 1.0 microeinsteins m^2 sec^{-1} (3 microeinsteins m^{-2} sec^{-1} = 0.3 Watts m^{-2} = 30 Lux = 2.787 foot candles).

4.4 MEASUREMENT OF CHEMICAL PARAMETERS

A number of chemical parameters were measured monthly throughout the 1976 field season. Table 3 lists these parameters, the techniques used, and the accuracy of determination. Additional data were provided by the Alberta Research Council Hydrology Team on a bi-weekly basis from a gauging station situated 0.5 km downstream of Site 1.

4.5 STATISTICAL ANALYSIS

4.5.1 Distribution and Transformation of Data.

Prior to analysis, all data were analyzed for goodness of fit using the G statistic (Snedecor and Cochran 1967) to determine whether or not the data satisfied the assumptions of a normal distribution. Since some data were normally distributed and some were not, all non-parametric data were transformed.

A program TRANS was modified from Bissett (1975) to perform all appropriate transformation of scale. This program tests the assumptions of the analysis of variance and regression, and examines each of the following transformations for their ability to normalize the data:

1. Square Root transformation
2. Square root +0.5 transformation
3. Log_{10} transformation
4. Arc Sin transformation
5. Arc Sin +0.5 Transformation
6. Arc SinH transformation
7. Arc SinH +0.5 transformation

These transformations include those theoretically required to normalize the Poisson (1,2), geometric (3), binomial (4,5), and negative binomial (6,7) distributions (Bissett 1975, Elliott 1977).

Table 3. Chemical Parameters Measured in 1976 and Equipment Used.

MEASUREMENT	INSTRUMENT	ACCURACY LEVEL
Dissolved Oxygen	Hach Portable Dissolved Oxygen Meter	± 0.5 mg/L
Total Alkalinity (as $CaCO_3$)	Hach Phenolphthalein titration	± 1.0 mg/L
Total Hardness (as $CaCO_3$)	Hach KOH and Titraver titration	± 1.0 mg/L
Chloride	Hach Diphenylcarbizone titration	± 2.0%
pH	Metrohm pH meter Model #E280A	± 0.1 pH units
Specific Conductance	Dionic Conductivity Meter Series 3	± 1.0 mS, ± 10%

4.5.2 Regression Analysis.

This type of analysis examines the relationship between two variables and provides an equation relating one variable to another. A regression line describes the average change in a dependent variable (y, e.g. numbers of species), for a unit change in an independent variable (x, e.g. various environmental parameters). The relationship between the two variables is therefore the regression of y on x.

For the analysis of the effect of two or more independent variables on the dependent variable, multiple regression analysis techniques (Snedecor and Cochran 1967) from the Statistical Package for the Social Sciences (SPSS), written at Stanford University, Stanford, California (Nie, Bent, and Hull 1979), were used.

4.5.3 Correlation Techniques.

The product-moment correlation coefficient (r) is frequently used to measure the degree of correlation between two variables. Its calculation is fully described in Snedecor and Cochran (1967). The correlation is either positive (+r) or negative (-r), and can be tested for significance (Elliott 1977).

Use of this coefficient requires that both variables in the comparison are normally distributed. As this condition cannot be fulfilled by species counts, the data were normalized by transformation into density per square metre prior to calculation. The second variable in all cases was an environmental factor normally distributed.

Correlation shows the direction and significance of trends but is not predictive. Regression analysis, on the other hand, is predictive. Therefore, correlations were conducted first and all the trends tested using regression analysis to allow predictions to be made.

Correlation analysis was done using the SPSS subroutine PARTIAL CORR.

4.5.4 Ordination Analysis.

The main function of ordination analyses is to isolate and identify the primary sources of variation within a matrix of data. In ecological studies, the data matrix usually consists of sampled individuals or sample plots for each of which a number of variables or attributes (e.g., chemical or physical properties or species frequencies) have been measured.

An ordination of the sites and/or individuals is obtained by manipulation of the correlation matrix of variables to reduce the dimensionality of the observed variations to a relatively few major components of variation (which may correspond to environmental gradients) along which the organisms or sites can be ordered and compared (Whittaker 1973; Bissett 1975).

In the present study, ordination of sites and species was done using a percentage similarity coefficient; PS = min (a,b) (Sorenson 1948; Whittaker 1973).

4.5.5 Reciprocal Averaging.

A combination of Whittaker's (1973) gradient analysis and the method of successive approximation leads to a technique of ordination similar to principal components analysis termed Reciprocal Averaging and was described by Hill (1973).

Species are initially ranked from 0-100 to approximate their positions along a specific gradient. Site scores are then produced according to these initial rankings, by averaging the scores of the species which occur at each site. Species scores are then re-calculated from the site scores by averaging the scores of the sites which contain the species. Species scores are re-scaled between 0-100 and this process is continued for many iterations until the site and species scores stabilize.

This process of repeated cross-calibration gives a one-dimensional ordination of both the species and sites. Hill (1973) emphasized that this process does not depend on the initial weighting of species scores.

This technique was applied to each of the seven monthly

data matrices from 1976 sites and was re-used in a different form on the 1977 data from Site 8T. In some cases, species data were omitted from analysis when that species represented less than 10% of the total number or 10% of total biomass. Whittaker (1973) showed that the addition of species of such low values confuses the analysis. A Fortran program (RECIP) computed this test.

4.5.6 Computer Programs.

Two Fortran computer programs were written: One computed the surface areas of the inorganic substrates from samples taken in 1977 as well as the percentage composition of each category of inorganic and organic substrate, the mineral composition of samples, and classified each sample in terms of weight of each type of substrate; the second calculated the percent composition of the species of Trichoptera from the sites sampled in 1976 and the same function was performed on the major benthic invertebrates sampled during 1977, i.e., those which represented more than 10% of the total numbers.

5. RESULTS

5.1 ABIOTIC FACTORS

5.1.1 pH

The pH values recorded at Sites 1, 5, and 8 during the period May-October 1976 (Table 4) show that there is an appreciable increase during the summer months, probably related to increased photosynthesis resulting from the higher temperatures and light intensities. The increase at Site 8 is less apparent than at the other two sites owing to the high value recorded in May.

5.1.2 Specific Conductance.

The values of specific conductance recorded at Sites 1, 5, and 8 from May to October 1976 (Table 5) show a summer increase at all three sites. The 1977 data from Site 1 (Table 6) also shows a summer increase but the very high readings in January and March are noteworthy. The higher specific conductance values appear to reflect periods of reduced discharge (see Section 5.1.3).

5.1.3 Stream Discharge.

Figure 15 illustrates the stream discharge pattern at Site 5 from May to October 1976; similar values were recorded at Sites 1 and 8. It is noteworthy that the curve is inverse to those illustrating aspects of the dissolved content of the water (e.g. specific conductance, hardness, alkalinity).

5.1.4 Turbidity and Light Penetration.

The values for turbidity (in Formazin turbidity units) for Sites 1, 5, and 8 from May to September 1976 (Table 7) and for Site 1 from January to November 1977 (Table 8) show that turbidity falls slightly during periods of reduced discharge. The light intensities measured underwater at Site 8T (Table 9)

Table 4. pH at Sites 1, 5, and 8, May-October 1976.

Month	Sites 1	5	8
May	8.0	7.8	8.8
June	7.8	7.7	7.3
July	8.4	8.2	8.3
Aug.	8.6	8.6	8.6
Sept.	8.1	8.2	8.0
Oct.	7.6	8.0	8.0

Table 5. Specific conductance (umhos.cm^{-1}) at Sites 1, 5, and 8, May-October 1976.

Month	Sites 1	5	8
May	110	110	110
June	160	160	150
July	190	160	160
Aug.	175	170	175
Sept.	110	110	110
Oct.	130	130	130

Table 6. Specific conductance (umhos.cm^{-1}) at Site 1, 1977.

Date	Specific conductance
January 26	600
March 7	660
April 18	105
May 16	179
June 27	208
July 13	196
July 18	320
August 16	230
September 13	214
October 4	214
November 11	210

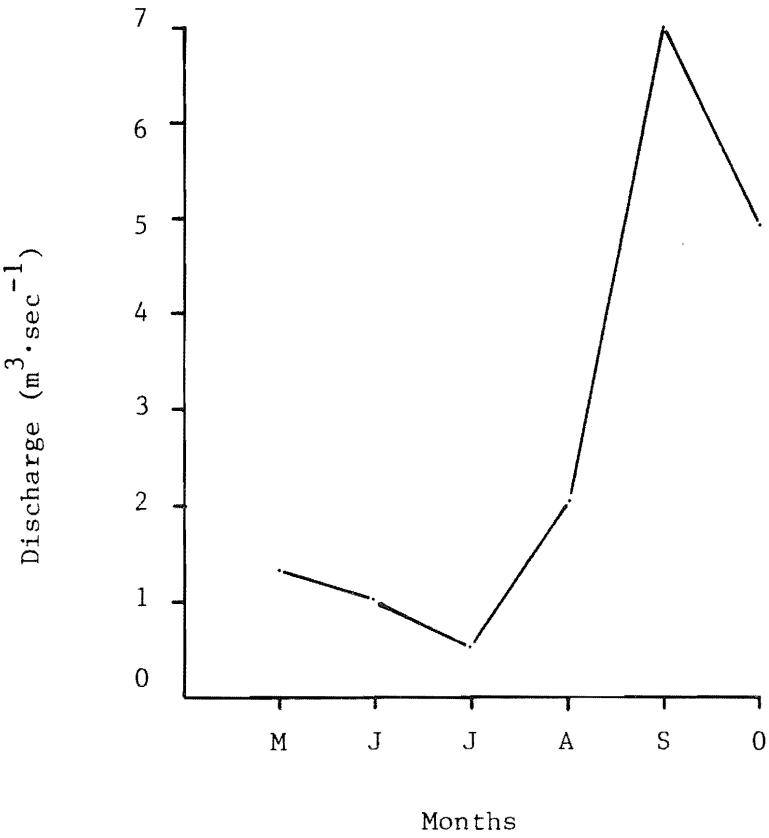


Figure 15. Stream discharge at Site 5, May-October 1976 (September estimated).

Table 7. Turbidity (FTU) at Sites 1, 5, and 8, May-October 1976.

Month	Sites 1	5	8
May	3.1	2.3	0.8
June	1.70	2.20	1.80
July	2.2	1.70	1.90
Aug.	2.0	1.70	1.90
Sept.	3.10	2.30	2.10
Oct.	No readings		

Table 8. Turbidity (FTU) at Site 1, 1977.

Date	Turbidity (FTU)
January 26	No reading
March 7	2.0
April 18	3.9
May 16	2.9
June 27	2.4
July 13	3.5
July 18	3.3
August 16	1.85
September 13	0.9
October 4	2.95
November 11	No reading

Table 9. Light values (microeinsteins.m^{-2}.sec^{-1}) at different depths at Site 8T recorded between June and November 1977.

Depth	Light Readings						
(cm)	June 12	August 27	August 30	September 21	October 27	November 11	Under Ice
0	300	1350	1050	220	300	405	ICE
5	240	950	700	150	255	295	
10	215	810	615	128	225	245	260
15	190	690	550	115	190	230	220
20	158	540	485	100	170	215	195
25	130	480	415	88	145	200	170
30	118	415	360	84	140	190	150
35	95	400	325	76	105	175	135
40	88	350	300	69	102	165	125
45	84	325	270	62	93	150	110
50	82	290	230	57	54	135	105
55	-	270	-	51	32	120	100
60	-	240	-	47	34	-	-
65	-	230	-	42	-	-	-
70	-	190	-	37	-	-	-
75	-	200	-	36	-	-	-
80	-	175	-	32	-	-	-
85	-	155	-	29	-	-	-
90	-	140	-	27	-	-	-
95	-	140	-	25	-	-	-
100	-	130	-	23	-	-	-
105	-	125	-	20	-	-	-

show an inverse relation to turbidity.

5.1.5 Temperature.

Figure 16 shows the mean water temperature for all sites during the period May to November 1976, and Figure 17 shows the maximum and minimum temperatures measured by continuous thermographs at Site 8H from May to November 1976. The maximum-minimum data have been converted to a two-week sample interval in order to smooth out the daily fluctuations. It is still evident however that substantial falls in maximum temperature occur sporadically; these reflect the effect of rain storms. After a gradual increase from May to August the mean temperature falls rather rapidly to reach 1°C in November.

5.1.6 Total Hardness, Total Alkalinity, and Dissolved Chloride.

The values for total hardness (Table 10) and total alkalinity (Table 11) recorded for Sites 1, 5, and 8 from May to October 1976 show inverse relationships to discharge. The values for dissolved chloride (Table 12) do not show this relationship. Sites 5 and 8 show high spring readings followed by low summer and fall values while Site 1 also had some high mid-summer values.

5.1.7 Dissolved Oxygen.

The values of dissolved oxygen recorded at Sites 1, 5, and 8 from May to October 1976 (Table 13) are all high and close to 100% saturation.

5.2 COMMUNITY COMPOSITION

5.2.1 Riffle Communities.

Tables 14 and 15 show the densities (numbers of individuals.m^{-2}) of benthic invertebrates at riffle site 8T in May, July, and August. Chironomidae, Trichoptera, Ephemeroptera and Plecoptera always constitute at least 75% of the total

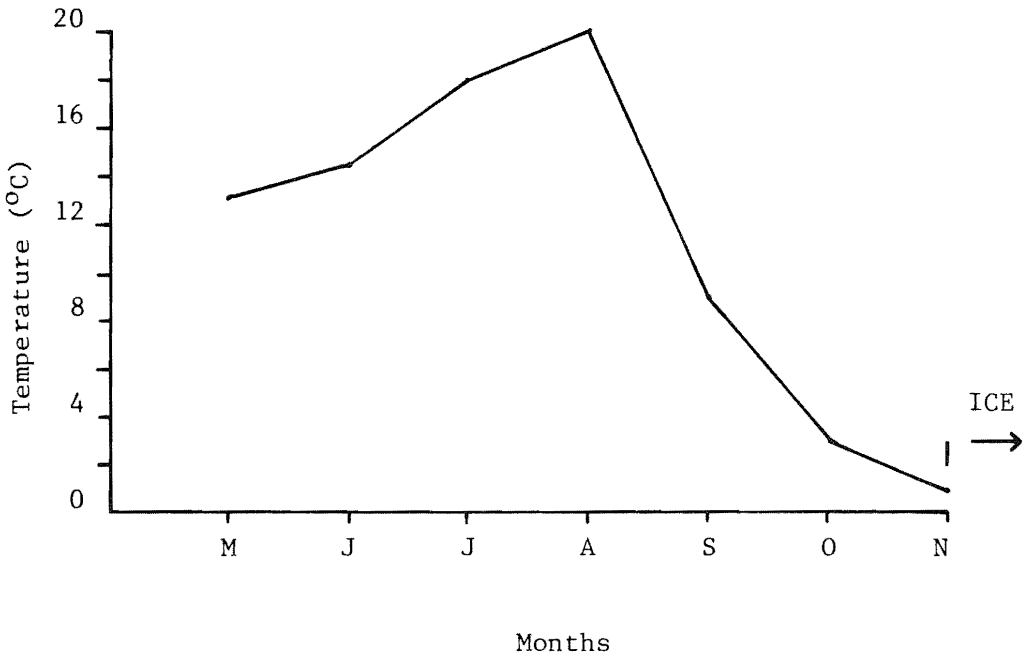


Figure 16. Mean water temperature of all sites, May-November 1976.

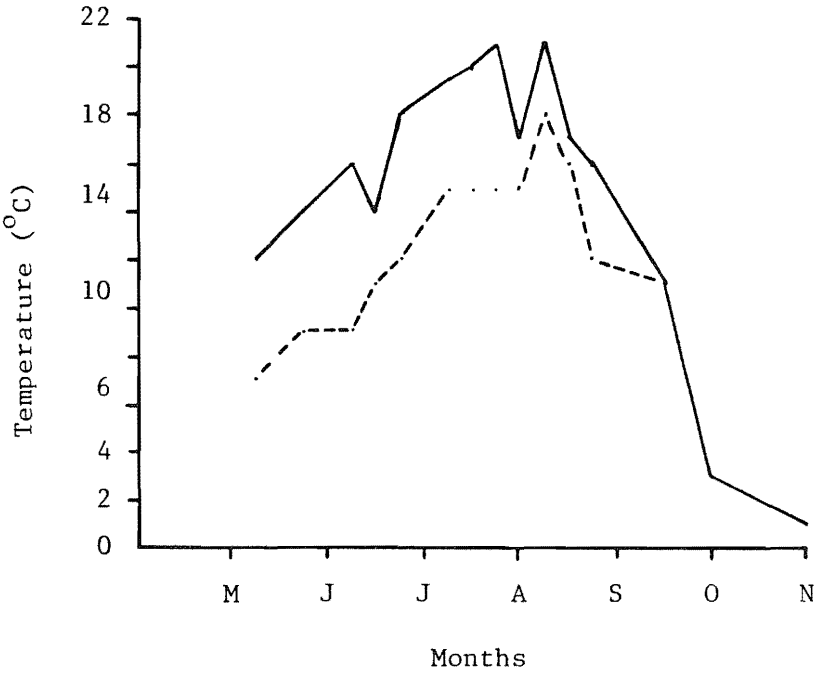


Figure 17. Maximum (——) and minimum (---) temperatures at Site 8H, May-November 1976.

Table 10. Total Hardness (mg.$CaCO_3$) at Sites 1, 5, and 8, May-October 1976.

Month	Sites 1	5	8
May 1976	80	80	80
June	100	100	100
July	130	110	120
Aug.	120	120	120
Sept.	90	90	90
Oct.	105	95	95

Table 11. Total Alkalinity (mg $CaCO_3$) at Sites 1, 5, and 8, May-October 1976.

Month	Sites 1	5	8
May	90	90	90
June	130	130	130
July	145	135	130
Aug.	150	145	150
Sept.	100	100	100
Oct.	105	110	105

Table 12. Chloride ($mg.l^{-1}$) at Sites 1, 5, and 8, May-October 1976.

Month	Sites 1	5	8
May	5.0	5.0	5.0
June	2.5	2.5	2.5
July	5.0	2.5	2.5
Aug.	5.0	2.5	2.5
Sept.	2.5	2.5	2.5
Oct.	2.5	2.5	2.5

Table 13. Dissolved oxygen ($mg.l^{-1}$) at Sites 1, 5, and 8, May-October 1976.

Month	Sites 1	5	8
May	10.0	10.6	9.8
June	10.5	11.4	9.6
July	9.4	9.6	9.5
Aug.	9.8	9.5	9.5
Sept.	10.6	11.0	10.5
Oct.	10.8	11.0	10.2

Table 14. Mean abundances (number.m^{-2}) of five taxa at Site 8T in May and August 1977 on riffle and cobble (pool) substrates.

Taxa	Riffle		Cobble	
	May	August	May	August
Chironomidae	38891	25392	12122	14649
Trichoptera	5843	11297	2144	19795
Ephemeroptera	82	1642	71	735
Plecoptera	68	410	0	28
Others	1819	12619	986	3223

Table 15. Mean abundances (number.m^{-2}) and mean percentage abundances of five taxa at Site 8T in July 1977 on riffle and four real substrate types.

Taxa	Riffle		Boulder		Cobble		Macrophyte		Sand	
	No.	%	No.	%	No.	%	No.	%	No.	%
Chironomidae	54124	74.6	26324	79.3	18594	81.2	34021	79.8	2814	56.7
Trichoptera	5071	7.0	758	2.3	693	3.0	523	1.2	28	0.6
Ephemeroptera	2377	3.3	1278	3.8	537	2.3	2121	5.0	651	13.1
Plecoptera	841	1.2	56	0.2	29	0.1	0	0	0	0
Others	10101	13.9	4796	14.4	3047	13.3	5953	14.0	1471	29.6

numbers, and that the relative numbers are always in the rank order listed.

Since the mean biomass of individual Chironomidae is very small compared to that of the Trichoptera, Ephemeroptera, and Plecoptera a comparison based on numbers alone can be misleading. When the biomasses ($g.m^{-2}$) of the three predominant taxa in riffle samples taken in July 1977 and their percentage contribution to the total biomass of these three taxa (Table 16) are compared to the numerical contributions (Table 15) it can be seen that the Trichoptera and Ephemeroptera are predominant.

5.2.2 Pool Communities.

Tables 14 and 15 show the densities ($numbers.m^{-2}$) of the five major categories of benthic invertebrates at pool sites in May, July, and August 1977. In comparison to riffle sites the densities of Chironomidae and Trichoptera are reduced and Plecoptera are absent. The numbers of Ephemeroptera nymphs are more comparable to those found at riffle sites, doubtless because many Baetidae are pool-dwelling forms.

5.2.3 Boulder, Cobble, Macrophyte, and Sand Communities.

The densities ($numbers.m^{-2}$) of the five major categories of benthic invertebrates and their percentage of abundances (Table 15) at a variety of sites in July 1977, shows that total numbers in all four pool communities are lower than in the riffle substrate. The lowest numbers occurred in the sand substrate where the numbers of Chironomidae are greatly reduced in comparison to the other pool substrates, and the Plecoptera are absent. Plecoptera are also absent from the samples taken from macrophytes. Otherwise the relative proportions of numbers of individuals of the different taxa in the four pool substrates are broadly comparable.

5.3 PLECOPTERA

The mean densities of Plecoptera nymphs at Sites 1, 5,

Table 16. Biomasses ($mg.m^{-2}$) of three predominant taxa in riffle samples taken in July 1977 at Site 8T and their percentage contributions to the total biomass of these taxa.

Taxa	Biomass ($mg.m^{-2}$)	% Contribution
Trichoptera	605.2	59
Ephemeroptera	380.2	36
Plecoptera	42.9	4

8H, and 8T for the period May-November 1976 are shown in Table 17. In contrast to the data for the Ephemeroptera there is here little sign of a summer decline in numbers of nymphs. This is because the most abundant stonefly nymphs in the stream are the nemourid genera *Prostoia* and *Zapada*, both of which are univoltine (i.e., one brood per year). Emergence occurs in April and May thus giving rise to new generations of nymphs in May and June. In addition there are several species present in the stream (*Claassenia sabulosa, Pteronarcys* sp., and *Isoperla* spp.) which are probably semivoltine (one brood in two or three years) and thus always have at least two generations of nymphs present at any one time.

Table 18 shows the densities in terms of numbers (numbers.m^{-2}) and of biomass (mg.m^{-2}) of the five families of Plecoptera found in riffles and pools with a boulder substrate in July 1977. In terms of numbers at the riffle sites, Nemouridae nymphs are slightly more abundant than those of Perlidae, with nymphs of Perlodidae somewhat less abundant. However, since Nemouridae are small compared to nymphs of the other two families, and since the Perlodidae are, in July, larger on average than the Perlidae, the rank order in terms of biomass is: Perlodidae, Perlidae, followed by Nemouridae. The other two families contribute less than 5% to total numbers and less than 1% in total biomass, nymphs of Taeniopterygidae and Chloroperlidae both being small at this time of year.

The data for the boulder (pool) samples are not very informative since the sample was small. It is however not surprising that Chloroperlidae are absent since these nymphs characteristically inhabit small rock and gravel substrates. Nymphs of Nemouridae are often found in abundance amongst detritus which may be absent from the boulder type of substrate.

Table 19 shows the mean headwidths of *Zapada* spp., *Prostoia* spp., and *Taeniopteryx* sp. during the period June-October. It is noteworthy that the maximum increase in size of all these univoltine herbivores occurs in the late summer - early fall

Table 17. Mean densities of Plecoptera nymphs in 1976 (numbers.m^{-2} of streambed).

Month	Sites 1	5	8H	8T
May	No sample	No sample	97	No sample
June	574	135	86	No sample
July	624	226	145	414
August	194	350	355	257
Sept.	No sample	193	552	223
Oct.	150	112	407	324
Nov.	205	172	523	No sample

Table 18. Densities of plecopteran families at Site 8T in July 1977 on two substrate types, expressed in terms of abundance (numbers.m^{-2}) and in terms of biomass (mg.m^{-2}).

Family	Riffle		Boulder	
	No.	Biomass	No.	Biomass
Nemouridae	332	9.33	0	0
Taeniopterygidae	7	0.35	0	0
Perlodidae	158	21.95	45	4.07
Chloroperlidae	28	0.212	0	0
Perlidae	290	11.10	11	1.61

Table 19. Mean headwidths (mm) of nymphs of *Prostoia*, *Zapada*, and *Taeniopteryx* spp. taken in Hartley Creek during the period June-September 1976.

Month	*Prostoia*	*Zapada*	*Taeniopteryx*
June	0.469	0.231	0.296
July	0.568	0.344	-
August	0.539	0.470	-
September	0.699	0.617	0.672
October	0.908	-	0.984
November	0.988	-	1.265

period when allochthonous input is greatest.

5.3.1 Life-Histories

5.3.1.1 *Zapada* species (Figure 18). No adults have yet been obtained from these nymphs although rearing has been attempted. The *Zapada* spp. in Hartley Creek are unlikely to be *Z. cinctipes*, the gills of which are sometimes five-branched, but may be any of five other species. Western Canadian species of *Zapada* have all been recorded as univoltine and to possess slow seasonal life-cycles (Hartland-Rowe 1964; Radford & Hartland-Rowe 1971; Cather & Gaufin 1976) with the adults appearing in spring (February-June in Utah, April-May in southern Alberta).

The pooled data from Hartley Creek suggests that this is the case here with the small nymphs in the June samples being young-of-the-year. Adult Nemouridae were observed in abundance at Site 5 in May 1976 but unfortunately none were *Zapada* species.

5.3.1.2 *Prostoia* species (Figure 19). A sample with low numbers of adult *Prostoia* was collected at Site 5 in May but all the specimens belonged to a single undescribed species. It is possible that all the *Prostoia* nymphs belong to this undescribed species but it is also possible that some nymphs belong to *P. besametsa* which commonly occurs in southern Alberta.

In eastern Canada, *Prostoia completa* (close to *P. besametsa*) has been shown to possess a long embryonic diapause with the eggs laid in May not hatching until November (Coleman & Hynes 1969; Harper 1973).

The data from Hartley Creek are incompatible with this type of life-cycle as nymphs are present from June through to October. The data presently available are most compatible with a univoltine slow seasonal cycle with adult emergence in the early spring. There are some problems with this interpretation, since the mean size of nymphs in June would imply exceedingly rapid growth during the first month, and the single very large nymph

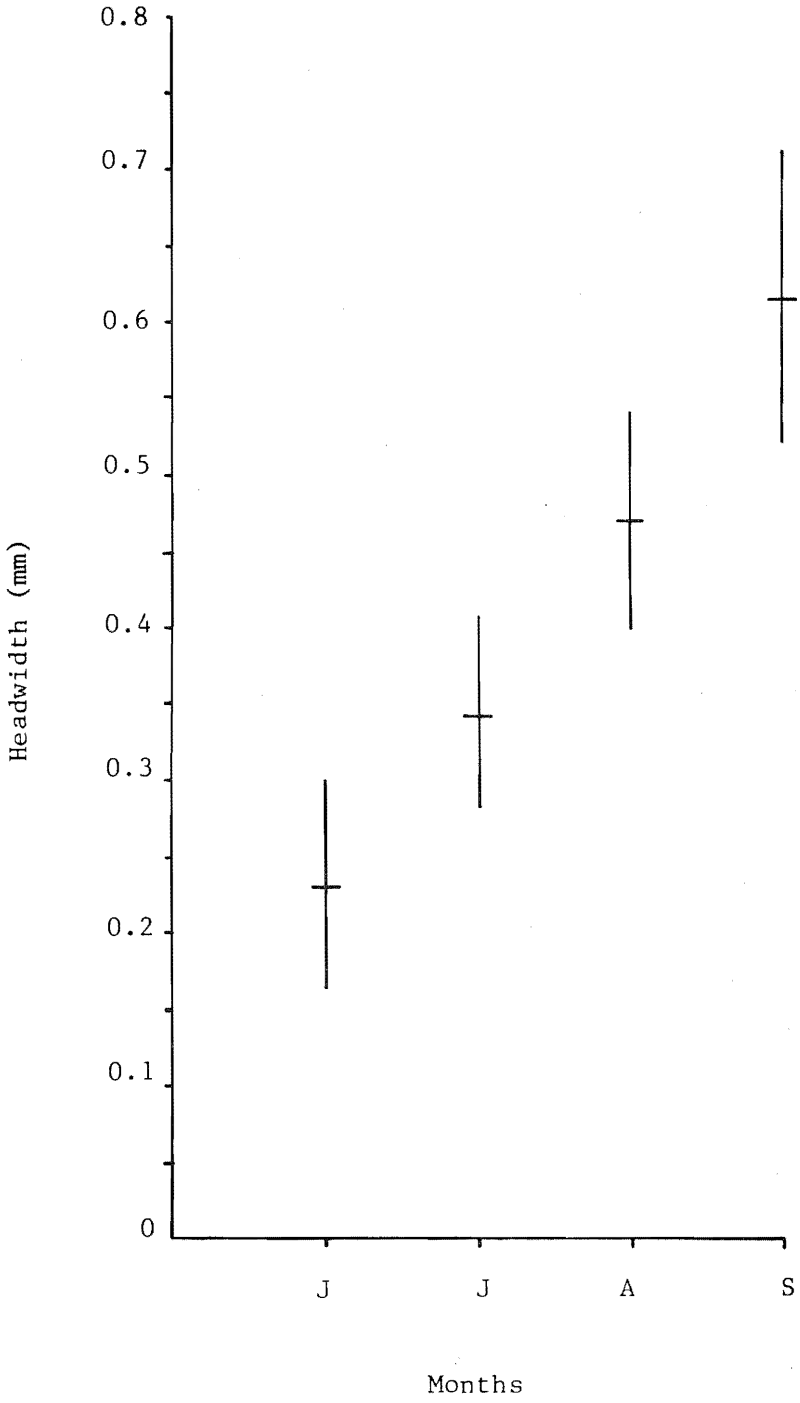


Figure 18. Mean headwiths (mm) with 95% confidence limits of *Zapada* nymphs, June-September 1976.

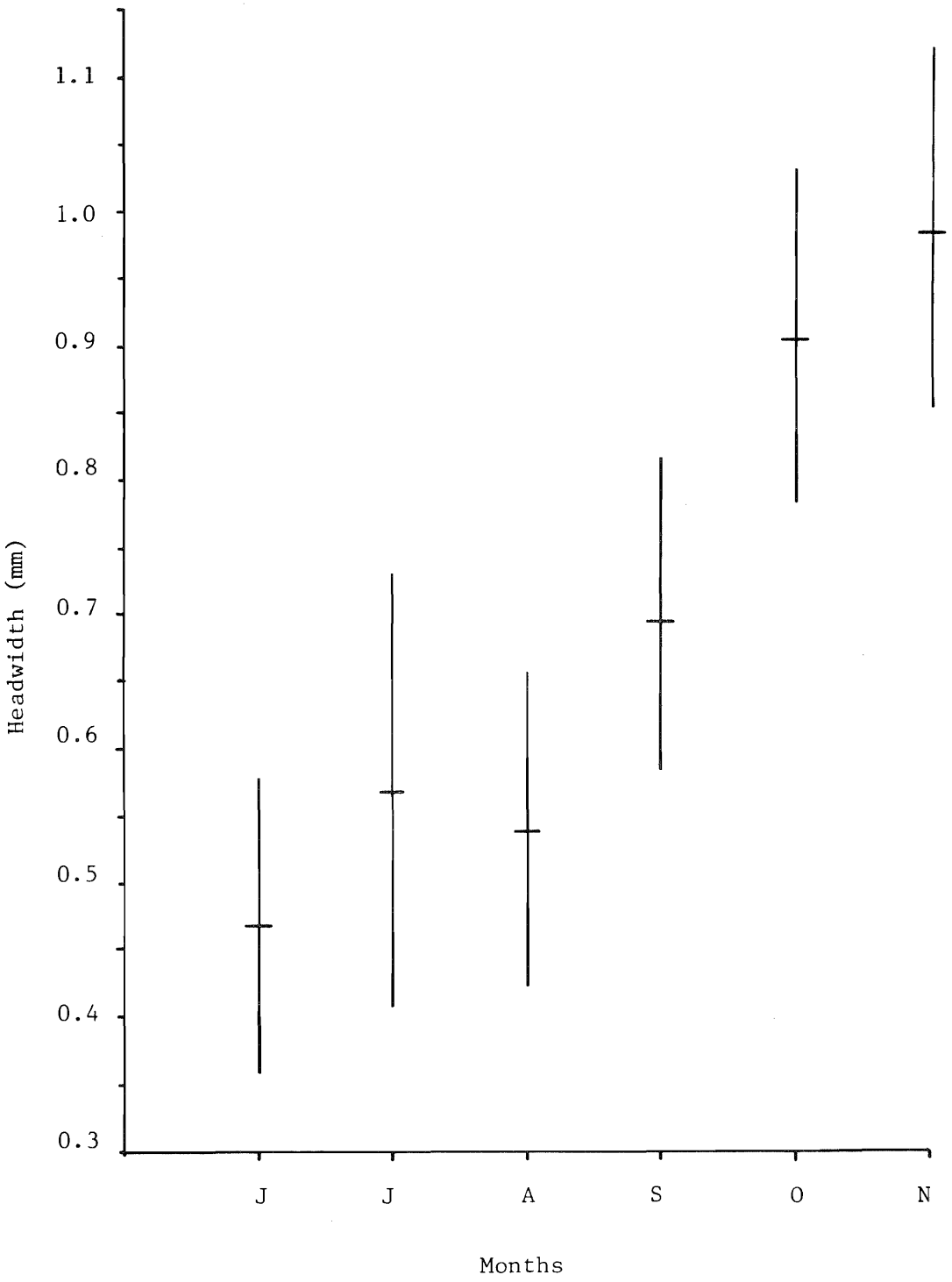


Figure 19. Mean headwidths (mm) with 95% confidence limits of *Prostoia* nymphs, June-September 1976.

present in July is unlikely to have attained its size in two months. Thus it is assumed that there are at least two species present displaying some temporal separation.

5.3.1.3 *Pteronarcys* species. While adults have been obtained of two species of *Pteronarcella*, no nymphs of this genus have been found. The Pteronarcid nymphs collected have been tentatively identified as *Pteronarcys dorsata* but might in the absence of conclusive taxonomic keys be *P. californica*. The latter species is stated to possess a three-year life cycle in Montana (Gaufin et al. 1972) and a three-year or a four-year cycle has been suggested by Barton & Wallace (1978) from their studies on the Muskeg, Steepbank, and other rivers in the AOSERP study area. It is clear from a comparison of the June and August samples that there must be at least two cohorts present.

5.3.1.4 *Claassenia sabuloa* (Figure 20). The life-cycle of *Claassenia sabulosa* is difficult to interpret from the limited occurrence of nymphs in samples, particularly since the samples for September, October, and November 1977 are small.

It is clear that the species takes more than one year to develop, since the size distributions of headwidths are very wide, particularly in June and July (Table 20). The headwidths were measured to the nearest 0.05 mm but it was found that the frequency distributions were more easily interpreted if they were grouped into 0.5 mm size classes. On this basis the suggestion of Barton & Wallace (in press) that the life-cycle may last three years is supported.

The horizontal lines marked in Table 20 indicate the proposed boundaries between cohorts and from the frequency distributions of the individuals within these boundaries, mean headwidths have been calculated and plotted on Figure 20 which shows the growth curves of these putative cohorts and the years in which the cohorts would be expected to mature.

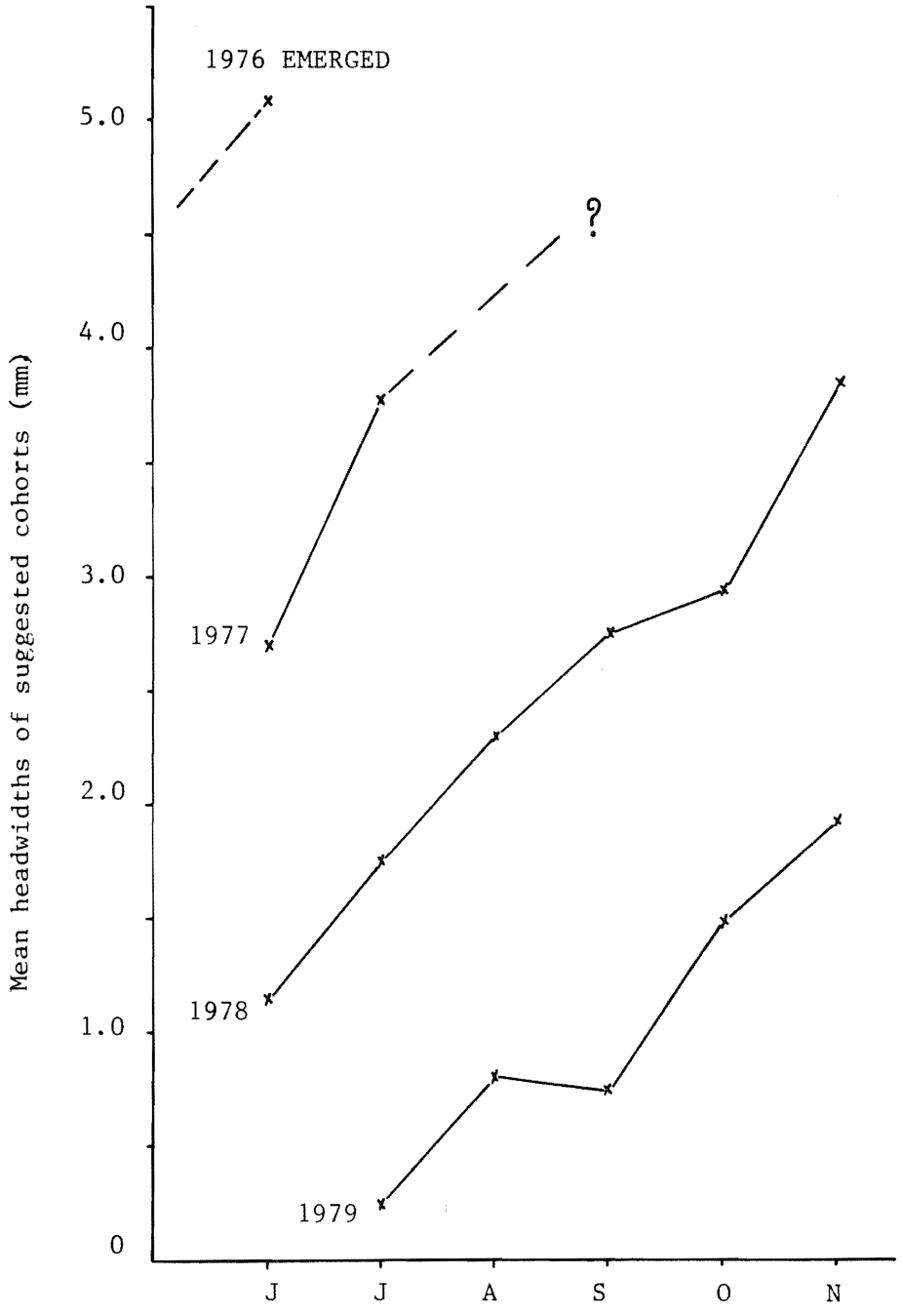


Figure 20. Estimated growth curves of *Claassenia sabulosa* in Hartley Creek. Dates denote expected year of emergence.

Table 20. Growth of maximum headwidths (mm) of nymphs of *Claassenia sabulosa* from all sites sampled June-November 1976. The horizontal lines indicate the boundaries between cohorts.

Headwidth: mean of class interval (mm)	Frequency of individual nymphs						
	May	June	July	August	September	October	November
0.25			2	1			
0.75	1	15	3	11	1		2
1.25	1	24	14	3		1	2
1.75		5	36	21	1	1	15
2.25		5	17	14	2	6	10
2.75		6	2	6	4	9	4
3.25		2	7	4	1	3	1
3.75		1	5	3		1	4
4.25		1	4	1	1	3	3
4.75			2				
5.25		1				1	
5.75		1				1	
Totals:	2	61	92	64	10	26	41

5.3.1.5 *Taeniopteryx* species. Mature larvae of *Taeniopteryx* species have been found in October and November samples but no larvae of this genus were recorded in July and August.

In eastern Canada, the larvae of *Taeniopteryx* undergo a summer diapause but the apparently substantial growth between June and September (Table 19) suggests this is unlikely in Hartley Creek. The mature condition of the October and November larvae suggests that adult emergence takes place very early in the spring.

5.4 EPHEMEROPTERA

Table 21 shows the mean densities of Ephemeroptera (mayfly) nymphs at Sites 1, 5, 8H, and 8T for the period June-October 1976. More than 98% of the mayfly nymph population at all times consisted of members of three families; Baetidae, Ephemerellidae, and Heptageniidae; the remainder were members of the families Caenidae, Leptophlebiidae, and Ephemeridae.

While the mean population densities fluctuate considerably there is an appreciable decrease evident in September and to a lesser extent in August; the one high density recorded in August resulted from a very large number of baetid nymphs taken at Site 8H. The late summer drop in the population density of the nymphs reflects the emergence periods of at least the majority of the species present. Adults are on the wing during July-September and consequently at this time mature nymphs of the univoltine species are absent, and the newly hatched nymphs are still too small to be sampled. The rise in October reflects the appearance of these nymphs in the samples.

An examination of the proportional abundance of the three major families is more revealing (Table 22). With the sole exception of Site 1 in June 1976 the family Baetidae is consistently the most abundant family present and constitutes 50-80% of the total Ephemeroptera nymph density. Of the Baetidae, 80-90% are three-tailed *Baetis* sp. nymphs, the remainder being almost exclusively two-tailed *Baetis* sp. nymphs. The almost continuous prevalence of Baetidae reflects the fact that these are multivoltine

Table 21. Mean densities of Ephemeroptera nymphs in 1976 (numbers.m^{-2} of streambed).

Month	Sites 1	5	8H	8T
June	222	1036	846	No sample
July	459	326	789	1136
August	416	384	1502	423
September	No sample	401	401	466
October	563	742	1237	509

Table 22. Densities of ephemeropteran families at Site 8T in July 1977 on five substrate types, expressed in terms of abundance (numbers.m^{-2}) and in terms of biomass (mg.m^{-2}).

Family	Riffle		Boulders		Macrophyte		Cobble		Sand	
	Nos.	Biomass	Nos.	Biomass	Nos.	Biomass	Nos.	Biomass	Nos.	Biomass
Baetidae	1032	118.08	226	47.51	1697	47.37	37	35.82	495	73.39
Caenidae	28	8.91	3	2.38	283	79.89	2	3.58	85	46.52
Heptageniidae	302	35.63	8	51.47	0	0	1	0.57	14	1.41
Ephemerellidae	123	217.62	11	21.49	1	9.90	7	105.60	14	0.85
Leptophlebiidae	0	0	0	0	9	13.86	0	0	28	1.41
Ephemeridae	0	0	3	41.85	0	0	0	0	0	0

species with several overlapping generations and thus there is no period during which the nymphal population is totally depleted through the emergence of adults.

The second most frequent family represented is the family Ephemerellidae, represented by at least six species. The proportional abundance of this family falls sharply in July and remains low until September (Table 22) reflecting the fact the emergence periods of *Ephemerella* species are in July and August.

The third abundant family, Heptageniidae, displays considerable fluctuations between months and between sites, although there do not appear to be more than two abundant species present, *Stenonema vicarium* and *Heptagenia* sp.

Table 22 shows the densities in terms of numbers (numbers.m^{-2}) and of biomass (mg.m^{-2}) of the six families of Ephemeroptera found on substrates of five types, riffle, boulder, macrophyte, cobble, and sand, at Site 8T in July 1977. On all five substrates Baetidae predominate in terms of numbers, though not necessarily in terms of biomass since these are small mayflies. Present in substantially lower numbers, Ephemerellidae predominate in terms of biomass on riffle and cobble substrates. It is clear from the data that Ephemerellidae present in the sand samples were very small and the low numbers in the boulder samples probably reflects the fact that only *Ephemerella doddsi* is well adapted for resting on rocks in strong currents, the nymph having a ventral adhesive sucker.

The nymphs of Caenidae are crawling forms incapable of strong swimming or withstanding strong currents, and thus their predominance in the macrophyte sample is therefore not unexpected. Heptageniidae nymphs, on the other hand, are flattened forms adapted for dwelling on rock surfaces washed by water currents; they would not be expected to occur in macrophyte samples. It is surprising that more were not found in the cobble samples. Leptophlebiidae nymphs generally inhabit regions of low current velocity and were thus found only in the sand and macrophyte samples, while the many nymphs of Ephemeridae are burrowing forms which

can only exist where there is fine particulate matter, mud or silt, available for occupation. Their presence in the boulder samples indicates that there was such material available in the interstices.

5.5 TRICHOPTERA

Table 23 shows the mean densities of Trichoptera (caddis) larvae at Sites 1, 5, 8H, and 8T between June and November 1976. It can be seen that in general the abundance is lowest at Site 1, moderate at Site 5, and highest at Site 8H.

The temporal distribution of abundance shows two periods of high abundance. The first of these, seen in the data for Sites 1, 8T and 8H, probably reflects the appearance of young of the year in July and August. The second peak, seen in the data for Sites 5 and 8H, is more difficult to explain but may reflect either movements of larvae from one type of substrate to another or to regions of high detrital standing crop.

The mean percentage contributions of nine families to the total density of trichopteran larvae on five substrate types at Site 8T in July 1977 are shown in Table 24. The boulder, cobble, macrophyte, and sand substrates were all located in the pool area and thus had lower rates of water flow.

It will be observed that the number of families present is highest in the riffle substrate, probably reflecting the heterogeneity of habitats available in this substrate. Of the remaining four pool substrate types, the boulder substrate is diverse, providing not only rocks for the attachment of lithophilic forms but also fine detritus between the boulders. This may account for the rather high number of families observed on this substrate. Although the macrophyte substrate is not highly diverse, it does offer a very large surface area available for colonization and it appears that the standing biomass in July is highest on this type of substrate. The cobble substrate does not appear to be a suitable habitat for many Trichoptera larvae, the vast majority of those present being *Micrasema* sp. The lowest

Table 23. Mean densities of Trichoptera larvae in 1976 (numbers.m^2 of streambed).

Month	Sites 1	5	8T	8H
June	495	957	no sample	1608
July	1226	1993	3452	2204
Aug.	806	1979	4588	7910
Sept.	flood	2348	2940	4352
Oct.	367	3413	2847	6283
Nov.	781	4006	no sample	3278

Table 24. Mean percentage contributions to total trichopteran density of nine families of Trichoptera on five substrate types at Site 8T in July 1977.

Family	Riffle	Boulder	Cobble	Macrophyte	Sand
Hydropsychidae	36.65	7.1	0.6	0	0
Brachycentridae	26.68	4.9	96.8	24.1	0
Glossosomatidae	17.21	0 0	0.9	0	0
Hydroptilidae	2.0	14.7	0.3	11.8	88.3
Leptoceridae	2.4	25.8	0.4	0	0
Lepidostomatidae	1.0	36.0	0.9	6.2	0
Psychomyidae	0.6	12.0	0	0	0
Polycentropidae	0.5	0	0	0	0
Philopotamidae	12.9	0	0	0	0
Limnophilidae	0	0	0	57.9	11.7

number of families is observed on the sand substrate, a very uniform habitat.

An examination of the distribution of trichopteran families among substrate types is revealing. The larvae of Hydropsychidae are filter-feeders which employ nets. Their requirement for relatively high current flows to keep the nets expanded is manifested in their abundance on riffle substrates and their scarcity on other substrate types. The distribution pattern of brachycentrid larvae is somewhat obscured by the fact that the predominant species differ between substrate types. On the macrophyte substrate the family is represented solely by *Brachycentrus occidentalis*. *B. americanus*, by contrast, occurs only in habitats where moss is available as a substrate. On cobble substrates the only brachycentrid present is a species of *Micrasema*.

Similar differences between the habitat preferences of individual species may also account for the patchy occurrence of Hydroptilidae. On the macrophyte substrate they occur almost exclusively attached to *Potamogeton*. The high proportional abundances of Leptoceridae and Lepidostomatidae on the boulder substrate is probably a reflection of the high availability of bacteria and of suitable coarse gravel for case-building, since larvae of both families are fine filter-feeders which consume bacteria. The sand substrate is predominantly occupied by the very small larvae of Hydroptilidae together with a moderate number of Limnephilidae. These sand areas also, however, appear to act as deposition areas or emergence sites since many empty larval cases of diverse families are found on this substrate.

Life-history studies in preparation reveal that most, perhaps all, species of Trichoptera in Hartley Creek are univoltine with a summer emergence period.

5.6 MICRODISTRIBUTION OF TRICHOPTERAN LARVAE ON ROCKS AT SITES 5(a), 5(b), and 5(c).

Of approximately sixty taxa of Trichoptera identified

from Hartley Creek, eighteen were found living on rocks in September and October 1977 at Sites 5(a), 5(b), and 5(c). A list of these taxa is included as Table 25. By far the most abundant family was the Hydropsychidae represented by seven species of Hydropsychinae (*Hydropsyche simulans, H. betteni, H. recurvata, H. slossonae, H. bifida* group, and two species of *Cheumatopsyche*) and a single Arctopsychinae species, *Arctopsyche ladogensis*. Glossosomatidae were abundant and included *Glossosoma* sp. and more rarely *Anagapetus* sp. Pupae of *Glossosoma* were common. Two species of Brachycentridae occurred, *Brachycentrus occidentalis* and *B. americanus*, the latter being very common on the moss-covered rocks at Site 5(a). The family Lepidostomatidae was represented by two unidentified species of *Lepidostoma*, *Lepidostoma* sp. 1 occurring with *Brachycentrus americanus* on the moss-covered rocks at Site 5(a).

5.6.1 Trichopteran Larval Density in Relation to Rock Size and Moss Cover.

5.6.1.1 Site 5(a), September 1977. The rocks sampled at Site 5(a) in September 1977 were covered with moss (*Hydroamblystegium*) and the results shown in Figure 21 indicate very clearly that the presence of moss had a substantial effect on the densities and the dominance structure of the trichopteran larvae found. This community was numerically dominated by *Lepidostoma* sp. 1 and *Brachycentrus americanus* which had densities of 505 and 470 individuals per square metre of rock surface respectively. Other taxa with densities greater than $100.m^{-2}$ included *Cheumatopsyche* sp. 1, *Glossosoma* sp., *Psychomyia flavida*, *Micrasema* sp. 1, and *Ceraclea annulicornis*. All of these taxa except *Glossosoma* were much rarer at Sites 5(b) and 5(c), and *Hydropsyche betteni* and *H. simulans*, which were co-dominant with *Glossosoma* sp. at Sites 5(b) and 5(c) were rare at Site 5(a).

Table 25. Species of Trichoptera found on rocks at Site 5 in September and October 1977.

Hydropsyche simulans
Hydropsyche betteni
Hydropsyche recurvata
Hydropsyche bifida grp.
Hydropsyche slossonae
Brachycentrus americanus
Brachycentrus occidentalis
Cheumatopsyche sp. 1
Cheumatopsyche sp. 2
Arctopsyche ladogensis
Glossosoma spp.
Psychomyia flavida
Lepidostoma sp. 1
Lepidostoma sp. 2
Micrasema sp. 1
Micrasema sp. 2
Ceraclea annulicornis
Protoptila sp.
Anagapetus sp.
Stactobiella sp.

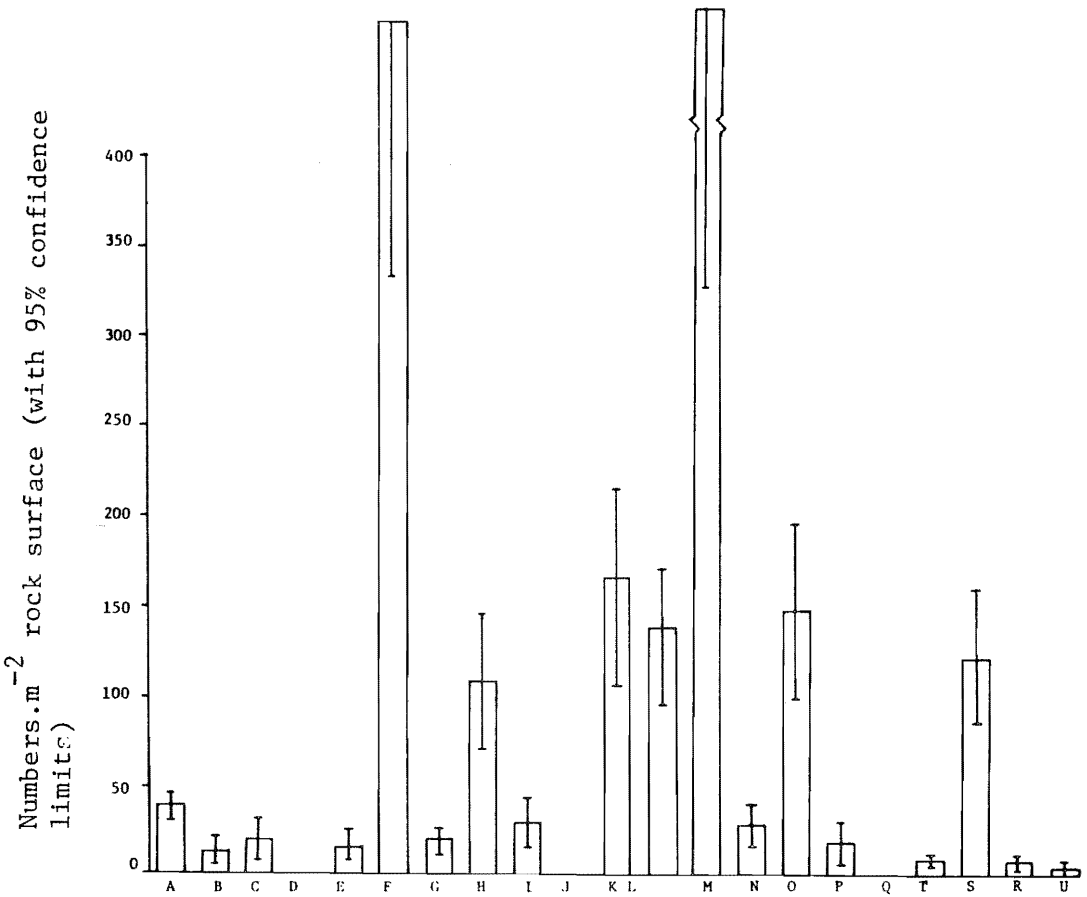


Figure 21. Abundance of Trichoptera larvae at Site 5(a), September 1977. Species code on page 78.

Coded list of species of Trichoptera cited in Figures 21-28.

A: *Hydropsyche simulans*
B: *H. betteni*
C: *H. recurvata*
D: *H. bifida* grp.
E: *H. slossonae*
F: *Brachycentrus americanus*
G: *B. occidentalis*
H: *Cheumatopsyche* sp. 1
I: *Cheumatopsyche* sp. 2
J: *Arctopsyche ladogensis*
K: *Glossosoma velona*
L: *Potamyia flava*
M: *Lepidostoma* sp. 1
N: *Lepidostoma* sp. 2
O: *Micrasema* sp. 1
P: *Micrasema* sp. 2
Q: *Ceraclea* sp.
R: *Protoptila* sp.
S: *Ceraclea annulicornis*
T: *Anagapetus* sp.
U: *Stactobiella* sp.

5.6.1.2 Site 5(b), October 1977. Figures 22, 23, and 24 show the abundances (numbers.m^{-2} rock surface) of trichopteran larvae on rocks of three size classes (0-100 cm^2; 100-200 cm^2; greater than 200 cm^2) in October 1977.

The densities of the three numerically dominant species varied significantly ($p < 0.05$) between rock size classes. On the smallest rocks (0-100 cm^2) *H. betteni* had a density of 274 larvae per m^2 of rock surface, *Glossosoma* had 171 larvae per m^2, and *H. simulans* had 124 larvae per m^2. The densities of the other species ranged from 4-23 larvae per m^2 of rock surface.

On rocks of intermediate size (100-200 cm^2) the densities of both species of *Hydropsyche* were somewhat lower though *Glossosoma* was equally abundant on small and intermediate sized rocks.

On large rocks (200 cm^2) all three species were more abundant with densities of 468.m^{-2} for *Glossosoma*, 353.m^{-2} for *H. betteni*, and 185.m^{-2} for *H. simulans*. Other taxa were rarer, though more taxa occurred on large rocks than on small or intermediate sized rocks.

5.6.1.3 Site 5(c), October 1977. Figures 25, 26, and 27 show the abundances of trichopteran larvae on rocks of three size classes at Site 5(c) in October 1977.

The three numerically dominant species are the same as at Site 5(b). In general the densities of the two species of *Hydropsyche* increase with increasing rock size, while the density of *Glossosoma* sp. remains fairly constant at about 200 individuals.m^{-2} on all rock sizes. In contrast to Site 5(b), *Hydropsyche simulans* was more abundant than *H. betteni* on large rocks, and *Lepidostoma* sp. 1 was also abundant on large rocks.

5.6.2 Trichopteran Larval Densities per Unit Area of Stream Bed.

The data presented in the previous section may be used to estimate the densities of trichopteran larvae per unit area of

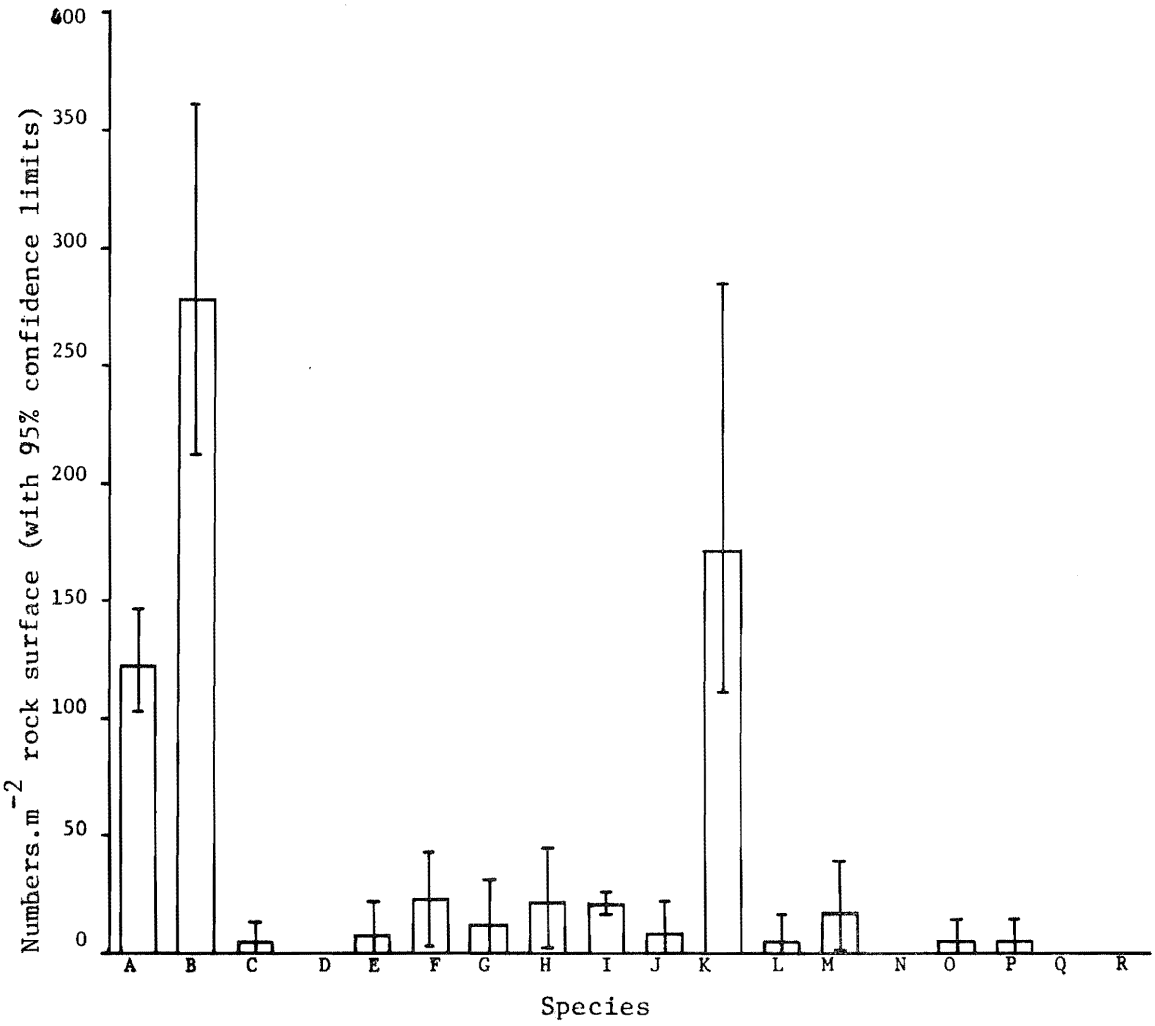


Figure 22. Abundance of Trichoptera larvae at Site 5(b) on rocks 0-100 cm^2, October 1977. Species code on page 78.

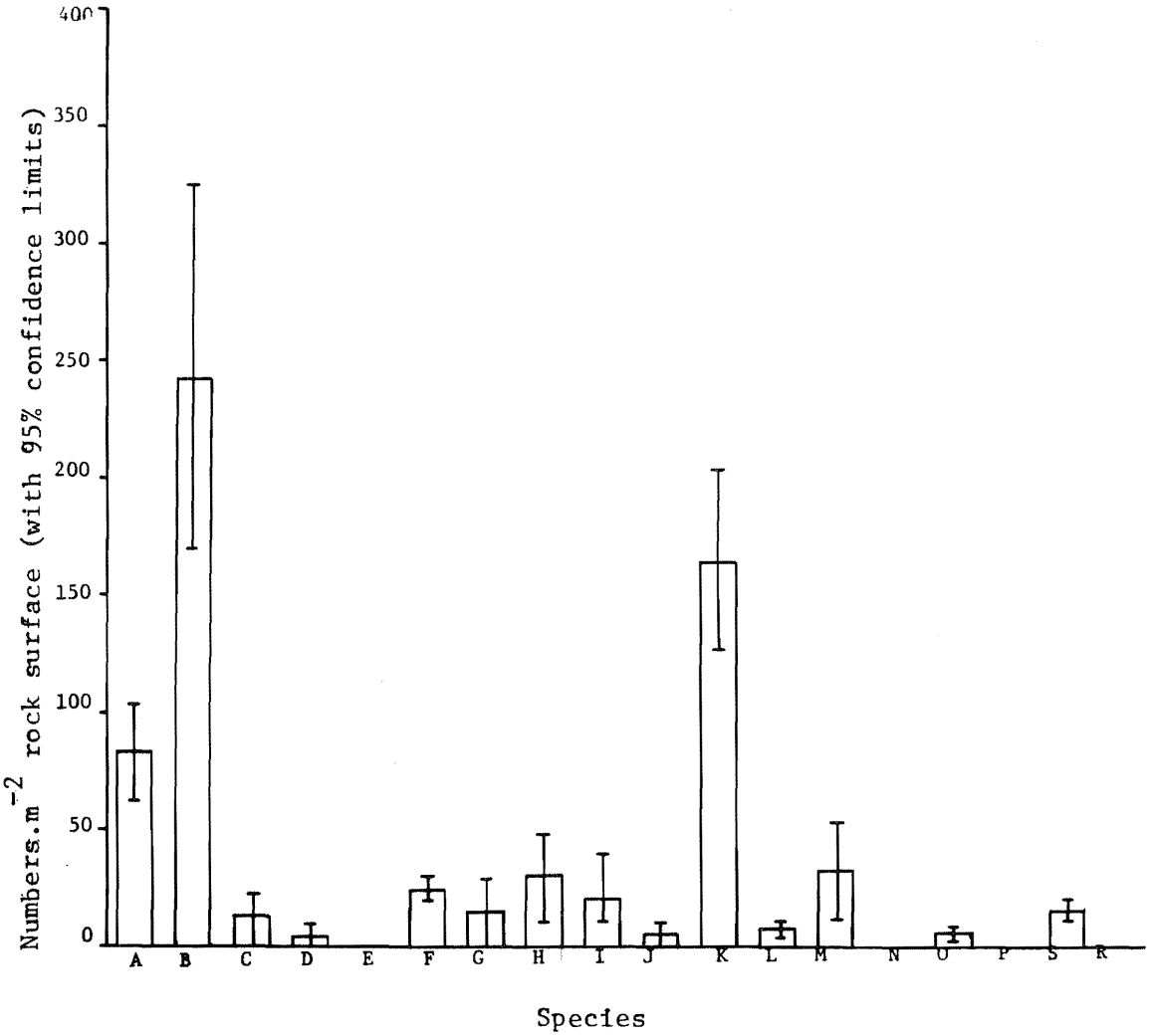


Figure 23. Abundance of Trichoptera larvae at Site 5(b) on rocks 100-200 cm^2, October 1977. Species code on page 78.

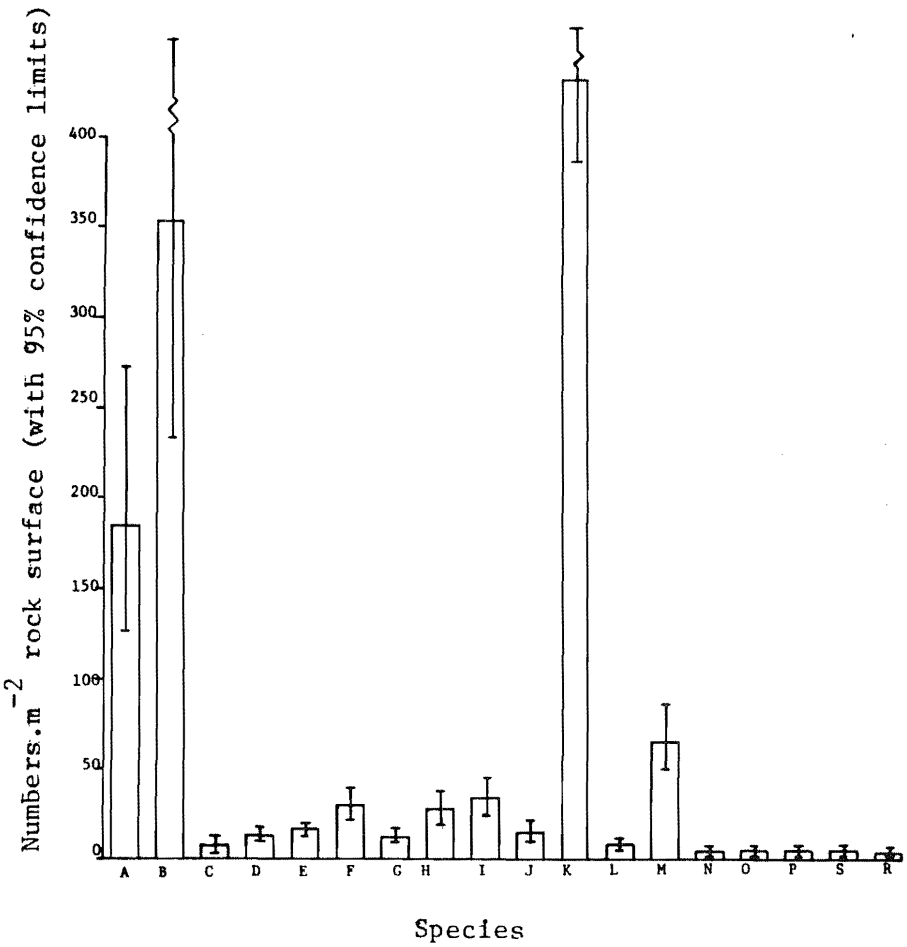


Figure 24. Abundance of Trichoptera larvae at Site 5(b) on rocks >200 cm^2, October 1977. Species code on page 78.

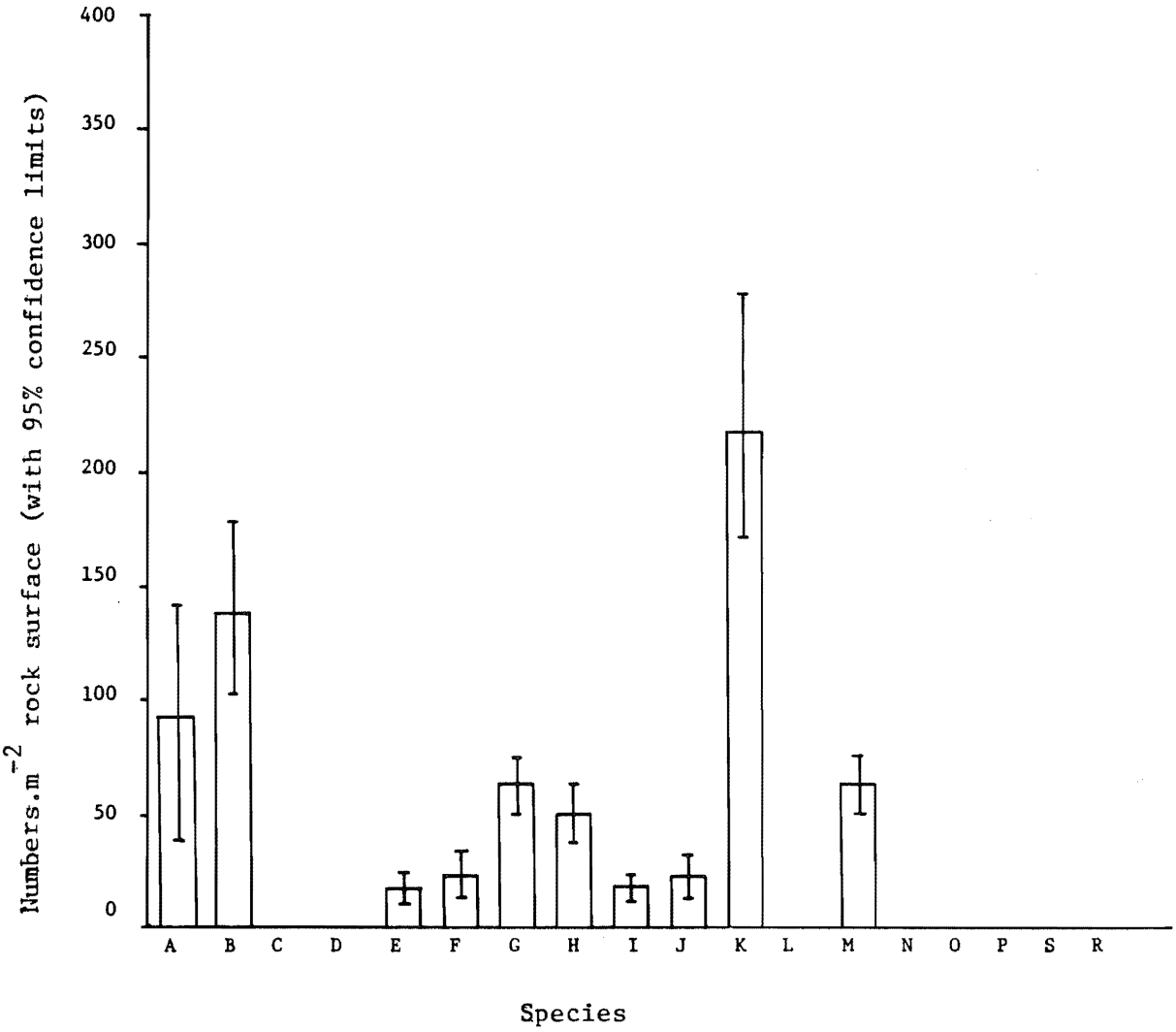


Figure 25. Abundance of Trichoptera larvae at Site 5(c) on rocks 0-001 cm^2, October 1977. Species code on page 78.

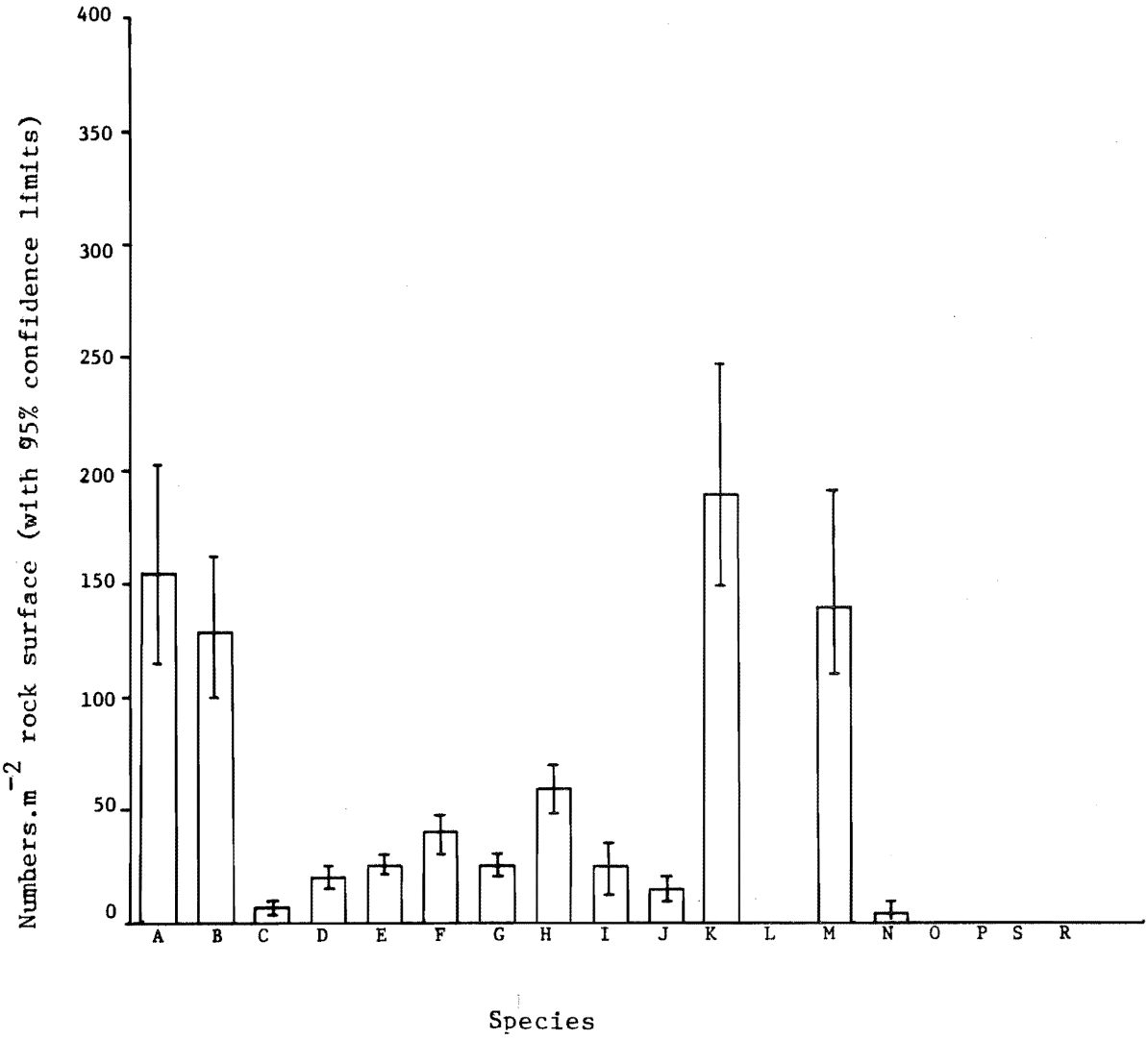


Figure 26. Abundance of Trichoptera larvae at Site 5(c) on rocks 100-200 cm^2, October 1977. Species code on page 78.

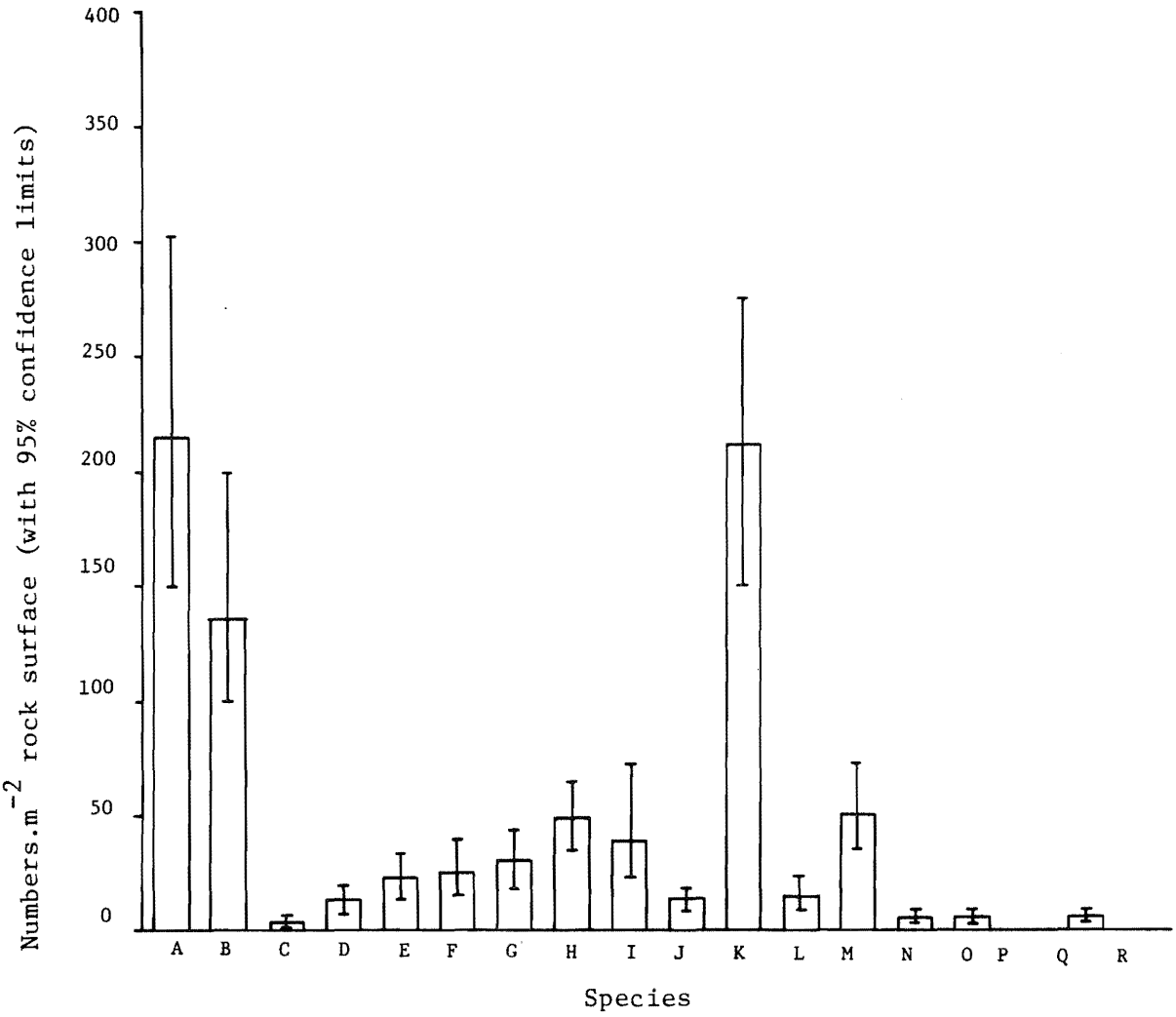


Figure 27. Abundance of Trichoptera larvae at Site 5(c) on rocks >200 cm^2, October 1977. Species code on page 78.

streambed, given the mean numbers of rocks of different size classes per unit area. These data are shown in Table 26.

Figure 28 shows the mean densities (individuals.m^{-2} streambed) of trichopteran larvae at Site 5(b). *Glossosoma* sp. was the most abundant, with a mean density of 1787.m^{-2} stream bed. High densities of *H. betteni* (1477.m^{-2}) and *H. simulans* (721.m^{-2}) were also found. Four other taxa (*B. americanus*, *Cheumatopsyche* sp. 1, *C.* sp. 2, and *Lepidostoma* sp. 1) had densities greater than 100.m^{-2}, while the remaining eleven taxa had low densities.

Figure 28 shows that there were differences in the densities of the dominant taxa at Sites 5(b) and 5(c) with Site 5(b) having nearly three times the numbers of individuals.m^{2} as Site 5(c). This difference is attributable to the fact that the larger rocks, on which the dominant species were most abundant, were significantly less abundant at Site 5(c). This observation stresses the importance of taking rock size into consideration when determining densities per unit area of stream bed.

5.6.3 The Relationship Between Rock Size and the Number of Trichopteran Taxa.

The number of taxa per rock at Site 5(b) in October 1977 was variable, ranging between 0 and 12 (Figure 29). A total of eighteen taxa were found at this site, hence no single rock closely approached the total taxonomic complement.

The distribution of the number of taxa per rock at Site 5(b) is skewed, with peaks at two and four taxa per rock and a mean of 4.92 taxa per rock (Table 27). Analysis of variance revealed that the mean number of taxa per rock differed significantly between rock size classes ($P < 0.001$) with large rocks having more taxa per rock (Table 27 and Figures 29 and 30). On the smallest rocks (0-100 cm^{2}) the number of taxa per rock varied between 0 and 5 with a mean of 2.69; on intermediate sized rocks (100-200 cm^{2}) there was a range of 0-6 with a mean of 3.36. The distribution of the number of taxa per rock in both of these size classes of rocks did not differ significantly from the Poisson

Table 26. The mean numbers of rocks and the mean total rock surface areas per square metre of streambed at Sites 5(b) and 5(c).

Sites	Number of rocks per meter of stream bottom			Total surface area (cm^{-2}) per metre of stream bottom
	Rock size classes:			
	0-100	100-200	200	
5(b)	61±19	40±16	60±12	3190±566
5(c)	115±15	94±17	17±12	2181±175

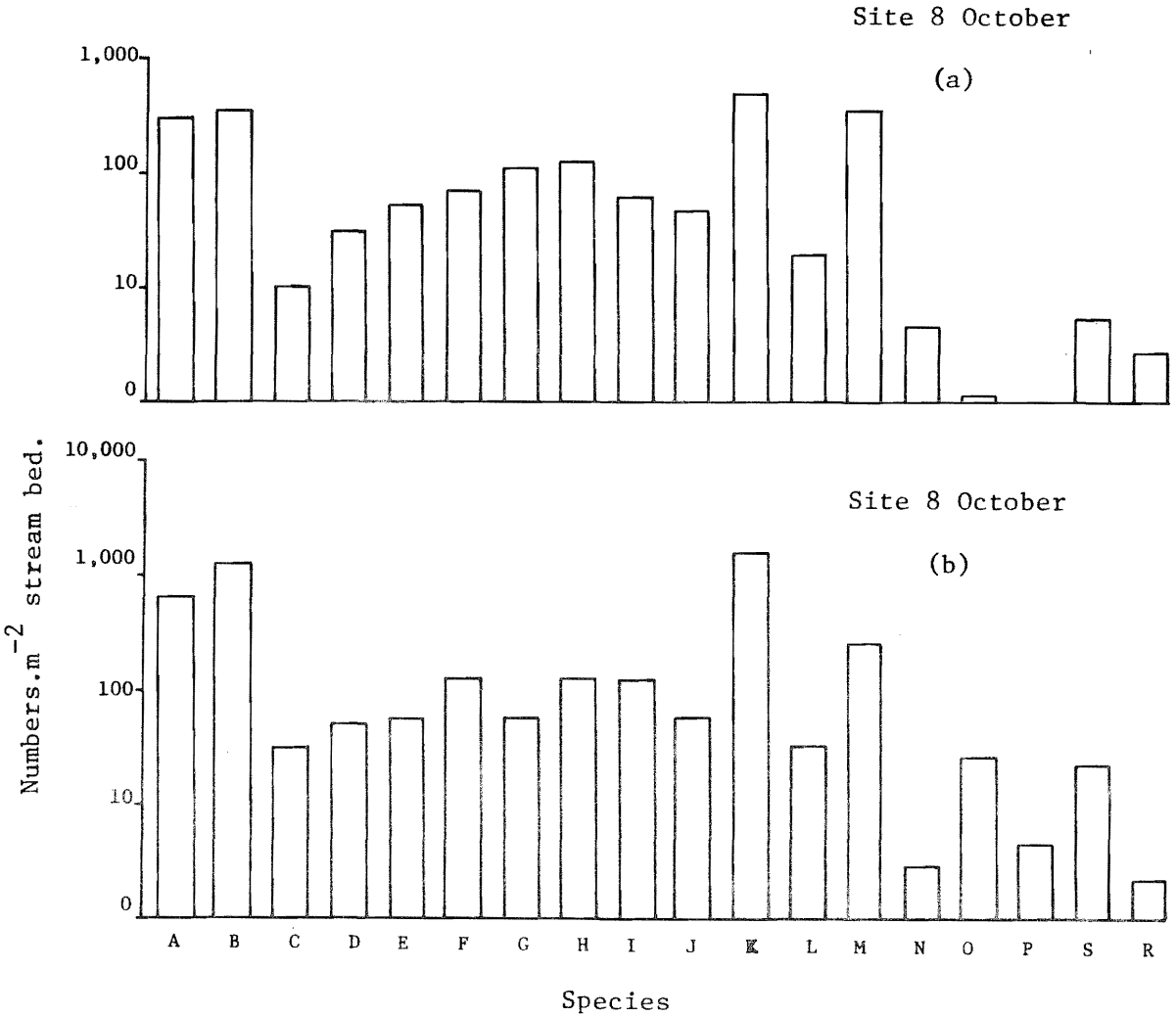


Figure 28. Mean abundances of Trichoptera larvae at Sites 5(b) and 5(c) in October 1977 expressed as numbers per unit area of streambed. Species code on page 78.

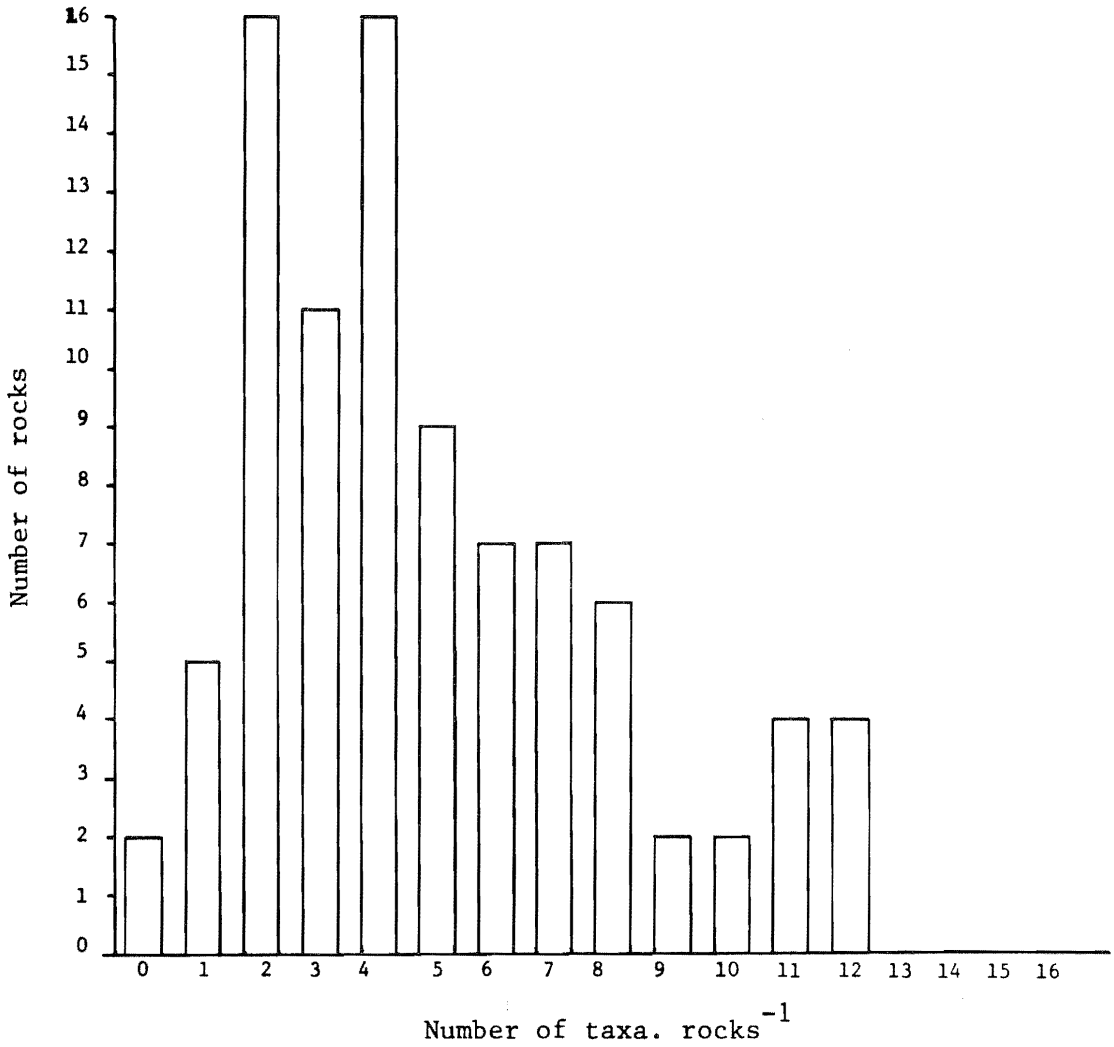


Figure 29. Frequency distribution of the numbers of Trichoptera taxa per rock for all rock sizes at Site 5(b), October 1977.

Table 27. The mean numbers of taxa of Trichoptera per rock at Sites 5(b) and 5(c) in October 1977.

	Rock size (cm^{-2})			
	0-100	100-200	> 200	ALL
Site 5(b)				
$\bar{x}$	2.69	3.36	7.61	4.92
s^2	1.59	2.23	7.03	9.28
Site 5(c)				
$\bar{x}$	2.87	4.16	7.08	4.71
s^2	2.72	6.07	3.50	7.22

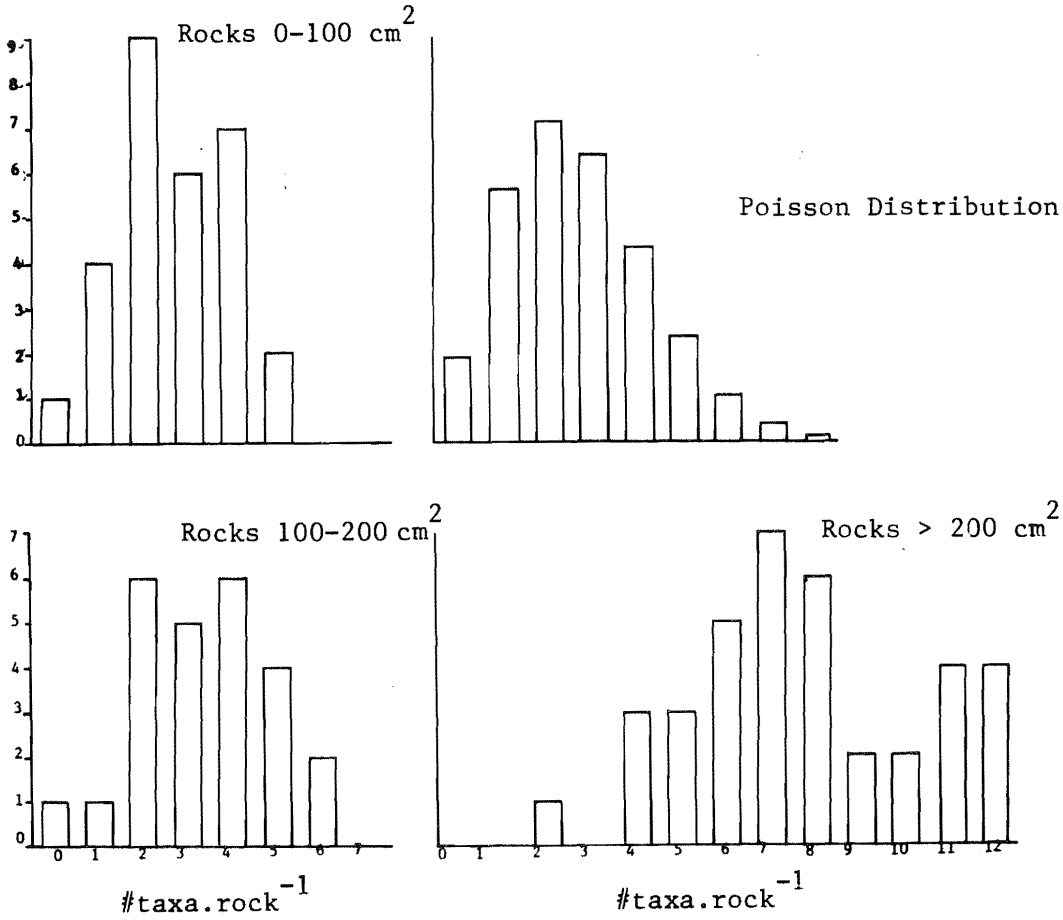


Figure 30. Frequency distributions of numbers of Trichoptera taxa per rock at Site 5(b), October 1977.

distribution, suggesting that the number of taxa per rock is randomly distributed.

The distribution of the number of taxa per rock in the large rock class (> 200 cm^2) differed greatly from that on the smaller rock classes. The range of taxa per rock varied between 2 and 12, with a mode of 7 and a mean of 7.6. This distribution did not differ significantly from a Poisson distribution, though there was some clumping with eight rocks each having 11 or 12 taxa.

It is remarkable that these three distributions, each conforming to a Poisson distribution, produce, when combined, a clumped distribution resembling a negative binomial distribution (Figure 30).

The numbers of taxa per rock at Site 5(c) were similar to those observed at Site 5(b) (Figure 31) in that the number of taxa per rock was usually small. However differences do exist, most notably in that at Site 5(c) there is a single mode at two taxa per rock and there are few rocks with 10 or more taxa. The mean numbers of taxa per rock are similar at both sites (Table 27).

As at Site 5(b), the mean number of taxa per rock increases with rock size (Table 27). The frequency distributions of the numbers of taxa per rock in the three rock size classes differ somewhat from those of Site 5(b) because the numbers of taxa per rock on the smaller rock size classes at Site 5(c) have a more clumped distribution (Figure 32) as shown by the larger variances (Table 27). By contrast the numbers of taxa per rock in the large rock size class was less variable at Site 5(c), with a range of 4-11 taxa per rock and with no clumping of large numbers of taxa on single rocks.

Figure 33 shows the relationship between the surface areas of individual rocks at Site 5(b) and the numbers of taxa present on them. The number of taxa per rock increases with surface area rapidly and reaches an asymptote at a rock size of 1100-1200 cm^2 with 10-12 taxa present per rock.

Figure 34 shows that the relationship between the

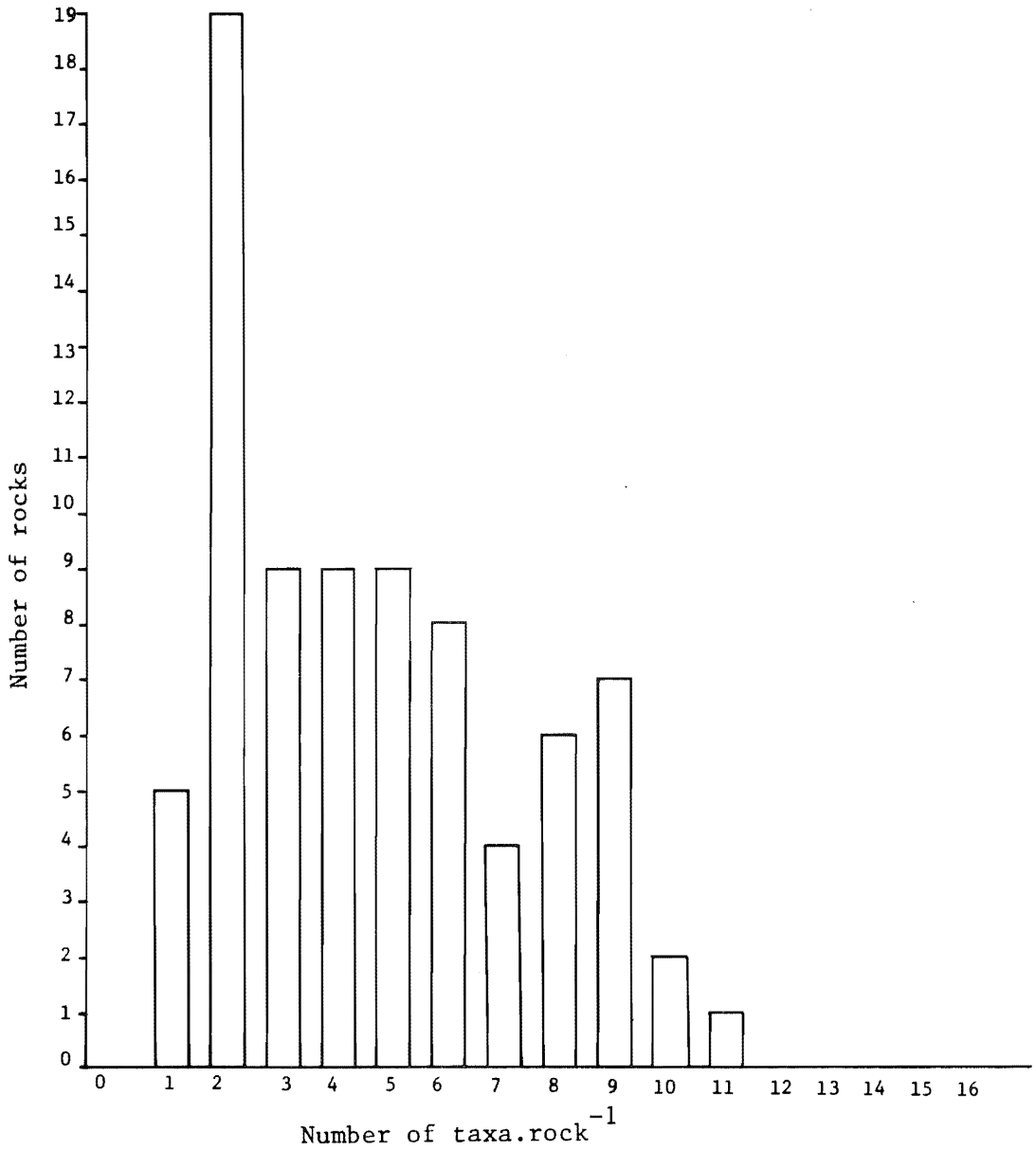


Figure 31. Frequency distribution of the numbers of Trichoptera taxa per rock for all rock sizes at Site 5(c), October 1977.

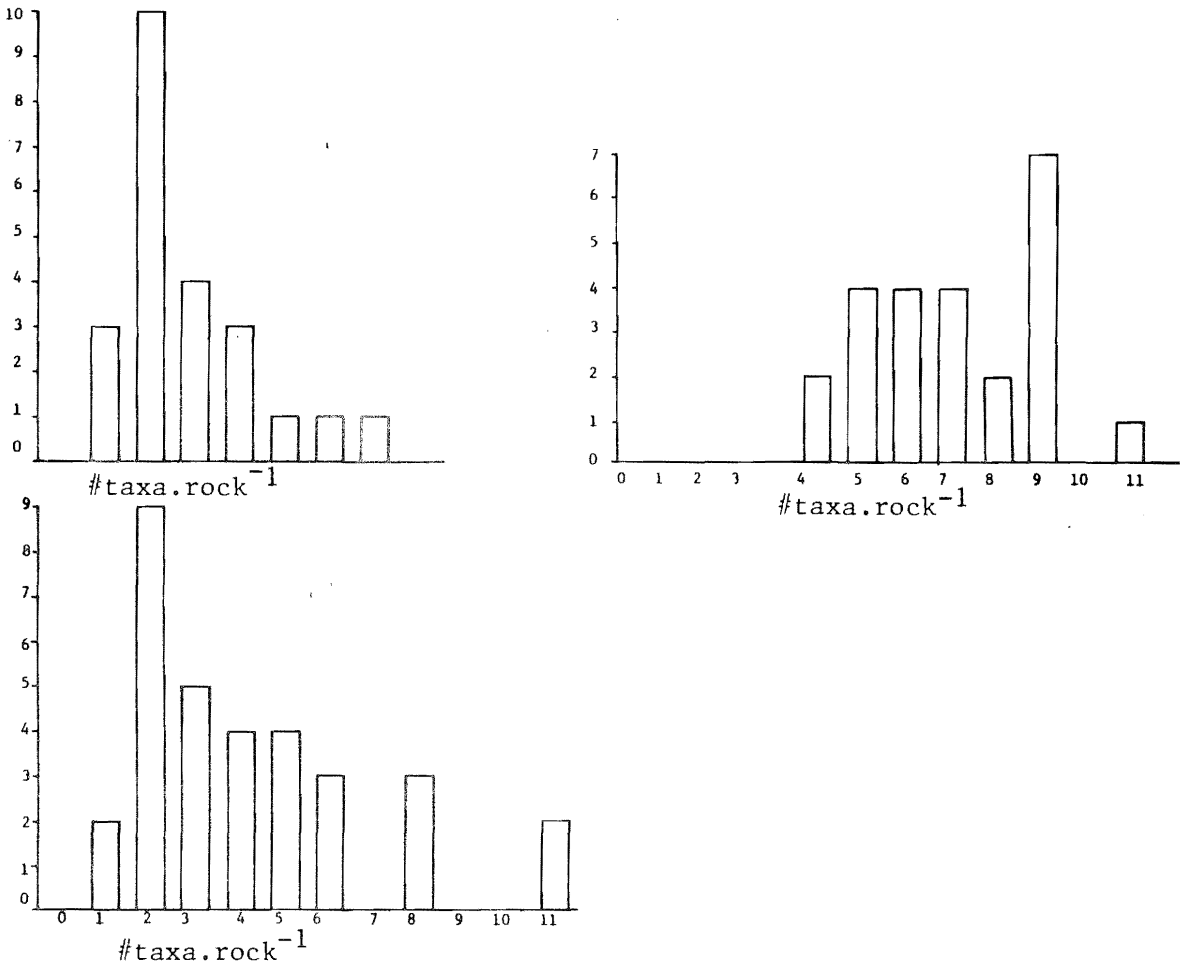


Figure 32. Frequency distributions of numbers of Trichoptera taxa per rock at Site 5(c), October 1977.

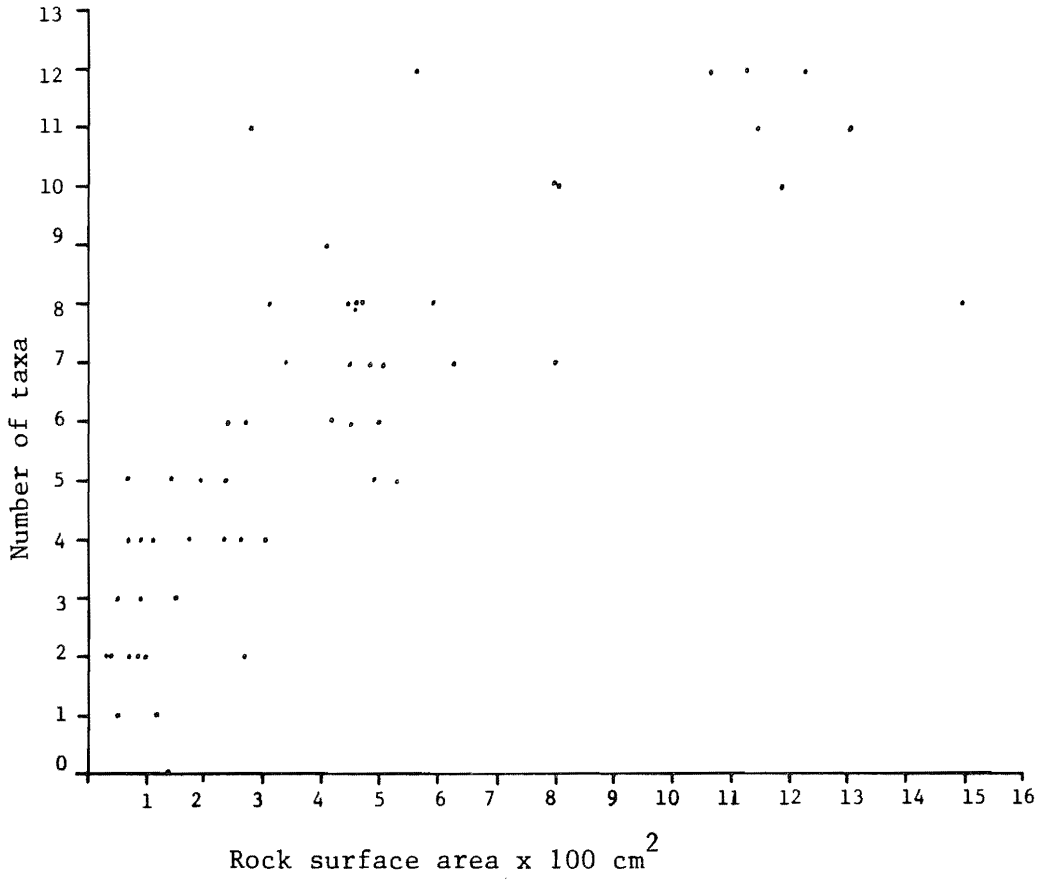


Figure 33. The relationship between the surface areas of individual rocks at Site 5(b) and the numbers of Trichoptera taxa recorded.

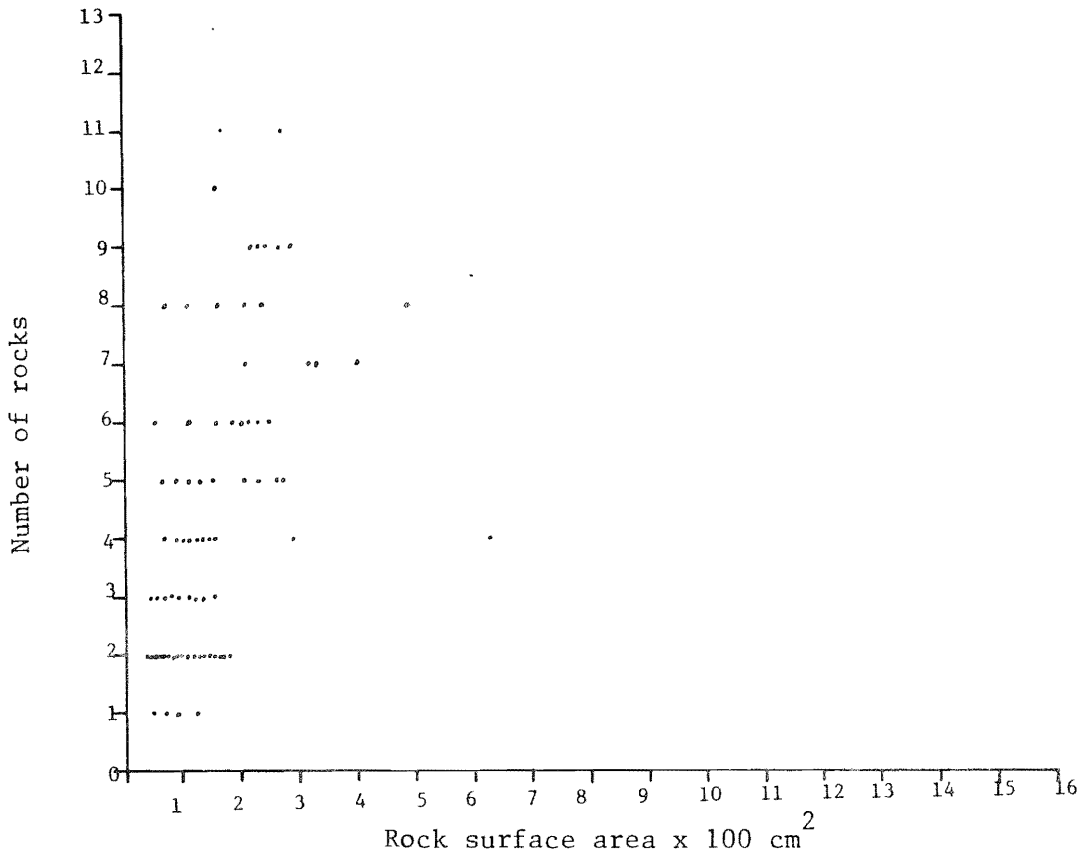


Figure 34. The relationship between the surface areas of individual rocks at Site 5(c) and the numbers of Trichopteran taxa recorded.

surface areas of rocks at Site 5(c) and the numbers of taxa present on them is somewhat different from that found at Site 5(b) primarily because of the absence of rocks larger than 700 cm^2.

5.6.4 The Relationship Between Trichopteran Species Diversity and Rock Size.

Figure 35 shows the frequency distribution of the species diversity per rock for rocks of the three rock size classes at Sites 5(b) and 5(c). Species diversity was measured using the Shannon-Weaver Diversity Index. $\bar{H} = -\sum_{i=1}^{s} P_i \log_2 p_i$ where p_i = importance value.

It is clear that the species diversity per rock increases with rock size. In general, the range of diversity per rock is greatest for smaller rocks, and as expected the largest size class of rocks have high diversities.

5.7 INVERTEBRATE DRIFT

Invertebrate drift was sampled through two 24 hour periods at two sites, 8H and 8T, for each of two months (July and August 1976). As pointed out in Section 4.1.6, drift was sampled at all depths at the centre of the stream and at both margins. The results presented here thus represent the total invertebrate drift.

The number of individuals collected per m^3 of water for each sampling interval at both sites in July and August 1976 is shown in Tables 28-31. The raw drift data were converted to drift densities ($\#.m^{-3}$) using the calculated mean water velocity shown in Table 32. The percentage of the total daily drift (Table 33) collected in each sampling interval is shown in Table 34 with the percentage composition of the total drift shown in Table 35.

5.7.1 Diel Fluctuations in Drift.

Tables 28-31 and 34 reveal that in Hartley Creek, as in other studies, drift shows diel fluctuations with peaks around

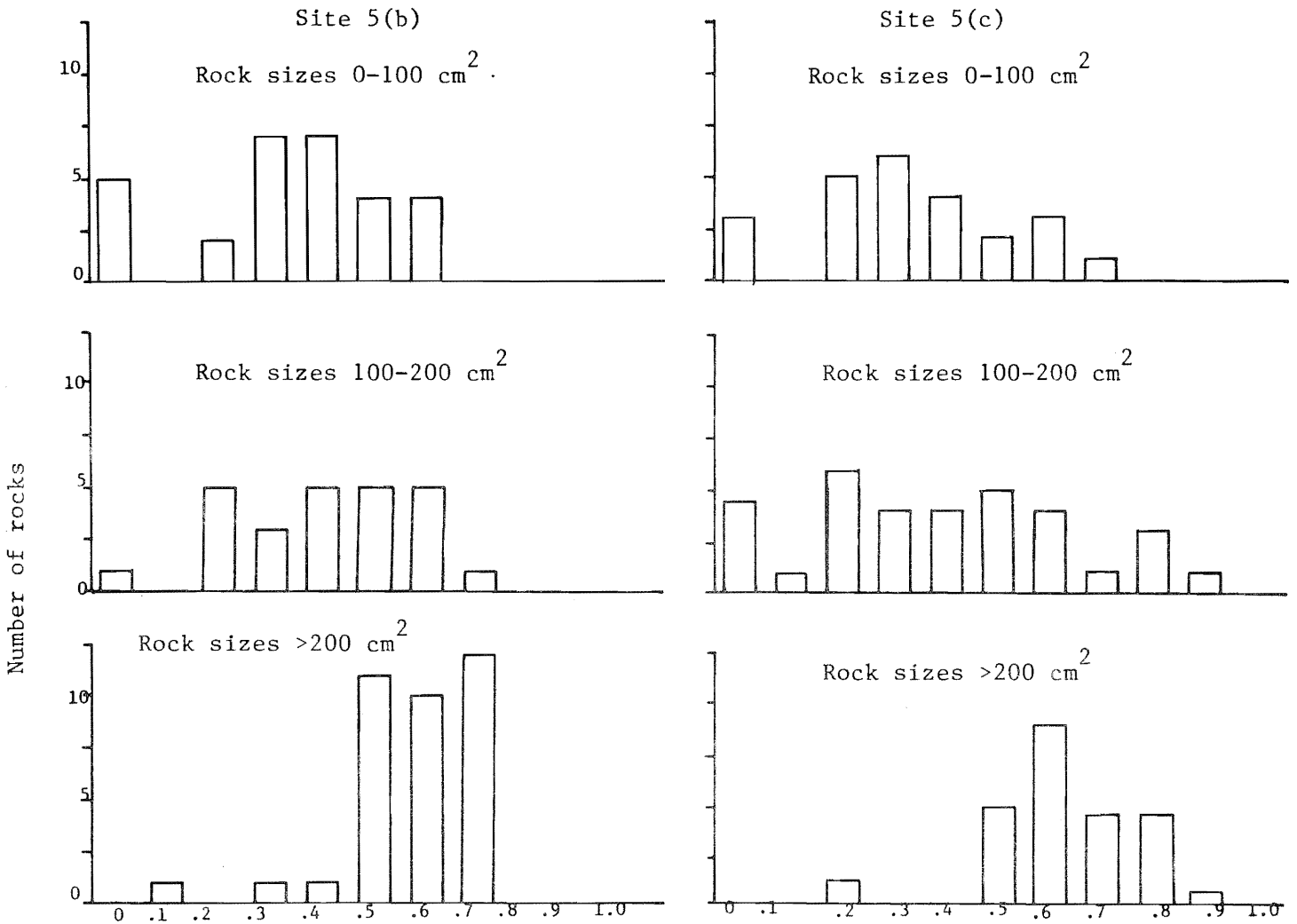


Figure 35. Frequency distributions of species diversity of Trichoptera larvae per rock at Sites 5(b) and 5(c).

Table 28. Numbers of individuals per m^3 in the drift at Site 8H, July 1976.

	Time 00-04	04-06	06-08	08-10	11-12	12-14	15-17	17-19	20-22	22-24
Plecoptera	-	-	-	-	-	-	-	-	-	-
Zapada	1.3	6.4	-	-	-	-	1.7	0.9	1.7	1.7
Prostoia	2.6	25.6	-	0.9	0.9	2.6	5.1	6.8	2.6	3.4
Claassenia	0.4	2.1	-	-	-	-	-	-	-	-
Isogenus	-	12.0	-	-	-	-	-	1.7	0.9	0.9
Ephemeroptera	-	-	-	-	-	-	-	-	-	-
Baetis sp (3)	20.5	115.4	3.4	-	0.9	12.0	8.5	42.7	17.9	52.0
Baetis sp (2)	7.7	17.5	-	-	-	3.4	-	12.8	5.9	15.4
Ephemerella sp.	6.0	31.2	-	-	-	2.6	-	14.5	7.7	15.4
Heptagenia	5.1	55.1	-	-	-	-	-	6.8	4.3	12.8
Chironomidae	-	-	-	-	-	-	-	-	-	-
Orthocladiinae	64.9	387.1	5.1	42.7	1.7	40.2	47.9	104.2	138.4	241.0
Trichoptera	-	-	-	-	-	-	-	-	-	-
Hydroptilidae	8.5	23.5	1.7	8.5	0.9	5.1	-	10.3	16.2	18.8
Hydropsyche sp.	3.8	20.1	-	3.4	-	-	-	4.3	7.7	8.5
Limnephilidae	-	15.0	-	2.6	-	-	-	-	-	1.7
Simuliidae	-	-	-	-	-	-	-	-	-	-
Simulium	3.0	2.1	-	-	-	-	-	0.9	-	2.6
Other Diptera	4.7	26.0	1.7	12.8	6.8	6.0	-	19.7	10.3	21.4
Copepoda	129.5	635.7	14.5	70.1	4.2	72.6	31.6	36.7	227.3	195.7
Cladocera	84.2	680.2	1.7	28.2	5.1	24.8	23.1	122.2	35.0	426.4
Oligochaeta	3.8	14.1	-	-	-	0.9	-	6.0	5.1	-
Coleoptera	-	1.3	-	-	-	-	-	0.9	-	-
Cnidaria	-	-	3.4	-	-	-	40.2	-	-	-
Terrestrial	3.0	3.4	4.3	5.1	0.9	0.9	3.4	3.4	3.4	-
Amphipoda	-	0.4	-	-	-	-	-	-	-	-
	349.0	2074.2	335.8	174.3	21.4	171.1	161.5	394.8	484.4	1017.8

Table 29. Numbers of individuals per m^3 in the drift at Site 8T, July 1976.

	00-04	04-06	06-08	08-10	10-13	13-15	15-17	17-19	19-22	22-24
Plecoptera	-	-	-	-	-	-	-	-	-	-
Zapada	0.4	8.0	-	7.2	4.8	1.6	-	4.0	-	7.2
Prostoia	-	4.8	0.8	0.8	3.2	-	-	-	1.1	1.6
Claassenia	-	1.6	-	1.6	0.8	-	-	-	-	-
Isogenus	-	0.8	-	-	-	-	-	-	-	-
Ephemeroptera	-	-	-	-	-	-	-	-	-	-
Baetis (3)	7.2	82.7	4.8	69.1	12.2	7.2	11.9	23.9	15.9	65.2
Baetis (2)	0.8	18.3	-	12.7	6.4	1.6	2.4	8.0	5.3	16.7
Ephemerella	0.8	23.9	-	8.0	2.4	0.8	2.4	4.0	2.7	14.3
Heptagenia	-	21.5	-	17.5	-	-	2.4	-	-	4.0
Chironomidae	-	-	-	-	-	-	-	-	-	-
Orthocladiinae	12.3	225.0	18.3	247.2	51.4	-	30.2	56.4	86.4	286.2
Trichoptera	-	-	-	-	-	-	-	-	-	-
Hydroptilidae	0.4	28.6	2.4	19.9	17.5	6.4	4.8	1.6	15.4	22.3
Hydropsyche	-	6.4	-	8.0	8.0	-	4.0	8.0	4.8	9.5
Limnephilidae	-	6.4	1.6	4.0	1.6	3.2	-	-	10.6	9.5
Simuliidae	-	-	-	-	-	-	-	-	-	-
Simulium	-	-	-	2.4	1.1	0.8	-	0.8	0.5	4.0
Other Diptera	1.2	22.3	6.4	31.8	75.8	27.8	10.3	10.3	32.3	30.2
Copepoda	139.1	302.1	25.4	480.2	114.0	89.8	79.5	117.7	204.1	791.8
Cladocera	134.0	307.7	22.3	456.3	75.3	37.4	54.1	42.1	56.2	198.8
Oligochaeta	-	-	-	32.6	10.1	5.6	-	3.1	12.2	-
Coleoptera	-	-	-	1.6	-	-	-	-	-	0.8
Cnidaria	8.3	53.3	8.7	-	-	-	-	23.1	-	-
Terrestrial	-	-	-	-	10.1	3.2	2.4	4.7	-	4.0
Amphipoda	-	-	-	-	-	-	-	-	-	-
	304.5	1060.1	90.7	1400.9	384.6	185.4	227.5	284.6	447.5	1467.7

Table 30. Numbers of individuals per m^3 in the draft at Site 8H, August 1976.

	01-03	03-05	05-07	07-09	09-11	11-13	13-15	15-17	17-19	19-21	21-23	23-01
Plecoptera	-	-	-	-	-	-	-	-	-	-	-	-
Zapada	-	-	3.5	-	-	-	-	-	-	-	-	-
Prostoia	-	-	-	-	-	-	-	-	-	-	-	-
Claassenia	-	-	-	-	-	-	-	-	-	-	-	-
Isogenus	-	-	-	-	-	-	-	-	-	-	-	-
Ephemeroptera	-	-	-	-	-	-	-	-	-	-	-	-
Baetis (3)	10.7	-		10.7	-	7.1	3.6	3.6	3.6	3.6	3.6	14.2
Baetis (2)	-	-	-	-	-	-	-	-	-	-	-	-
Ephemerella	3.6	-	-	-	7.1	3.6	-	7.1	-	-	-	7.1
Heptagenia	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae	-	-	-	-	-	-	-	-	-	-	-	-
Orthocladiinae	32.0	56.9	46.2	60.4	-	17.8	21.3	78.2	21.3	10.6	35.5	42.6
Trichoptera	-	-	-	-	-	-	-	-	-	-	-	-
Hydroptilidae	3.6	10.7	7.1	-	-	3.6	3.6	3.6	7.1	3.6	-	10.7
Hydropsyche	7.1	7.1	3.5	-	7.1	-	-	7.1	-	-	-	-
Limnephilidae	7.1	-	3.5	10.7	-	-	-	7.1	-	-	-	14.2
Simuliidae	-	-	-	-	-	-	-	-	-	-	-	-
Simulium	-	-	-	-	-	-	-	-	-	-	-	-
Other Diptera	3.6	10.7	3.5	3.5	21.3	-	7.1	10.7	3.6	3.6	3.6	24.9
Copepoda	-	28.4	24.9	7.1	14.2	14.2	3.6	10.7	3.6	17.8	7.1	24.9
Cladocera	24.8	35.5	28.4	17.6	28.4	3.5	3.6	21.3	14.2	28.4	14.2	88.8
Oligochaeta	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera	-	-	-	-	-	-	-	-	-	-	-	-
Cnidaria	7.1	10.7	3.5	17.8	7.1	3.5	3.6	21.3	3.6	7.1	17.8	10.7
Terrestrial	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda	-	-	-	-	-	-	-	-	-	-	-	-
	103.2	160.0	124.1	128.1	85.2	60.4	46.4	170.7	57.0	74.7	81.8	245.2

Table 31. Numbers of individuals per m^3 in the draft at Site 8T, August 1976.

	Time 01-03	03-05	05-07	07-09	09-11	11-13	15-17	17-19	19-21	23-01
Plecoptera	-	-	-	-	-	-	-	-	-	-
Zapada	3.0	-	6.1	-	-	3.0	-	-	-	6.1
Prostoia	-	-	3.0	-	-	-	-	-	-	3.0
Claassenia	-	-	-	-	-	-	-	-	-	-
Isogenus	3.0	-	3.0	-	3.0	-	-	3.0	-	3.0
Ephemeroptera	-	-	-	-	-	-	-	-	-	-
Baetis (3)	18.3	18.3	9.1	3.0	9.1	-	3.0	12.2	-	42.7
Baetis (2)	12.2	12.2	6.1	-	-	-	-	-	-	27.4
Ephemerella	-	6.1	-	-	-	-	-	6.1	-	9.1
Heptagenia	24.4	12.2	-	-	-	-	-	-	-	39.6
Chironomidae	-	-	-	-	-	-	-	-	-	-
Orthocladinae	100.6	79.2	82.3	88.4	152.4	-	64.0	88.4	76.2	234.6
Trichoptera	-	-	-	-	-	-	-	-	-	-
Hydroptilidae	9.1	9.1	6.1	-	-	12.2	6.1	3.0	-	30.5
Hydropsyche	6.1	6.1	6.1	-	-	-	3.0	-	9.1	36.6
Limnophilidae	3.0	-	3.0	-	3.0	-	-	-	3.0	15.2
Simuliidae	-	-	-	-	-	-	-	-	-	-
Other Diptera	9.1	12.2	21.3	18.3	15.2	12.2	24.4	-	6.1	15.2
Copepoda	91.4	85.3	91.4	9.1	27.4	70.1	18.3	36.6	24.4	158.4
Cladocera	213.3	222.4	173.7	57.9	18.3	18.3	18.3	100.6	30.5	420.5
Oligochaeta	-	-	-	-	-	-	-	-	-	-
Coleoptera	-	-	-	-	-	-	-	-	-	-
Cnidaria	-	18.3	18.3	33.5	-	60.9	18.3	18.3	21.3	18.3
Terrestrial	-	-	-	-	-	-	-	-	-	-
Amphipoda	-	-	-	-	-	-	-	-	-	-
	493.5	481.4	429.5	210.2	228.4	176.7	155.4	262.1	170.6	1069.3

Table 32. Mean water velocity at Sites 8H and 8T in July and August 1976.

	Mean Water Velocity (m/sec)	
	July	August
Site		
8 Head	0.2193	0.2280
8 Tail	0.2040	0.1955

Table 33. Total drift (numbers of individuals per day) for both sample sites and sampling periods.

Site	July	August
8 Head	4884.3	1336.8
8 Tail	5853.5	3677.1

Table 34. Percentage of total daily drift during sample intervals; July and August 1976.

July	0001-0400	0400-0600	0600-0800	0800-1000	1100-1200	1200-1400	1500-1700	1700-1900	2000-2200	2200-2400		
8 Head	7.1	42.5	0.7	3.6	0.4	3.5	3.3	8.1	9.9	20.8		
	0001-0400	0400-0600	0600-0800	0800-1000	1100-1300	1300-1500	1500-1700	1700-1900	1900-2200	2200-2400		
8 Tail	5.2	18.1	18.1	23.9	6.6	3.2	3.9	4.9	7.6	25.1		
August	0001-0300	0300-0500	0500-0700	0700-0900	0900-1100	1100-1300	1300-1500	1500-1700	1700-1900	1900-2100	2100-2300	2300-0100
8 Head	7.7	12.0	9.2	9.6	6.4	4.5	3.5	12.8	4.3	5.6	6.1	18.3
	0100-0300	0300-0500	0500-0700	0700-0900	0900-1100	1100-1300		1500-1700	1700-1900	1900-2100		2300-0100
8 Tail	13.4	13.1	11.7	5.7	6.2	4.8		4.2	7.1	4.6		29.1

Table 35. Percentage composition of the total drift for Sites 8H and 8T in July and August 1976.

	% of Total Drift			
	July		August	
	8 Tail	8 Head	8 Tail	8 Head
Plecoptera				
Zapada	0.6	0.3	0.5	0.3
Prostoia	0.4	1.0	0.2	0
Claassenia	0.2	0.05	0	0
Isogenus	0.04	0.3	0.4	
Ephemeroptera				
Baetis (3)	5.1	5.6	3.1	4.5
Baetis (2)	1.2	1.3	1.6	0
Ephemerella	1.0	1.6	0.6	2.1
Heptagenia	0.8	1.7	2.1	1.3
Chironomidae				
Orthocladiinae	17.3	22.1	26.3	31.6
Trichoptera				
Hydroptilidae	2.0	1.9	2.1	4.0
Hydropsyche	0.8	1.0	1.8	2.4
Limnephilidae	0.6	0.4	0.7	3.2
Simuliidae	0.2	0.2	0	0
Other Diptera	4.2	2.3	3.6	7.2
Copepoda	40.0	29.2	16.7	11.7
Cladocera	23.6	29.5	34.6	23.1
Oligochaeta	1.1	0.6	0	0
Coleoptera	0.04	0.05	0	0
Hydra canadensis	1.6	0.9	5.6	8.5
Terrestrial	0.4	0.6	0.2	0
Gammarus	0.0	0.1	0	0

dusk and dawn. In July, at Site 8H 42.5% of the total day's drift occurs between 0400 and 0600 hours, and a further 20.8% between 2200 and 2400 hours. At Site 8T, drift was high between 0400 and 1000 hours and again between 2200 and 2400 hours. The longer duration of the morning drift at Site 8T may perhaps be related to physical differences in the topography of the two sites. The presence of a pool immediately upstream of Site 8T may act to protract the dawn drift period, but this does not account for the lack of an extended drift period in the evening. In contrast the results of August reveal that while Site 8H shows high drift only between 2300 and 0100 hours, Site 8T shows a considerable extension of high drift rate after 0100 hours, diminishing only after 0700 hours.

In July, elevations in drift rate at Site 8H were due to increase drift of Ephemeroptera, Trichoptera, Orthocladiinae, and Cladocera. In addition, Copepoda and some Plecoptera (*Isogenus, Prostoia*) showed higher drift rates between 0400 and 0600 hours but not between 2200 and 2400 hours.

At Site 8T in July, *Zapada, Prostoia*, Ephemeroptera, Orthocladiinae, Hydroptilidae, and Limnephilidae were the major constituents of the increased drift during parts of the periods 0400-1000 and 2200-2400 hours. *Claassenia* only drifted during the 0400-1000 hour period and the peak drift rate for Copepoda was between 2200 and 2400 hours.

In August, the high drift rates between 2300 and 0100 hours at Site 8H were due to Cladocera, *Baetis* (three-tailed), and "Other Diptera", while the peak at Site 8T between 2300 and 0100 hours, and the high levels of drift between 0100 and 0700 hours were due to *Zapada, Baetis* (two-tailed and three-tailed), *Heptagenia*, Orthocladiinae, and Cladocera.

5.7.2 Taxonomic Distribution of the Drift.

It can be seen from Tables 28-31 that there are more taxa in the drift in July (20 at Site 8T, 21 at Site 8H) than in August (16 at Site 8T, 12 at Site 8H), with a proportionately

greater reduction at Site 8H. At Site 8T the following taxa drifted in July but not in August: *Claassenia*, *Simulium*, Oligochaeta, Coleoptera. At Site 8H taxa did not drift in August and in addition the following: *Prostoia*, *Isogenus*, *Baetis* (two-tailed), and terrestrial forms.

At both sites and sampling periods the drift was composed predominantly of three taxa: Orthocladiinae, Copepoda, and Cladocera. In July at Sites 8H and 8T they constituted 80.8% and 80.9% respectively of the total numbers of organisms, while in August the corresponding figures were 66.4% and 77.6%. Some differences were apparent between the taxonomic composition of the drifts at the two sites; in July Copepoda formed 40.0% of the total numbers of drift at Site 8T but only 29.2% at Site 8H. In August, *Prostoia*, *Isogenus*, *Baetis* (two-tailed), and terrestrials were absent from the drift at Site 8H, and Cladocera formed only 23.1% at this site compared to 34.6% at Site 8T.

5.7.3. Differences Between Months

The drift rates of certain taxa (Copepoda, *Claassenia*, Oligochaeta, Coleoptera, terrestrials) were higher in July than in August but the opposite was true of Orthocladiinae and *Hydra canadensis*.

Total drift (numbers per 24 hours) was higher at both sites in July than in August (Table 33) by factors of 1.6 and 3.7 respectively for Sites 8T and 8H. Examination of Table 32 reveals that there is no relation between these differences and the mean water velocities at these times and sites. However, examination of the stream discharge data (see Section 5.1.3) reveals that there is a positive correlation between the total drift and the stream discharge.

5.7.4. Comparison Between Drift and Benthos

Table 35 shows the percentage taxonomic composition of the total drift for both sites and sample periods. Comparison with Table 15 reveals some major differences between the

proportional composition of the drift and the benthic invertebrates inhabiting riffles. This is shown more clearly in Table 36 which shows the percentage compositions of benthic riffle samples and drift samples for July and August. It is clear that two categories, Other Invertebrates and Ephemeroptera appear disproportionately abundant in the drift. The data are somewhat misleading since the category of "Other Invertebrates" includes a very high proportion of two taxa which did not occur in appreciable numbers in the benthic samples; these are Copepoda and Cladocera. These are not benthic organisms and their presence in the drift denotes that there is an appreciable component of drift which is derived from the sluggish pools at the heads of tributaries of the creek. Apart from this component, the benthic contribution to the drift is comparable to the findings of other studies of drift; two taxa, baetid Ephemeroptera and Orthocladiinae Chironomidae, are generally the most abundant benthic-derived components of the drift, while the larger Plecoptera, Trichoptera, and Ephemeroptera tend not to drift.

5.8 BACTERIA AND ALGAE

Figures 36 and 37 show the abundances of attached and suspended bacteria and algae. The abundance of sessile bacteria peaks in mid-summer and then falls rapidly to a low in August after which it rapidly rises to a second peak in December. The numbers of suspended bacteria remain fairly constant from May until August and then fall to a low in October.

Algal biomass tends to fluctuate inversely to bacterial numbers, sessile algae being low in June and July and rising erratically to a small peak in October. Suspended algae appear to be highest in summer and fall to low values in August and September.

Table 36. Percentage taxonomic compositions of benthic riffle samples and drift samples taken in July and August 1976.

	July			August		
		Drift			Drift	
Taxa	Riffle	Site 8H	Site 8T	Riffle	Site 8H	Site 8T
Chironomidae	74.6	22.1	17.3	49.4	31.6	26.3
Trichoptera	7.0	3.3	3.4	22.0	9.6	4.6
Ephemeroptera	3.3	10.2	8.1	3.2	7.9	7.4
Plecoptera	1.2	1.6	1.2	0.8	0.3	1.1
Others	13.9	62.7	70.0	24.6	50.6	60.6

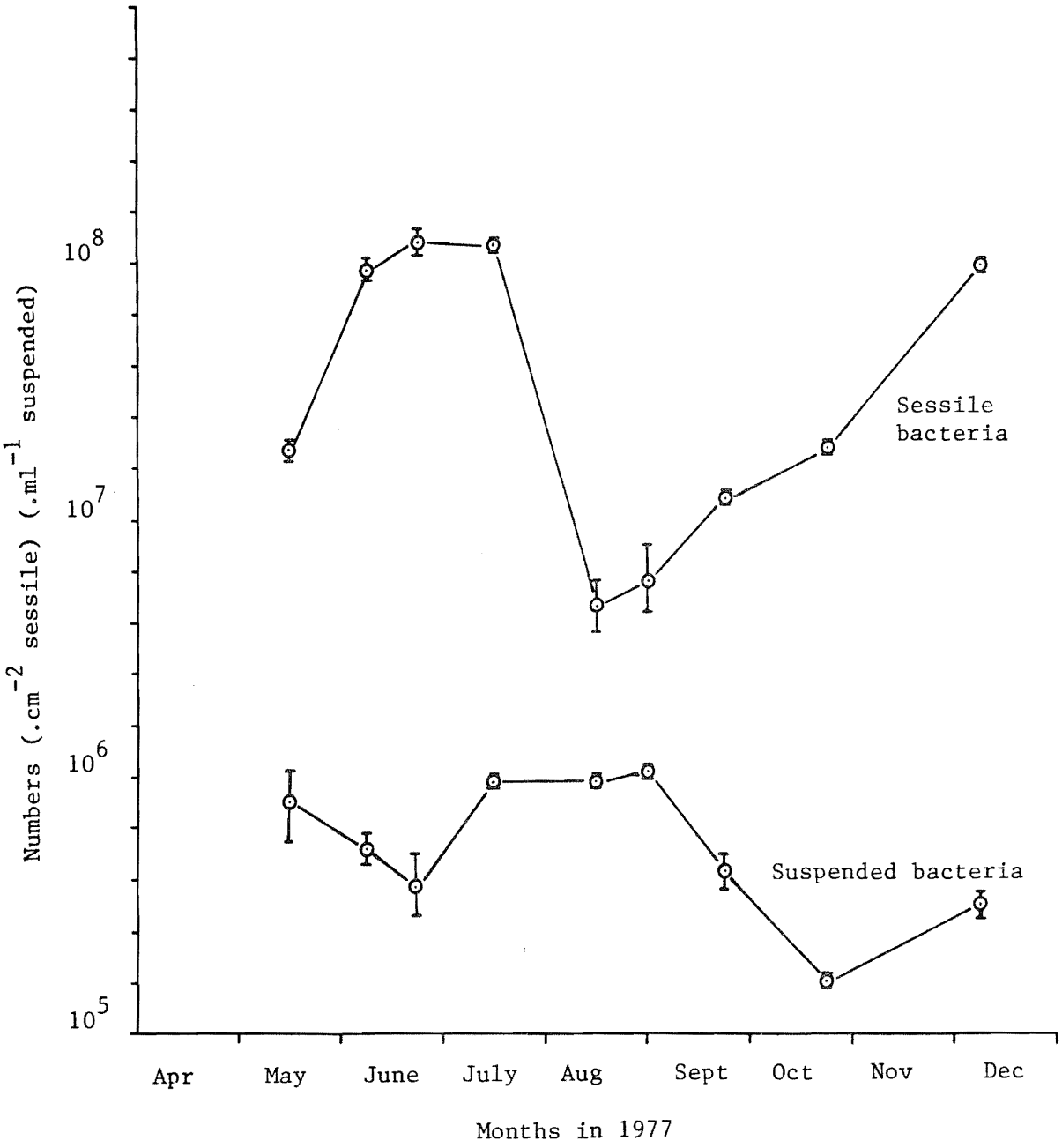


Figure 36. Mean abuendance and 95% confidence limits of sessile bacteria and suspended bacteria.

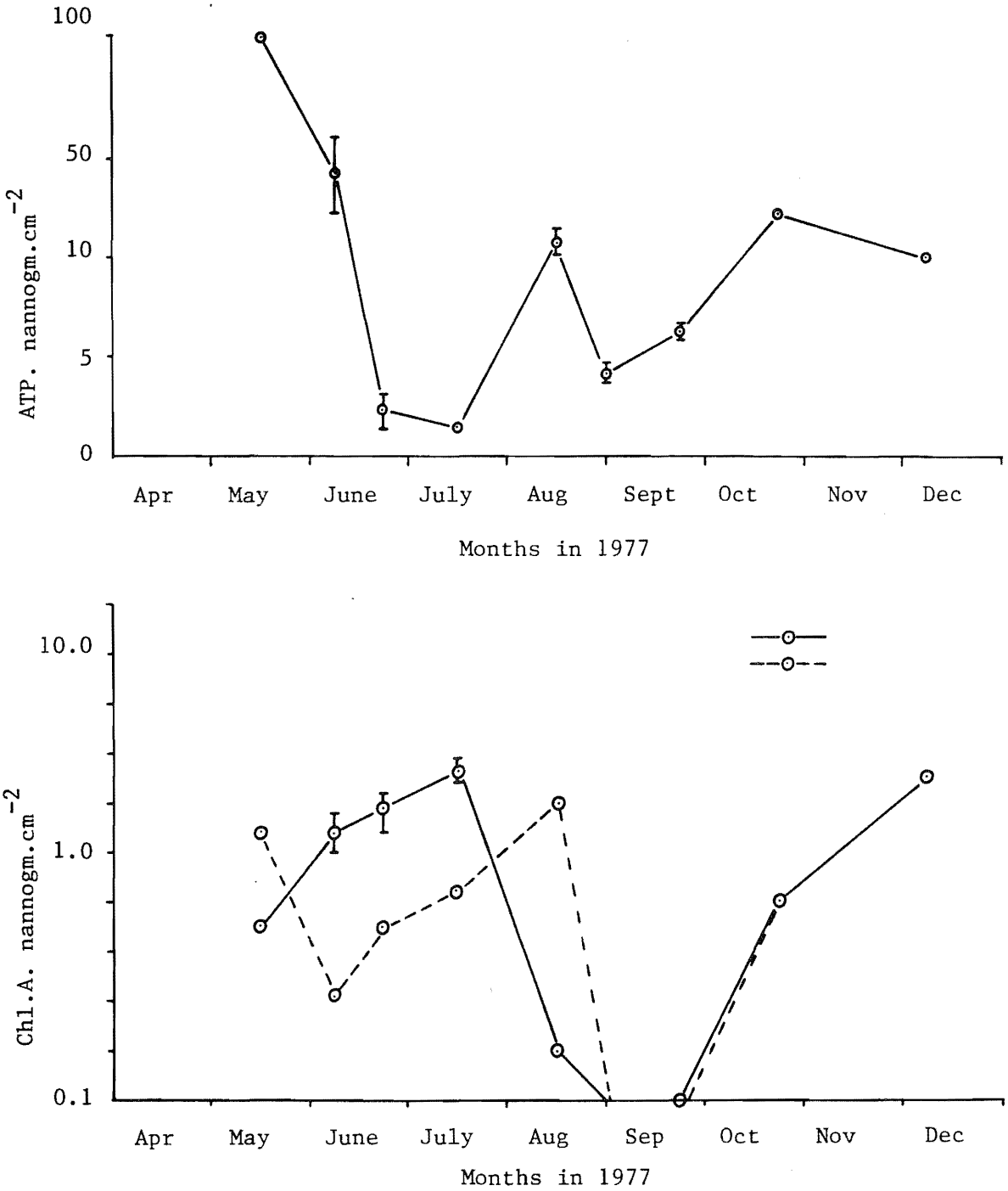


Figure 37. Measures of abundance and 95% confidence limits of periphyton (——) and phytoplankton (----).

6. DISCUSSION

The original design for this study incorporated three phases, the first a baseline study of selected abiotic and biotic factors, the second a manipulative phase during which portions of the stream would be subjected to simulations of some of the effects of oilsand recovery, and the third a recuperation phase during which the response of the system to the cessation of manipulation would be examined.

It is regrettable that the second and third phase of the study were eliminated and that the fiscal restraints imposed upon the first phase were such that important components could not be investigated. In particular the restrictions upon fieldwork necessitated omission of work which required frequent or prolonged visits to the field. The result is that, while meeting the eight objectives listed in the Introduction, the study is an incomplete overview of the baseline conditions in Hartley Creek.

The first objective was the identification of the aquatic invertebrate species of the creek. It was found that the invertebrate fauna of Hartley Creek is both abundant and diverse. Appendix 10.1 lists the 134 genera and 68 species hitherto identified. Undoubtedly the total list of macroinvertebrates is much longer, but the difficulties of rearing larvae during brief visits to the creek coupled with the fact that few of the aquatic insects can be identified to species from larvae made it impossible to make specific identifications in many cases. Chironomidae were identified only to subfamilial level for fiscal reasons.

The second objective was the determination of the temporal and spatial distribution and abundance of the principal invertebrate species of the creek. A preliminary survey revealed that in riffles, the predominant habitat type, the invertebrate community was dominated by larvae of Trichoptera in terms of biomass, though by chironomid larvae in terms of numbers. Since numbers *per se* provide no information on the distribution of matter within the community it was decided to place emphasis on Trichoptera, together with Ephemeroptera and Plecoptera, two

other insect orders which were frequent.

Net-spinning larvae of Trichoptera are commonly dominant members of stream communities downstream of lakes and impoundments (Hynes 1970; Cushing 1963). Their predominance in Hartley Creek probably reflects the abundance of particulate organic matter (POM) in the creek, coupled with water flow rates sufficient to distend their nets. Some other streams in the area also carry high POM loads but do not support net-spinning trichopteran larvae because their substrates are unsuitable; this is true, for example, of Upper Beaver Creek where gravel and rubble riffle substrates do not occur (Syncrude Ltd. 1978).

In contrast to Upper Beaver Creek (Syncrude Ltd. 1978) the population densities of benthic macroinvertebrates in Hartley Creek are high and comparable in magnitude to those observed in other streams and rivers in Alberta (e.g. Radford & Hartland-Rowe 1971; Clifford 1978; Davies et al. 1978). The low spring and summer population densities observed in Upper Beaver Creek were attributed to substrate instability at those seasons. None of the substrate types in Hartley Creek displayed marked instability.

The third objective of the study was the investigation of the life-cycle patterns of the principal aquatic invertebrates. Owing to fiscal constraints it was necessary to restrict investigation to those species which were amenable to study based on relatively infrequent sampling intervals. It was therefore necessary to exclude Chironomidae since they seemed likely to include many multivoltine species.

Most of the species studied, including a number of species of Trichoptera, Ephemeroptera, and Plecoptera, displayed univoltine life-cycles (i.e. one generation per annum) and all had a single brief emergence period in the spring or summer. This was the commonest type of pattern observed in other Alberta streams by Clifford (1978) and Hartland-Rowe (1964), though the latter author remarked that some unstudied species probably took two or more years to complete their life-cycles. In Hartley Creek it was found that *Claassenia sabulosa* takes more than a year

to develop; the evidence supports the view of Barton & Wallace (in press) that it takes three years. *Pteronarcys* and *Pteronarcella* species also probably take more than one year, but larvae were obtained in insufficient numbers for study.

The fourth objective of the study was an investigation of the drift of benthic invertebrates in Hartley Creek. It was found that drift here conforms to patterns which have been observed in many other streams by other workers (e.g. Bishop & Hynes 1969; Elliott 1969). The faunal composition of the drift differs from that of the benthos and there is a diel cycle in the numbers of individuals drifting. Numbers rise to a peak soon after dusk, fall during the night, rise to a second usually smaller peak near dawn and then fall again during the daylight hours. In Hartley Creek, as elsewhere, the drift fauna is dominated by larvae of Chironomidae and Baetinae. However, the drift in Hartley Creek was unusual in also including a substantial proportion of Cladocera and Copepoda derived from pools. This crustacean component of the drift may partly account for the anomalous observation that more organisms appear to drift out of pools than into them; most drift studies have suggested that drifting invertebrates tend to accumulate in pools. As has often been observed elsewhere, there is a positive relation between the density of drifting invertebrates and rates of stream discharge.

The quantitative definition of community structures formed the fifth objective of this study. It was found that benthic communities in Hartley Creek could broadly be classified in five categories, each occupying a different type of habitat. Four of these habitat types occurred in pools and the fifth in riffle areas. Total numbers of individuals are lower in all four pool communities than in the riffle community. Plecoptera are almost absent from pool communities and the numbers of larvae of Chironomidae and Trichoptera are lower than in riffles. The lowest numbers were found in the sand substrate where there were relatively few Chironomidae, very few Trichoptera, and no Plecoptera. The macrophyte community also contained no Plecoptera

but included large numbers of Chironomidae and Ephemeroptera (Baetidae). The other two pool communities, occupying boulder and cobble substrates, were generally similar in quality to the riffle community though the numbers of organisms were lower.

In order to study the micro-distribution of aquatic invertebrates in the creek, the sixth objective of the study, a "single-rock" sampling technique was developed. Use of this technique demonstrated that the micro-distribution of eighteen species of Trichoptera is influenced by rock size and by the presence or absence of moss on the rock. The technique also made it possible to estimate the abundance of benthic invertebrates in terms of rock surface area.

The seventh objective of this study was the quantitative definition of the principal aquatic invertebrates as components of the community. From the data presented it is evident that both numerically and in terms of biomass the distribution of organisms is broadly similar to other stream communities which have been studied. Since neither time nor funds were available to conduct studies of secondary production it is not possible to substantiate assertions about the trophic status of members of the community. However, the abundance of net-spinning larvae of Trichoptera does suggest that there is a substantial detrital component in the food webs of the stream benthic communities.

The final objective of the study was the definition and assessment of the principal interactions between the components of the stream community and the effects of primary environmental factors. The data contained in the report reveal that the communities of Hartley Creek differ from those studied by Clifford (1978) in Bigoray River, and from those of Upper Beaver Creek (Syncrude Ltd. 1978). The abundance and diversity of benthic communities in Upper Beaver Creek is lower than in either of the other streams, and this is attributable to the instability of the substrate in that stream during the spring and summer months. The authors of the report (Syncrude Ltd. 1978) report that the community is both more abundant and more diverse in the fall

season when there is (a) considerable allochthonous input, and (b) low discharge which permits greater stability of the sandy substrate.

While the abundance of benthic invertebrates in Bigoray River is comparable to that in Hartley Creek, the community diversity appears to be significantly lower (Clifford 1978). This may be attributed largely to the fact that Bigoray River is much smaller than Hartley Creek, with stream discharge generally about one fifth as high as in Hartley Creek. In consequence there is less possibility of diversity of substrate type. This is because, with high discharge it is possible for water velocity to vary within a wider range of values depending on the morphometry of the streambed. In Hartley Creek five different benthic communities were recognised, each occupying a different substrate type. The substrate type is ultimately dependent on the water velocity for its determination since different flow rates carry different-sized particles.

The presence in Hartley Creek of a number of different benthic communities all of considerable diversity implies that the stream, and others like it, is likely to be resistant to perturbation. In the first place, alterations in stream discharge may result in alteration of the relative proportions of the different communities but is unlikely to eliminate all of them. And in the second place, communities of high diversity are more likely to be able to withstand perturbation than low diversity communities; this is because in a more diverse system of interacting components, such as a biological community, there are more interconnected pathways than in a simpler system. Thus, even it some of the connections are broken, as by the elimination of a species, alternative pathways exist by which the flow of matter and energy within the system can be maintained.

Clifford (1978) suggests that there are two primary driving forces in the Bigoray River benthic community: water temperature and stream flow. It has already been pointed out that stream discharge is of fundamental importance in determining

substrate types. In Hartley Creek there is also reason to suppose that water temperature plays a very important role in influencing the growth and life-cycle patterns of many of the benthic species. It is noteworthy that a large proportion of the benthic species are univoltine, with spring or summer periods of adult emergence. Although other factors, such as daylength, have been implicated in the regulation of life-history patterns of various benthic invertebrates elsewhere there is ample evidence that temperature is a fundamental factor in the regulation of growth. It is concluded that, of the abiotic variables measured, stream discharge and water temperature are the two prime factors influencing the benthic communities of Hartley Creek.

7. CONCLUSIONS

1. Hartley Creek is a small tributary of the Muskeg River characterized by low discharge which fluctuates seasonally between 0.5 and 7 $m^3.sec^{-1}$, pH which is somewhat alkaline, high oxygen concentrations, and temperatures fluctuating seasonally between 0 and 20°C;

2. The benthic fauna is diverse and abundant being dominated numerically by Chironomidae but by Trichoptera in terms of biomass;

3. Five different types of communities were distinguished in Hartley Creek. One of these is characteristic of riffle sites and the other four (boulder, cobble, macrophyte, and sand) occur in pool sites;

4. The development and use of a "single-rock" sampling technique has revealed that within a community type (riffle) differences are observed in the micro-distribution of Trichopteran larvae, related to the size of the rocks occupied and to the presence or absence of moss cover on the rocks;

5. Most species of Plecoptera, Ephemeroptera, and Trichoptera in Hartley Creek are univoltine with a summer emergence period which is usually brief;

6. The size distributions of nymphs of Baetidae suggest that these species are here, as elsewhere, multivoltine;

7. At least one of the large Plecoptera, *Claassenia sabulosa*, has a life-cycle longer than one year. The evidence suggests that it takes three years to complete its life-cycle;

8. Although most, perhaps all, of the Trichoptera are univoltine, some species appear to have two overlapping populations with different emergence periods;

9. Invertebrate drift in Hartley Creek consists largely of two benthic-derived components, Chironomidae and Baetidae, and two planktonic components, Cladocera and Copepoda;

10. There is a diel cycle in the abundance of organisms in the drift with evening and morning peaks;

11. The total drift rate varies between months and is

positively related to discharge rate;

12. The principal abiotic factors influencing the biology of the benthos are temperature and discharge;

13. Annual fluctuations in temperature are largely responsible for the annual variations in growth rates;

14. Fluctuations in discharge have a direct influence on rates of drift and also on the concentrations of suspended matter; and

15. Chemical variations observed in Hartley Creek do not appear to influence the benthos.

8. RECOMMENDATIONS

It is recommended that:

1. A survey of lotic systems in the AOSERP study area be conducted to determine the extent to which Hartley Creek is typical of such systems;

2. The trophic structure and interactions of and between the benthic communities of Hartley Creek be investigated;

3. Benthic secondary production studies be undertaken on Hartley Creek;

4. Hartley Creek be used as a site for perturbation-recovery experimentation, such experimentation to be conducted in such a manner as to preclude impairment of downstream waters, and such that the range of experimentation would include all probable types of anticipated perturbation, including altered salinity, sediment load increase, stream diversion, plant discharges, and other perturbations associated with development and operation of plants in the study area; and

5. A master plan for all future aquatic studies be developed and made available for public scrutiny.

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10. APPENDICES

10.1 BENTHIC TAXA COLLECTED FROM HARTLEY CREEK 1976-1977.

PORIFERA

Spongilla (Lamark)

COELENTERATA

Hydra sp.

Hydra canadensis (Rowan)

HIRUDINEA

Helobdella stagnalis (Linneaus)

OLIGOCHAETA

Lumbricidae

Lumbriculus variegatus (Muller)

Tubificidae

Limnodrilus hoffmeisteri (Clapareae)

Naididae

MOLLUSCA

Pelecypoda

Sphaeriidae

Musculium (Link)

Pisidium spp. (Pfeiffer)

Sphaerium spp. (Scopoli)

Gastropoda

Ferrissia (Walker) *rivularis?*

Helisoma trivolis

Physa integra

Lymnaea sp. (Lamark)

INSECTA

Ephemeroptera

Ephemeridae

Ephemera simulans (Walker)

Caenidae

Caenis spp. (Stephens)

Continued ...

Brachycercus (Curtis)

Tricorythodes (Ulmer)

Baetidae

Baetis spp. (Leach)

Callibaetis (Eaton)

Pseudocloeon (Klapalek)

Ephemerellidae

Ephemerella aurivillii (Bengtsson)

E. grandis ingens (McDonnough)

E. lita (Burks)

E. simplex (McDonnough)

E. walkeri (Eaton)

E. delantala (May)

Leptophlebiidae

Leptophlebia sp. (Westwood)

Paraleptophlebia sp. (Lestage)

Heptageniidae

Heptagenia spp. (Walsh)

Stenonema vicarium (Walker)

Odonata

Anisoptera

Aeshna interrupta (Walker)

Phyllocycla sp. (Calvert)

Plecoptera

Nemouridae

Amphinemoura Ricker

Malenka Ricker

Prostoia Walker

Taeoniopterygidae

Brachyptera Newport

Taeniopteryx Pictet

Pteronarcidae

Pteronarcella (Banks)

Pteronarcys Newman

Continued ...

Perlodidae

Arcynopteryx (Klapalek)

Isogenus (Newman)

Isoperla (Banks)

Chloroperlidae

Hastaperla brevis (Banks)

Perlidae

Acroneuria Pictet

Claassenia sabulosa (Banks)

Trichoptera

Rhyacophilidae

Rhyacophila (Pictet)

Glossosomatidae

Glossosoma (Curtis) *velona* (Ross)

Agapetus (Curtis)

Anagapetus (Ross) (Prob. new species)

Protoptila (Banks)

Philopotamidae

Wormaldia gabriella (Banks)

Psychomyidae

Psychomyia flavida (Hagen)

Psychomyia (Pictet)

Polycentropus (Curtis)

Nyctiophylax (Braeur)

Hydropsychidae

Arctopsyche ladogensis (Kolenati)

Parapsyche (Betten)

Diplectrona californica (Banks)

Potamyia flava (Hagen)

Hydropsyche betteni (Ross)

H. recurvata (Banks)

H. slossonae (Banks)

H. simulans (Ross)

Cheumatopsyche gracilis (Banks)

Continued ...

C. larsia (Ross)

Hydroptilidae

Hydroptila consimilis (Morton)

H. angusta (Ross)

H. waubesiana (Betten)

Oxyethira serrata (Ross)

Oxyethira (Eaton)

Ochrotrichia (Eaton)

Mayatrichia (Mosely)

Dibusa (Prob. new species)

Stactobiella (Ross)

Lepidostomatidae

Lepidostoma pluviale (Milne)

L. strophis (Ross)

Leptoceridae

Ceraclea arielles (Denning)

C. annulicornis (Stephens)

C. resurgens (Walker)

C. dilutus (Hagen)

Oecetis (McLachlan)

Triaenodes baris (Ross)

Nectopsyche spiloma (Ross)

Limnephilidae

Glyphopsyche (Banks)

Limnephilus minusculus (Banks)

Limnephilus sp. 2 (Nimmo)

Limnephilus sp. 3 (Nimmo)

Onocosmoecus quadrinotatus (Banks)

Platycentropus plectrus (Ross)

Pycnopsyche (Banks)

Hydatophylax

Hesperophylax (Banks)

Phryganeidae

Ptilostomis unicolor

Continued ...

Ptilostomis semifasciata (Say)

Banksiola (Martynov)

Brachycentridae

Brachycentrus americanus (Banks)

B. occidentalis (Banks)

Micrasema sp. 1 (McLachlan)

Micrasema sp. 2 (McLachlan)

Amiocentrus Ross

Helicopsychidae

Helicopsyche borealis (Hagen)

Lepidoptera

Nymphula (Schranik)

Hemiptera

Corixidae

Callicorixa audeni (Hungerford)

Gerridae

Metrobates Uhl.

Coleoptera

Dytiscidae

Dytiscus (Linnaeus)

Hydrophorus agalma Wheeler

Gyrinidae

Gyrinus pleuralis (Zau)

Elmidae

Optioservus fastidatus (LeConte)

O. divergens LeConte

Diptera

Tipulidae

Antocha (Osten Sacken)

Dicranota (Zetterstedt)

Eriocera fultonensis (Alex.)

Limnophila Macquart

Hemerodromia Meig. (Empididae)

Dicranomyia Stephens

Continued ...

Pedicia (Latreille)

Psychodidae

Simulidae

Simulium jenningsi (Malloch

S. pugetense Dyar & Shannon

S. trivittatum Malloch

Ceratopogonidae

Ceratopogonia bezzia

Stratiomyidae

Stratiomyia (Geoffroy)

Tabanidae

Chrysops carbonarius Meig.

Tabanus Linn.

Rhagionidae

Atherix prob. *pachypus* (Bigot)

Chironomidae

Tanypodinae

Ablabesmyia (Johannsen)

Conchapelopia (Fittkau)

Labrundinia (Fittkau)

Nartasia Fittkau

Procladius (Skuse)

Tanypus Meig.

Thienemannimyia (Fittkau)

Trissopelopia Kieffer

Chironominae

Cryptochironomus (Kieffer)

Glyptotendipes (Kieffer)

Paracladopelma (Harnisch)

Polypedilum (Kieffer)

Stictochironomus (Kieffer)

Tanytarsini

Cladotanytarsus (Kieffer)

Micropsetra (Kieffer)

Continued ...

Paratanytarsus (Kieffer)

Rheotanytarsus (Bause)

Stempellina (Bause)

Tanytarsus (van der Wulp)

Zavrelia (Kieffer)

Orthocladinae

Cardiocladius (Kieffer)

Corynoneura (Winnertz)

Cricotopus sp. 1 (van der Wulp)

Cricotopus sp. 2 (van der Wulp)

Diplocladius (Kieffer)

Eukiefferiella spp. (Thieneman)

Heterotrissocladius (Sparck)

Metriocnemus (van der Wulp)

Orthocladius (van der Wulp)

Psectrocladius (Kieffer)

Smittia spp.

Thienemanniella (Kieffer)

CRUSTACEA

Copepoda

Cladocera

Amphipoda

Hyallela azteca (Saussarue)

Gammarus pseudolimnaeus (Borisfield)

ARACHNIDA

Hydracarina

Lebetia Neuman

Mediopis Neuman

Tetrabates Thor

NEMATODA

10.2 LIST OF TAXONOMIC LITERATURE USED

Allen & Edmunds (1959, 1961a, 1961b, 1962a, 1962b, 1963a, 1963b, 1965)

Baumann, Gaufin & Surdick (1977)

Beck (1968)

Bousfield (1958)

Brown (1972)

Burks (1953)

Curry (1958)

Dosdall (1979)

Edmunds, Jensen & Berner (1976)

Fittkau (1962)

Flint (1960)

Gaufin, Ricker, Miner, Milam & Hays (1972)

Gaufin, Nebeker & Sessions (1966)

Hamilton, Saether & Oliver (1969)

Hirvenoja (1973)

Hitchcock (1974)

Lewis (1974)

Nimmo (1971, 1974, 1977a, 1977b)

Pankratova (1970)

Roback (1957)

Ross (1944, 1957)

Schmid (1953, 1954)

Smith (1968)

Thienemann (1944)

Usinger (1956)

Ward & Whipple (1959)

Wiggins (1977)

11. AOSERP RESEARCH REPORTS

1.		AOSERP First Annual Report, 1975
2.	AF 4.1.1	Walleye and Goldeye Fisheries Investigations in the Peace-Athabasca Delta--1975
3.	HE 1.1.1	Structure of a Traditional Baseline Data System
4.	VE 2.2	A Preliminary Vegetation Survey of the Alberta Oil Sands Environmental Research Program Study Area
5.	HY 3.1	The Evaluation of Wastewaters from an Oil Sand Extraction Plant
6.		Housing for the North--The Stackwall System
7.	AF 3.1.1	A Synopsis of the Physical and Biological Limnology and Fisheries Programs within the Alberta Oil Sands Area
8.	AF 1.2.1	The Impact of Saline Waters upon Freshwater Biota (A Literature Review and Bibliography)
9.	ME 3.3	Preliminary Investigations into the Magnitude of Fog Occurrence and Associated Problems in the Oil Sands Area
10.	HE 2.1	Development of a Research Design Related to Archaeological Studies in the Athabasca Oil Sands Area
11.	AF 2.2.1	Life Cycles of Some Common Aquatic Insects of the Athabasca River, Alberta
12.	ME 1.7	Very High Resolution Meteorological Satellite Study of Oil Sands Weather: "a Feasibility Study"
13.	ME 2.3.1	Plume Dispersion Measurements from an Oil Sands Extraction Plant, March 1976
14.	HE 2.4	Athabasca Oil Sands Historical Research Project. Volume I: Design
15.	ME 3.4	A Climatology of Low Level Air Trajectories in the Alberta Oil Sands Area
16.	ME 1.6	The Feasibility of a Weather Radar near Fort McMurray, Alberta
17.	AF 2.1.1	A Survey of Baseline Levels of Contaminants in Aquatic Biota of the AOSERP Study Area
18.	HY 1.1	Interim Compilation of Stream Gauging Data to December 1976 for the Alberta Oil Sands Environmental Research Program
19.	ME 4.1	Calculations of Annual Averaged Sulphur Dioxide Concentrations at Ground Level in the AOSERP Study Area
20.	HY 3.1.1	Characterization of Organic Constituents in Waters and Wastewaters of the Athabasca Oil Sands Mining Area

21.		AOSERP Second Annual Report, 1976-77
22.	HE 2.3	Maximization of Technical Training and Involvement of Area Manpower
23.	AF 1.1.2	Acute Lethality of Mine Depressurization Water on Trout Perch and Rainbow Trout
24.	ME 4.2.1	Review of Dispersion Models and Possible Applications in the Alberta Oil Sands Area
25.	ME 3.5.1	Review of Pollutant Transformation Processes Relevant to the Alberta Oil Sands Area
26.	AF 4.5.1	Interim Report on an Intensive Study of the Fish Fauna of the Muskeg River Watershed of Northeastern Alberta
27.	ME 1.5.1	Meteorology and Air Quality Winter Field Study in the AOSERP Study Area, March 1976
28.	VE 2.1	Interim Report on a Soils Inventory in the Athabasca Oil Sands Area
29.	ME 2.2	An Inventory System for Atmospheric Emissions in the AOSERP Study Area
30.	ME 2.1	Ambient Air Quality in the AOSERP Study Area, 1977
31.	VE 2.3	Ecological Habitat Mapping of the AOSERP Study Area: Phase I
32.		AOSERP Third Annual Report, 1977-78
33.	TF 1.2	Relationships Between Habitats, Forages, and Carrying Capacity of Moose Range in northern Alberta. Part I: Moose Preferences for Habitat Strata and Forages.
34.	HY 2.4	Heavy Metals in Bottom Sediments of the Mainstem Athabasca River System in the AOSERP Study Area
35.	AF 4.9.1	The Effects of Sedimentation on the Aquatic Biota
36.	AF 4.8.1	Fall Fisheries Investigations in the Athabasca and Clearwater Rivers Upstream of Fort McMurray: Volume I
37.	HE 2.2.2	Community Studies: Fort McMurray, Anzac, Fort MacKay
38.	VE 7.1.1	Techniques for the Control of Small Mammals: A Review
39.	ME 1.0	The Climatology of the Alberta Oil Sands Environmental Research Program Study Area
40.	VE 7.1	Interim Report on Reclamation for Afforestation by Suitable Native and Introduced Tree and Shrub Species
41.	AF 3.5.1	Acute and Chronic Toxicity of Vanadium to Fish
42.	TF 1.1.4	Analysis of Fish Production Records for Registered Traplines in the AOSERP Study Area, 1970-75
43.	TF 6.1	A Socioeconomic Evaluation of the Recreational Fish and Wildlife Resources in Alberta, with Particular Reference to the AOSERP Study Area. Volume I: Summary and Conclusions
44.	VE 3.1	Interim Report on Symptomology and Threshold Levels of Air Pollutant Injury to Vegetation, 1975 to 1978
45.	VE 3.3	Interim Report on Physiology and Mechanisms of Air-Borne Pollutant Injury to Vegetation, 1975 to 1978

46.	VE 3.4	Interim Report on Ecological Benchmarking and Biomonitoring for Detection of Air-Borne Pollutant
47.	TF 1.1.1	A Visibility Bias Model for Aerial Surveys of Moose on the AOSERP Study Area
48.	HG 1.1	Interim Report on a Hydrogeological Investigation of the Muskeg River Basin, Alberta
49.	WS 1.3.3	The Ecology of Macrobenthic Invertebrate Communities in Hartley Creek, Northeastern Alberta
50.	ME 3.6	Literature Review on Pollution Deposition Processes
51.	HY 1.3	Interim Compilation of 1976 Suspended Sediment Data in the AOSERP Study Area
52.	ME 2.3.2	Plume Dispersion Measurements from an Oil Sands Extraction Plant, June 1977
53.	HY 3.1.2	Baseline States of Organic Constituents in the Athabasca River System Upstream of Fort McMurray
54.	WS 2.3	A Preliminary Study of Chemical and Microbial Characteristics of the Athabasca River in the Athabasca Oil Sands Area of Northeastern Alberta.
55.	HY 2.6	Microbial Populations in the Athabasca River

These reports are not available upon request. For further information about availability and location of depositories, please contact:

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