A STUDY OF AQUATIC ENVIRONMENTS IN THE SYNCRUDE DEVELOPMENT AREA, 1984

R.L. & L. Environmental Services Ltd.
and A.A. Aquatic Research Ltd.

ENVIRONMENTAL RESEARCH MONOGRAPH 1985-3
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1984

Prepared for

SYNCRUDE CANADA LTD.
ENVIRONMENTAL AFFAIRS DEPARTMENT

by

R.L. & L. ENVIRONMENTAL SERVICES LTD.

and

A.A. AQUATIC RESEARCH LTD.

FOREWORD

The following report describes the physical, chemical and biological characteristics of streams and lakes on Syncrude's leases 17 and 22 for the open-water period of 1984. The study was designed to determine what changes, if any, have occurred since the Mildred Lake facility began operating in 1978.

Syncrude's Environmental Research Monographs are published verbatim from final reports of professional environmental consultants. Only proprietary technical or budget-related information is withheld. Because Syncrude does not necessarily base decisions on just one consultant's opinion, recommendations found in the text should not be construed as commitments to action by Syncrude.

Syncrude Canada Ltd., welcomes public and scientific interest in its environmental activities. Please address any [redacted] or comments to Environmental Affairs, Sync[redacted] Street, EDMONTON, Alberta, T5J 3E5.

EXECUTIVE SUMMARY

INTRODUCTION

Syncrude Canada Ltd., which has operated an oil sands extraction plant at Mildred Lake since 1978, has undertaken various environmental studies associated with the development since 1971. The purpose of the 1984 investigation, which involved a multi-disciplinary study team, was to characterize and re-define aquatic habitats and resources in the Syncrude development area. In general, the results of the study indicate that the aquatic habitat, water quality, flora, and fauna of the aquatic systems in the development area are typical of those found in the oil sands region of Alberta.

The present study entailed seasonal sampling of the following environmental components: water quality, stream flow, aquatic habitat, and aquatic biota (phytoplankton, zooplankton, zoobenthos, macrophytes, and fish). The three major sampling periods (selected by Syncrude Canada Ltd.) were early June, summer (late July to early August), and early fall (late September to early October).

AQUATIC HABITAT AND FISH

Aquatic habitats associated with both flowing and standing waterbodies were investigated. Flowing water habitats included high-order streams (e.g., MacKay River - summer flows in 1984 in the 5 to 40

$m^3 \cdot s^{-1}$ range), medium-order streams (e.g., Poplar Creek - summer flows in the 0.2 to 3.0 $m^3 \cdot s^{-1}$ range), and low-order streams (e.g., West Interception Ditch - summer flows in the 0.02 to 0.1 $m^3 \cdot s^{-1}$ range). In terms of streamflow, the contribution of run-off water from the development area (i.e., Leases #17 and #22) to the major drainage systems (i.e., MacKay River and Athabasca River) is small. Due to major differences between systems with respect to streamflow, size, gradient, and accessibility to fish, the availability and quality of habitat varied substantially. Low-order streams (West Interception Ditch and tributaries, Bridge Creek, Lower Beaver Creek, minor tributaries to MacKay River) contained low quality habitat suited only for seasonal use by forage species such as fathead minnow, brook stickleback and lake chub. Medium-order streams (Upper Beaver Creek, Dover River, Poplar Creek) exhibited fish habitat in the low to moderate suitability range. These systems provide habitat on a seasonal basis for the larger species in addition to possible year-round habitat for forage species. The sources of the seasonal migrants are Beaver Creek Reservoir, which contributes white suckers to Upper Beaver Creek; the Athabasca River, which contributes Arctic grayling, northern pike, burbot, and suckers to Poplar Creek; and the MacKay River, which likely serves as a source of numerous species for the Dover River. The MacKay River was characterized by moderate fish habitat suitability; it provided habitat for approximately 20 species (including goldeye, walleye, northern pike, Arctic grayling, and suckers), several on a year-round basis.

Standing waterbodies in the study area (Beaver Creek Reservoir, Ruth Lake, Poplar Creek Reservoir, and Horseshoe Lake) were characterized by shallow to moderately-shallow maximum depths (range 2 to 18 m), gently sloping shorelines, and substrates dominated by organic debris. Macrophyte communities in the standing waterbodies were well developed. Submersed vegetation occurred around the periphery, to a depth of 2 m. Waterbodies within the diversion system (Ruth Lake, Beaver Creek Reservoir and Poplar Creek Reservoir) supported a simplified assemblage of fish species. Of the larger species, only white suckers were present. White suckers were abundant in the system, particularly in Beaver Creek Reservoir. The remaining species in these waterbodies were fathead minnow, brook stickleback, and lake chub. Available data indicate that Horseshoe Lake was used to a limited extent for rearing by northern pike from the Athabasca River.

WATER QUALITY

In the flowing water systems, the waters were brown in colour (except for the Athabasca River) and indicative of a typical boreal watershed. Characteristics considered deleterious or seriously inhibitory to the existing aquatic life were not encountered. The waters generally were alkaline and of the calcium bicarbonate type, although sodium bicarbonate waters frequently were present. Salinity levels in the streams remained uniform throughout the study, even though ionic dominance varied greatly. Except for some tributaries associated with the West Interception Ditch, the dissolved oxygen concentrations were above the minimum acceptable limit for fish. Concentrations of total nitrogen, total phosphorous, total iron, total manganese, and phenol frequently exceeded the Alberta Surface Water Quality Objectives. The sources of these substances are considered natural since no anthropogenic inputs are known.

Standing waterbodies in the study area (i.e., Beaver Creek Reservoir, Ruth Lake, Poplar Creek Reservoir, and Horseshoe Lake) exhibited similar water quality. The waters were slightly acidic to alkaline and of the sodium bicarbonate type, with notably high concentrations of sodium and chloride ions. Beaver Creek Reservoir and Poplar Creek Reservoir were stratified. In Beaver Creek Reservoir dissolved oxygen concentrations in the deepest areas were reduced to levels below that required by fish. In Poplar Creek Reservoir, anaerobic conditions prevailed in the hypolimnion in June and July, and hydrogen sulphide gas was present. In both reservoirs, the epilimnetic waters were well oxygenated. In Poplar Creek Reservoir, highest levels of specific conductance, total nitrogen, total phosphorous, and reactive silica were present in the hypolimnion. Concentrations of total nitrogen and total phosphorus exceeded the Alberta Surface Water Quality Objectives, indicating the eutrophic nature of the system. As was the case in the flowing water systems, concentrations of trace metals and elements were generally below the detection limits. Concentrations of iron, manganese, and phenol generally exceeded the water quality objectives. The above conditions are typical of shallow and medium depth boreal lakes rich in organic matter.

Except for some minor differences, the results of this investigation were similar to those described by other researchers for both flowing and standing water systems in the study area.

PHYTOPLANKTON

Phytoplankton communities in Beaver Creek Reservoir were dominated (on a volumetric basis) by Cryptophyta (cryptomonads) in the late spring, by Cyanophyta (blue-green algae) followed closely by Bacillariophyta (diatoms) in the summer, and by Bacillariophyta in the fall. Ruth Lake phytoplankton was dominated by Euglenophyta (euglenoids) in spring, Cyanophyta in summer, and Cryptophyta in fall. Phytoplankton in Poplar Creek Reservoir was dominated during all three study periods by Cyanophyta.

The dominance of the phytoplankton communities by Cyanophyta during the summer in the three waterbodies suggests that physical conditions, including macronutrient levels (i.e., low available nitrogen) and high turbidity levels (narrow trophogenic zone), were favourable for the species of this division. Overall, the species composition and trend in seasonal abundance did not differ substantially from that recorded in 1977.

ZOOPLANKTON

Zooplankton communities in Beaver Creek Reservoir, Ruth Lake, and Poplar Creek Reservoir exhibited a similar species composition in

1984. Calanoid copepods were dominated by **Diaptomus oregonensis**; common cyclopoids included **Ancanthocylops vernalis**, **Diacyclops thomasi** and **Mesocyclops edax**. Cladocerans were dominated by **Daphnia parvula** and other small species such as **Bosmina longirostris**. Rotifers generally were dominated by **Keratella** spp.

In general, fewer commonly occurring crustacean species and more rotiferan species were present in 1984 than in previous studies. Communities of all three waterbodies were dominated by relatively small-bodied species in 1984, although large-bodied species had been common in 1974 and 1977. Zooplankton-feeding fish (e.g., fathead minnows) may account, in part, for the apparent shift in community structure.

ZOOBENTHOS

Zoobenthic communities at stations within the study area generally exhibited diversity, abundance, and composition typical of the boreal region of northeastern Alberta. Dominant groups in the standing waterbodies included Oligochaeta and Chironomidae, and to a lesser extent, Mollusca, and the dipteran **Chaoborus**. Changes in the relative abundance among these groups with reference to earlier studies suggest that Beaver Creek Reservoir may be becoming more eutrophic, and that Poplar Creek Reservoir may exhibit hypolimnetic anoxia of longer duration during summer months.

Flowing water systems showed relatively low diversity. Dominant taxa were Chironomidae and Oligochaeta in depositional habitats, and

Simuliidae (blackflies) and various mayfly groups in erosional habitats. During spring and summer months, the community structure appeared related to stream discharge and energy source. Erosional habitats on the larger streams harboured a community that depends on seston (i.e., drifting living and dead organic matter) probably produced within the system. Benthic communities in erosional habitats on smaller streams and in depositional habitats likely rely on dead organic matter (e.g., leaves, etc.); these habitats supported lower densities and different types of benthos.

ACKNOWLEDGMENTS

This study was conducted jointly by R.L. & L. Environmental Services Ltd. and A.A. Aquatic Research Ltd. with the aid of a number of outside specialists. The individuals who authored sections of the report, their affiliation, and their area of contribution include the following:

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L. Hildebrand	R.L. & L. Env. Serv. Ltd.	Fisheries, Aquatic Habitat
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J. Ciborowski	University of Alberta	Aquatic Invertebrates
D. Beliveau	Bio-Aquatics Research & Consulting	Phytoplankton
E.A.D. Allan	University of Alberta	Aquatic Macrophytes

In addition, the following staff of R.L. & L. Environmental Services Ltd. assisted in field data collection, sample identifications, data analyses or report typing: R. Nelson, C. Pattenden, R. Pattenden, B. Anderson, T. Clayton, C. Brodie, H. Neelands, and C. Henderson. Dr. R.S. Anderson of AMRS Bios provided the zooplankton identifications and counts. Drafting was conducted by R. Dressler of RSD Canadian Geographics Ltd.

The study team would like to thank the staff of the Environmental Affairs Department of Syncrude Canada Ltd. for their input and assistance throughout the study. The study was initiated and directed by Dr. M. Aleksiuk. Additional input and suggestions were provided by Drs. M. MacKinnon and H. Boerger. Field coordination on the Syncrude lease area was provided by J. Doyle.

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (CONT'D)

LIST OF TABLES (CONT'D)

LIST OF TABLES (CONT'D)

LIST OF FIGURES

LIST OF FIGURES (CONT'D)

LIST OF FIGURES (CONT'D)

LIST OF FIGURES (CONT'D)

SECTION 1.0
INTRODUCTION

1.1 BACKGROUND

Syncrude Canada Ltd. has operated an oil sands extraction plant at Mildred Lake in northeastern Alberta since 1978. Prior to development of the project, the natural streamflow of Beaver Creek and other surface drainages was diverted from the mine and plant area. To accomplish this for the major inflow, Beaver Creek was re-channeled via Ruth Lake and a second impoundment (Poplar Creek Reservoir) to Poplar Creek and eventually the Athabasca River. To re-direct runoff from other local drainages along the west side of the development area, a 17 km long ditch was constructed. This channel, completed in May 1976, was termed the West Interception Ditch. The flows from four small tributaries presently enter the ditch and are diverted northward entering Bridge Creek, a tributary to Lower Beaver Creek. A small dam, located near the southern end of the interception ditch, diverts the flows from a fifth tributary southward into Beaver Creek Reservoir.

Syncrude Canada Ltd. has conducted numerous baseline and impact related studies of the aquatic resources in the vicinity of their development; these have been summarized in detail in a report entitled "Biophysical impact assessment for the new facilities of the Syncrude Canada Ltd. Mildred Lake Plant" by Syncrude Canada Ltd. (1984).

1.2 OBJECTIVES

The objective of the present study was to characterize the aquatic habitats and resources in the Syncrude development area, specifically those in Lease 17, Lease 22, and the Beaver Creek Diversion System. The study comprised an assessment (on a seasonal basis where appropriate) of the following environmental components: water quality, streamflow, physical habitat, and biological resources in the major waterbodies in the Syncrude development area.

1.3 STUDY AREA

The study area encompassed the major waterbodies in the Syncrude development area, including those in the Beaver Creek Diversion System (Figure 1.1). Specifically, the major waterbodies sampled for one or more study components were as follows:

a) MacKay River and tributaries;
b) Lower Beaver Creek;
c) Bridge Creek;
d) West Interception Ditch and four tributaries;
e) Horseshoe Lake;
f) Upper Beaver Creek;
g) Beaver Creek Reservoir and one tributary (Creek B1);
h) Ruth Lake;
i) Poplar Creek Reservoir;

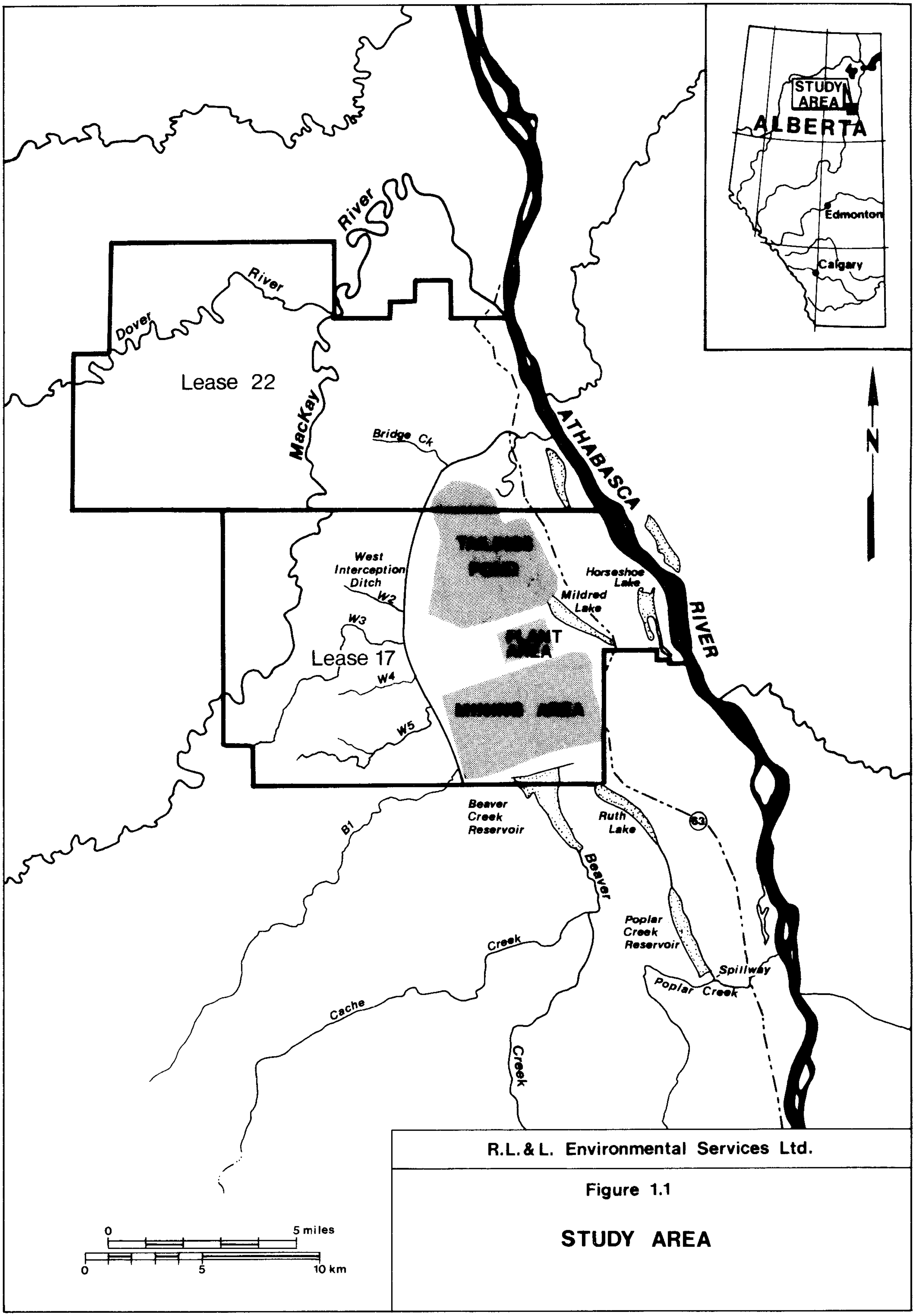

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Figure 1.1

STUDY AREA

j) Poplar Creek; and

k) Athabasca River (water quality sampling only).

Due to the importance of riverine habitat outside the Syncrude lease area to fish populations within the MacKay River system, the study area was extended to km 76 on the MacKay River and km 40 on the Dover River.

The present study also included sampling of the various unnamed tributaries entering the West Interception Ditch (W.I.D.). Prior to the construction of the W.I.D., tributaries designated as Creek No. 1, Creek No. 2, Creek No. 3, and Creek No. 4 entered Beaver Creek through the area presently occupied by the mine site (Noton and Chymko 1978; O'Neil 1979; Syncrude Canada Ltd. 1984). The construction of the W.I.D. intersected these streams and in the case of Creek No. 3, intersected two branches of the system creating two separate drainages. In this study, the watersheds have been designated as Creek W2 (formerly Creek No. 1), Creek W3 (formerly Creek No. 2), Creek W4 (formerly the northern branch of Creek No. 3), and Creek W5 (formerly the southern branch of Creek No. 3). W1 refers to a drainage situated to the northwest of the W.I.D. that lacks a defined stream channel, but which flows into the W.I.D. at numerous points along its course. The designation "W" indicates those drainages entering the W.I.D. The creek entering the section of the ditch that diverts flow southward to Beaver Creek Reservoir previously has been referred to as Creek No. 4 by the above authors. In the present study, Creek No. 4 and the section of the drainage ditch to Beaver Creek

Reservoir have been designated Creek B1 since this system is contiguous with the reservoir rather than the northward draining section of the West Interception Ditch. Consequently, Creek B1, including the southward draining section of the diversion ditch, will be discussed as part of the "Beaver Creek Diversion System" section of the report (i.e., Section 5).

1.4 APPROACH

In response to the conditions specified by Syncrude Canada Ltd., the study was conducted on a seasonal basis, with major sampling periods in early June, late July to early August, and late September to early October. Through consultation with personnel in the Environmental Affairs Department, the study was designed to include the following components:

a) physical habitat including discharge measurements;
b) water quality;
c) phytoplankton and zooplankton (Beaver Creek Reservoir, Ruth Lake and Poplar Creek Reservoir only);
d) benthic macroinvertebrates;
e) macrophytes (delineation of major macrophyte communities in the four standing waterbodies only); and
f) fish.

In addition, Syncrude Canada Ltd. requested that the following tasks be undertaken for each of 14 drainage basins identified within the study area:

a) calculate the drainage areas;

b) differentiate the drainage basin terrain (predominantly muskeg or highland);

c) determine frequency of beaver impoundments (from aerial photographs);

d) determine longitudinal gradient profiles of the major stream channel in each basin; and

e) estimate discharges at the mouths of selected streams.

The report has been divided into nine chapters with the results presented according to the major river/lake systems or diversion system. Within each system or major waterbody, the results are presented by study component (e.g., habitat, water quality, zooplankton, etc.).

SECTION 2.0

METHODOLOGY

2.1 STUDY CHRONOLOGY AND LOGISTICS

Field surveys were conducted in the late spring, summer, and fall of 1984. Authorization to proceed with the spring fish survey and the water quality sampling on the Athabasca River was received from Syncrude Canada Ltd. in a letter dated 18 May 1984. Field work on these components commenced on 22 May and continued to 31 May. Authorization to proceed with the remainder of the study program was received on 5 June upon finalization of the study plan with Syncrude Canada Ltd. Field activities associated with the study components were conducted concurrently (Table 2.1). For most study components, sampling was conducted by two-person study teams; however, an additional person was employed for the boat electroshocking survey (spring segment) on the MacKay River. Access to the majority of sample stations was achieved either by truck, outboard powered boat, or canoe; during the fall fisheries surveys on the MacKay and Dover rivers and during the water quality/benthic surveys on the MacKay River, access was gained by helicopter. The fall habitat survey on the MacKay River was carried out using a Zodiac inflatable boat; access to the river was by helicopter. A jet-drive river boat and an all-terrain vehicle were used to access MacKay River fisheries sample stations during the spring and summer surveys. Accommodation was provided by Syncrude Canada Ltd. at the Alberta Environment Mildred Lake Research Facility.

Table 2.1 Sampling chronology for the various study components examined on waterbodies within the Syncrude Development Area, 1984.

	Habitat		Water Quality			Benthic Invertebrate			Phytoplankton/ Zooplankton			Fisheries			Macro-phyte
	Summer 18-22 July	Fall 5-10 Sept.	Spring 15-21 June	Summer 23-31 July	Fall 21-27 Sept.	Spring 15-19 June	Summer 24-30 July	Fall 21-26 Sept.	Spring 15-16 June	Summer 24-25 July	Fall 23-25 Sept.	Spring 22-31 June	Summer 15-17 July	Fall 21-18 Sept.	Summer 24-26 July
MacKay River		X	X	X	X	X	X	X				X	X	X	
M1, M3, M4, M5, M7, M8, M9, M10, M11			X	X	X										
M2, M6			X	X	X	X	X	X							
Dover River		X	X	X	X	X	X	X				X	X	X	
Dover River Tributary (D1)			X	X	X										
W.I.D.	X											X	X	X	
W2												X			
W3			X	X	X	X	X	X							
W4			X	X	X										
W5			X	X	X										
Bridge Creek	X		X	X	X	X	X	X				X	X	X	
Lower Beaver Creek	X		X	X	X	X	X	X				X	X	X	
Upper Beaver Creek		X[a]	X	X	X	X	X	X				X		X	
Creek B1	X		X	X	X	X	X	X							
Beaver Creek Res.			X	X	X	X	X	X	X	X	X	X[b]	X		X
Ruth Lake			X	X	X	X	X	X	X	X	X	X[b]	X		X
Poplar Creek Res.			X	X	X	X	X	X	X	X	X		X		X
Poplar Creek		X[c]	X	X	X	X	X	X				X	X	X	
Athabasca River			X[d]	X	X										
Horseshoe Lake			X	X	X								X	X	X

[a]survey conducted on 26 September

[b]survey conducted on 13 June

[c]survey initiated in 5-10 September, completed in 21-28 September period

[d]survey conducted on 16 May

2.2 NUMBER AND DISTRIBUTION OF SAMPLE STATIONS

The selection of sample stations (Figures 2.1 to 2.9) was determined through discussions with Syncrude Canada Ltd. A minimum number of stations was selected to adequately characterize the various biological and chemical components of waterbodies within the study area, and allow for a reasonable comparison to previous study results.

The selection and distribution of sample stations were based on the location of previous study stations (i.e., in the Beaver Creek Diversion System), the geographical and physical characteristics of a waterbody in relation to the study component objectives, and the accessibility of the station.

To facilitate future location and identification, the 1984 sample stations were marked using paint or survey ribbon; a detailed description of location and identifying marks at each station is provided in Appendix A, Table A1.

2.3 AQUATIC HABITAT

Fluvial systems and standing waterbodies in the study area were investigated to identify pertinent physical habitat characteristics. The surveys were done in a systematic and reproducible manner to facilitate comparison of data between systems and on a year-to-year basis. The survey focused on the streams in the study area, as they had not

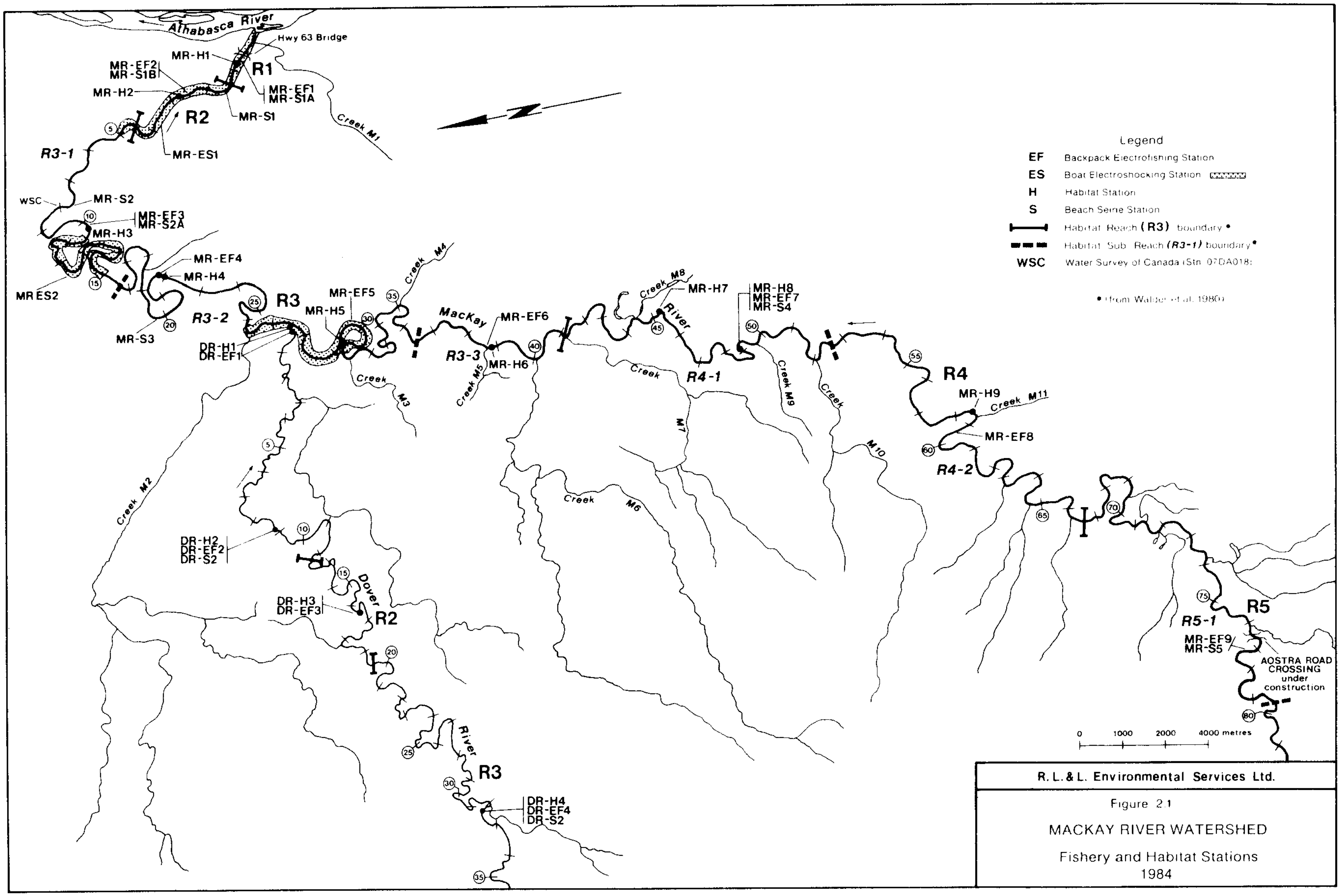

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Figure 2.1

MACKAY RIVER WATERSHED

Fishery and Habitat Stations
1984

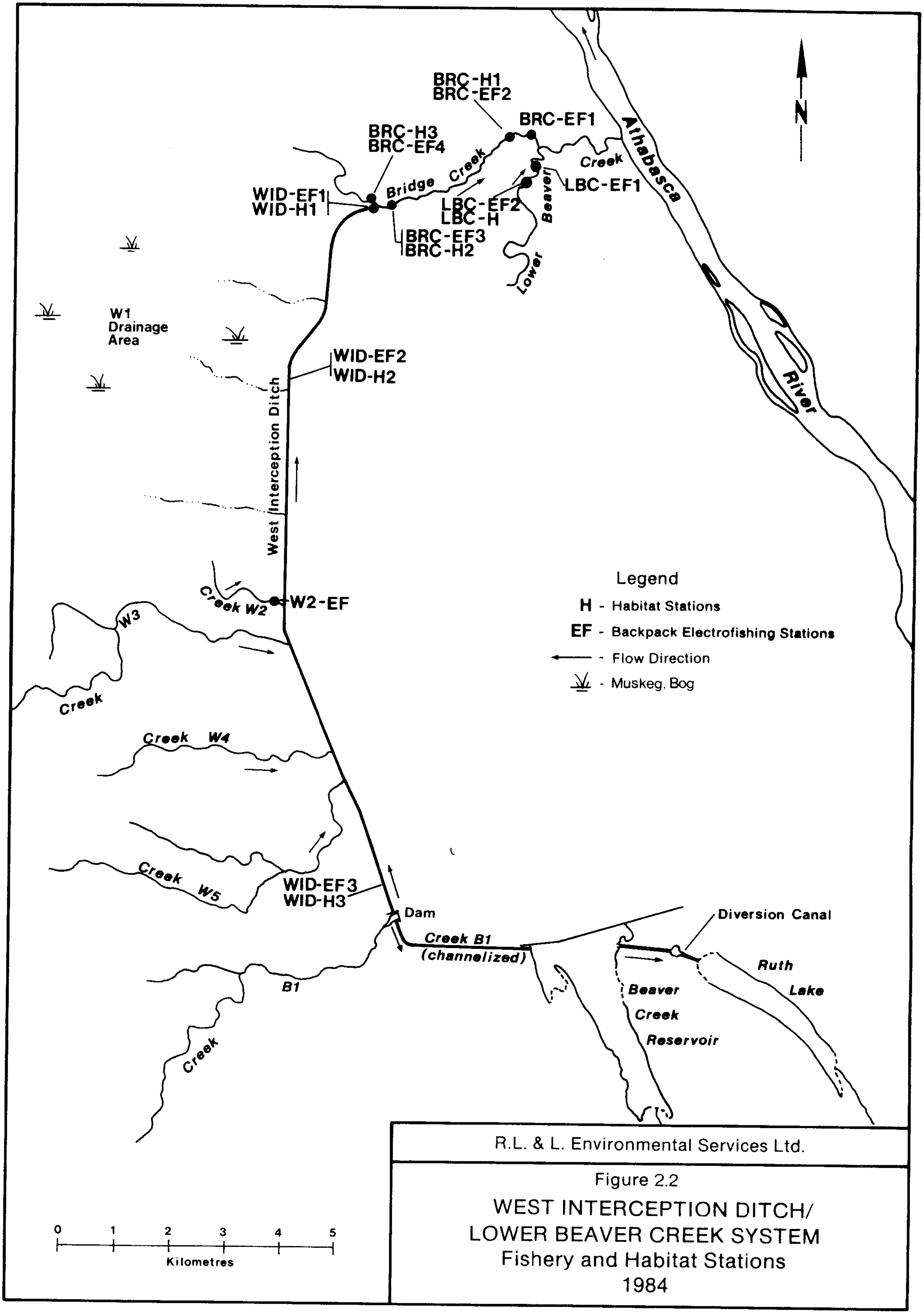

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Figure 2.2

WEST INTERCEPTION DITCH/
LOWER BEAVER CREEK SYSTEM
Fishery and Habitat Stations
1984

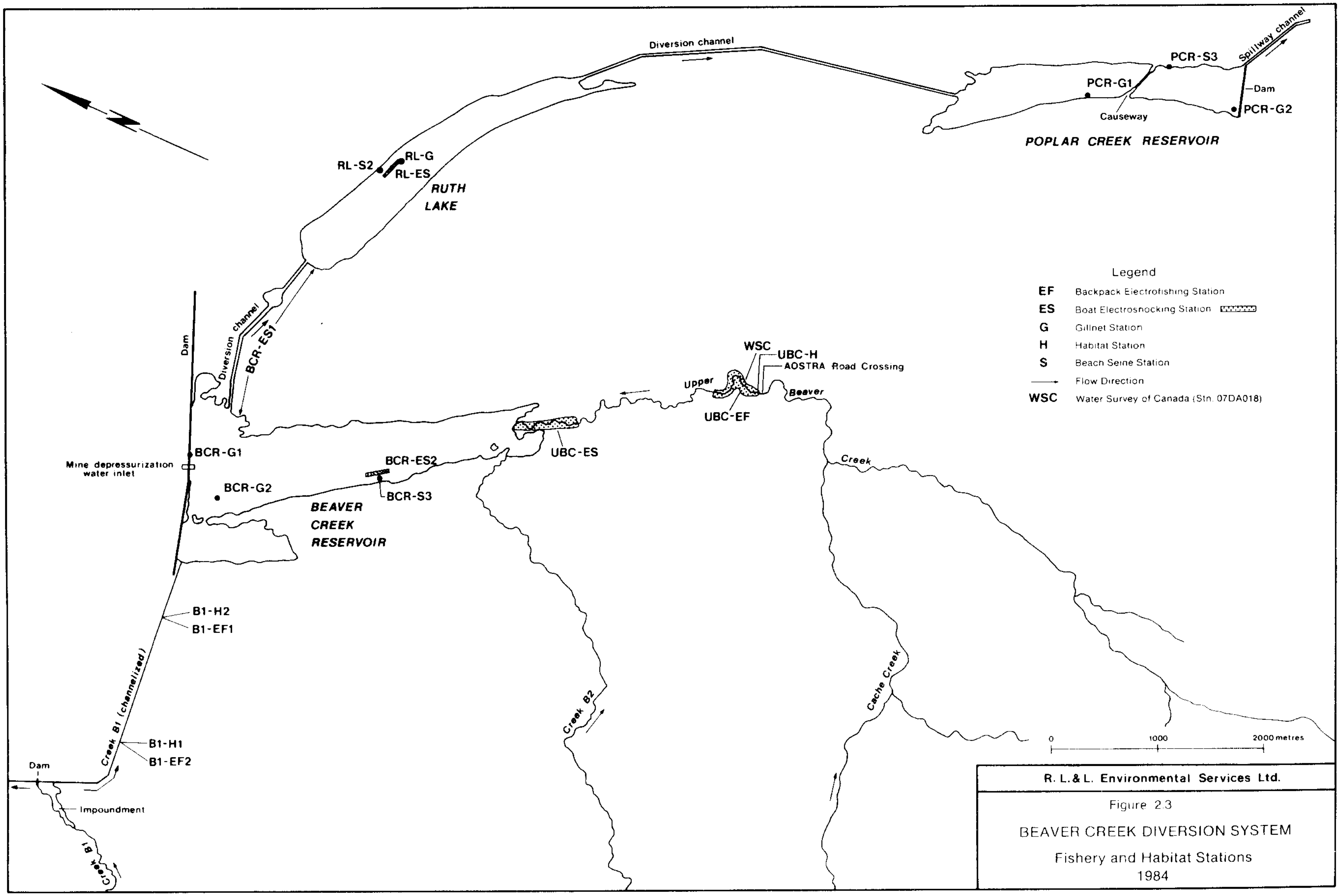

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Figure 2.3

BEAVER CREEK DIVERSION SYSTEM

Fishery and Habitat Stations

1984

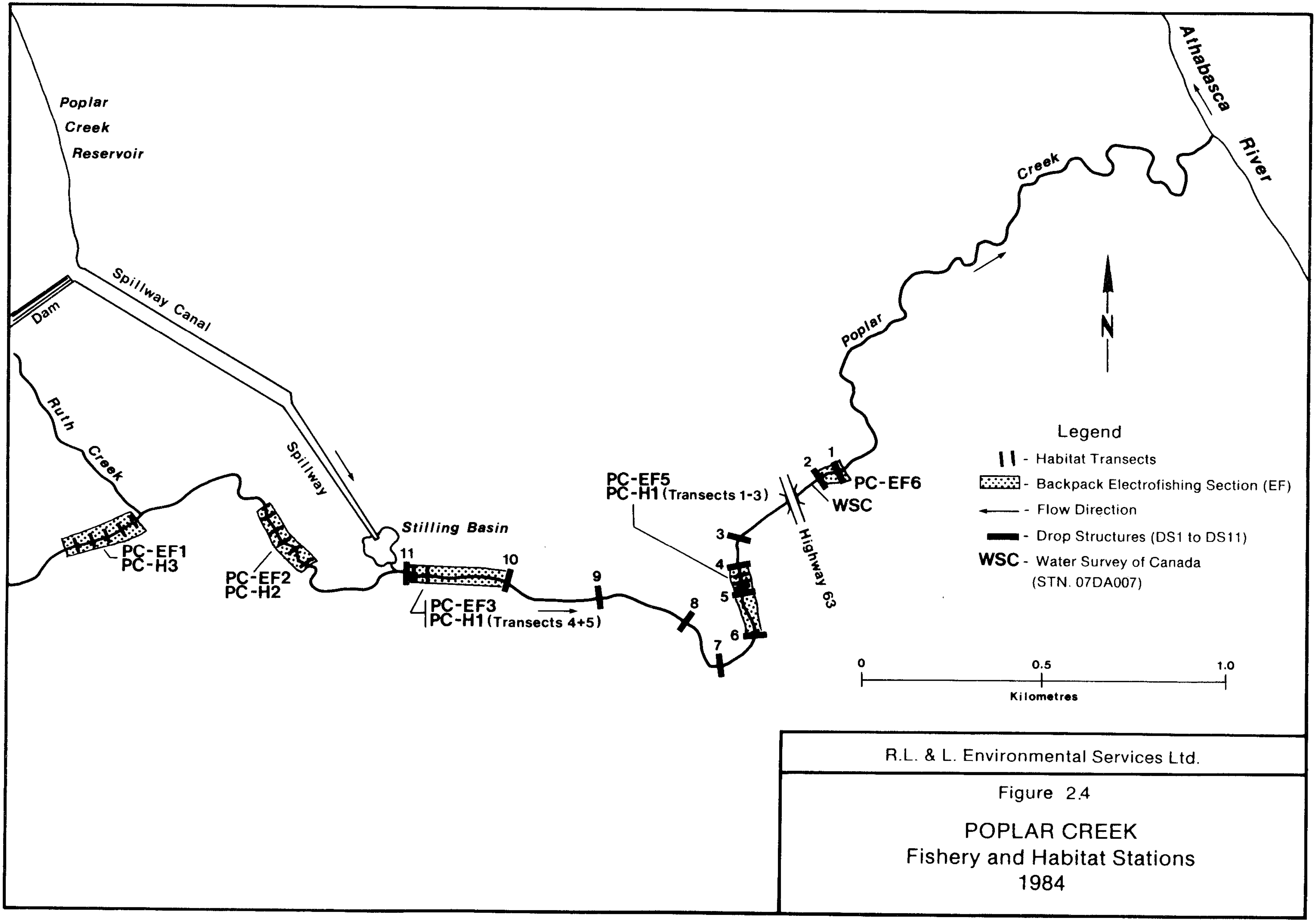

Figure 2.4

POPLAR CREEK
Fishery and Habitat Stations
1984

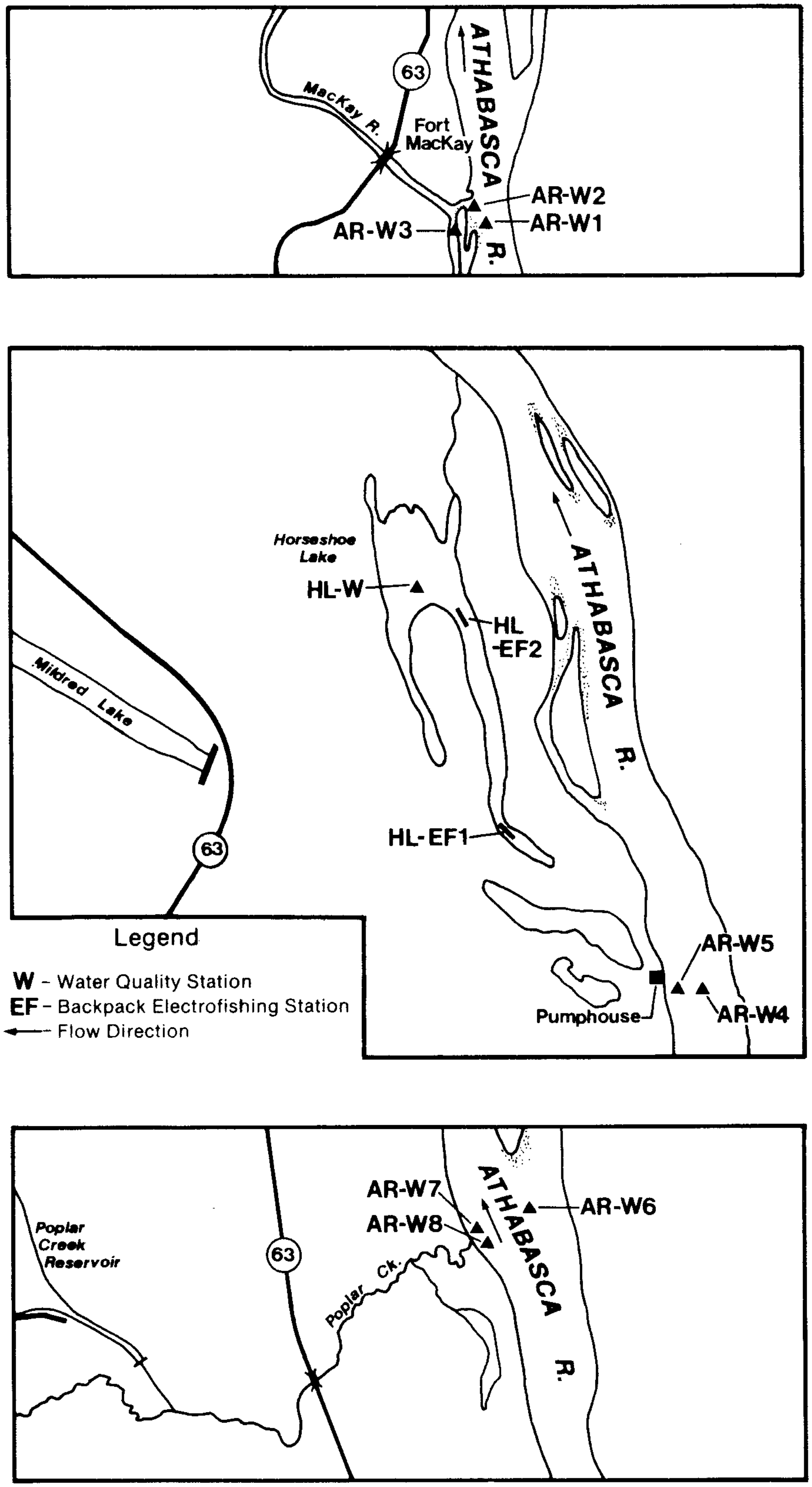

Figure 2.5 Athabasca River and Horseshoe Lake Water Quality and Fishery Stations 1984.

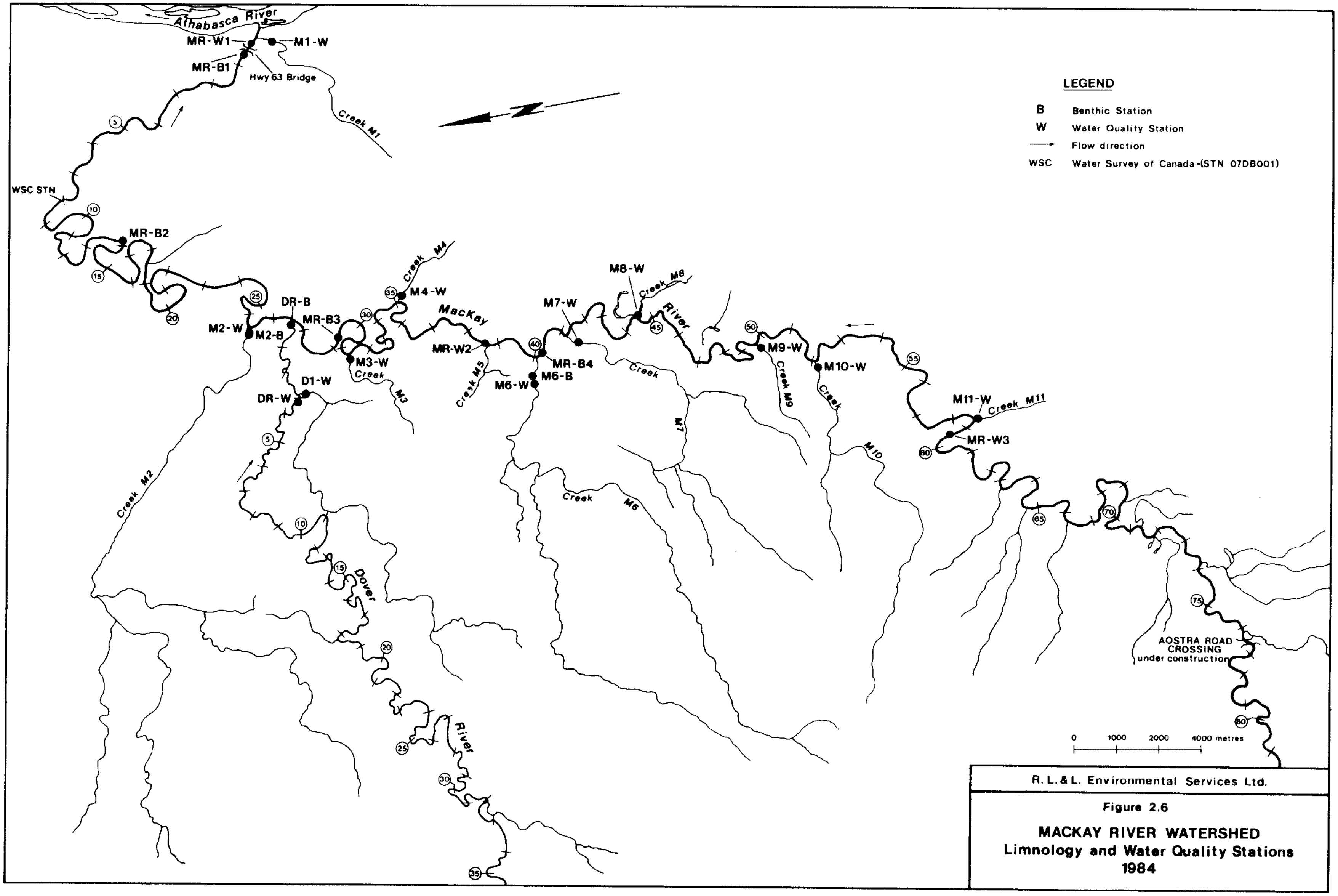

Figure 2.6

MACKAY RIVER WATERSHED
Limnology and Water Quality Stations
1984

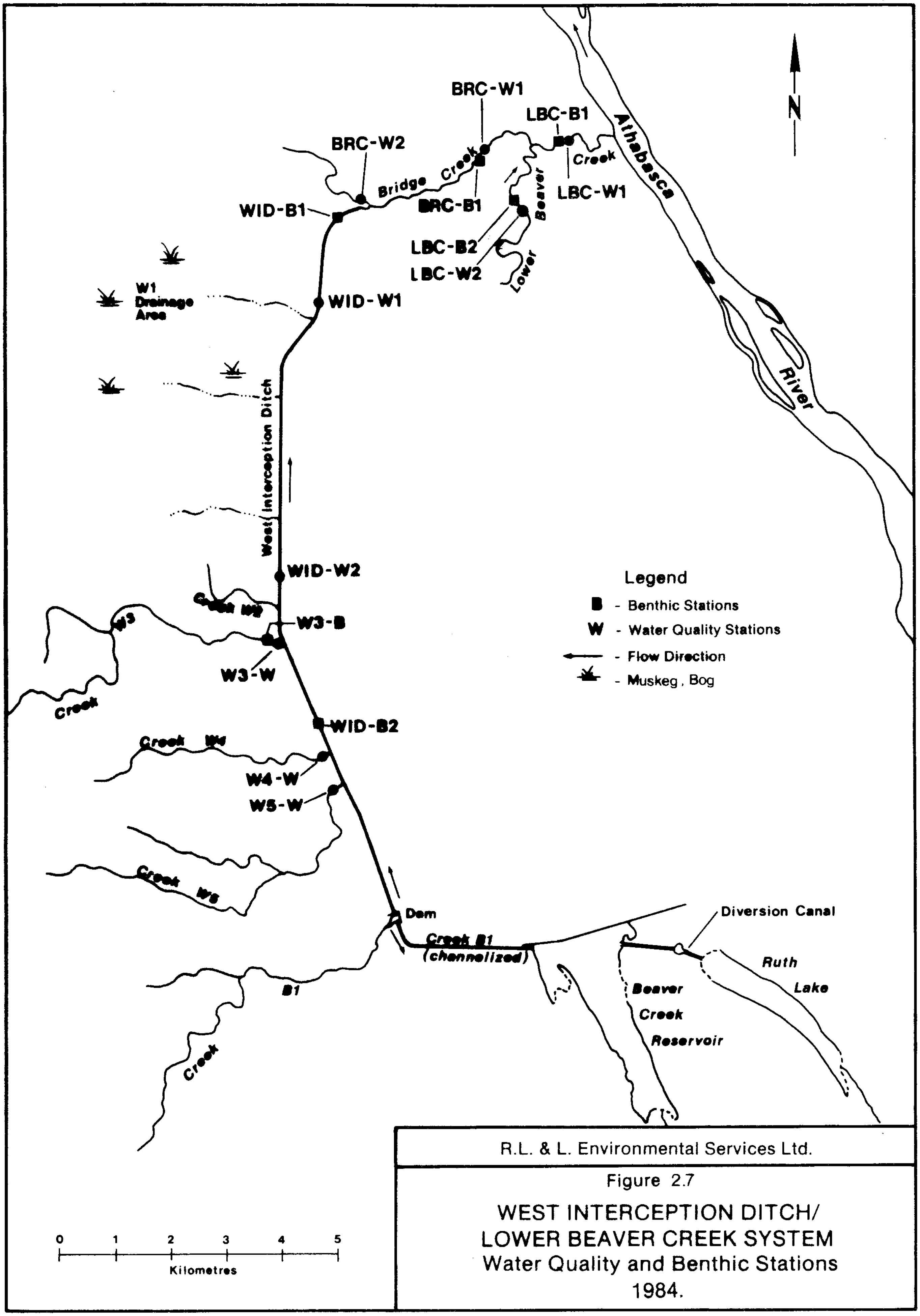

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Figure 2.7

WEST INTERCEPTION DITCH/
LOWER BEAVER CREEK SYSTEM
Water Quality and Benthic Stations
1984.

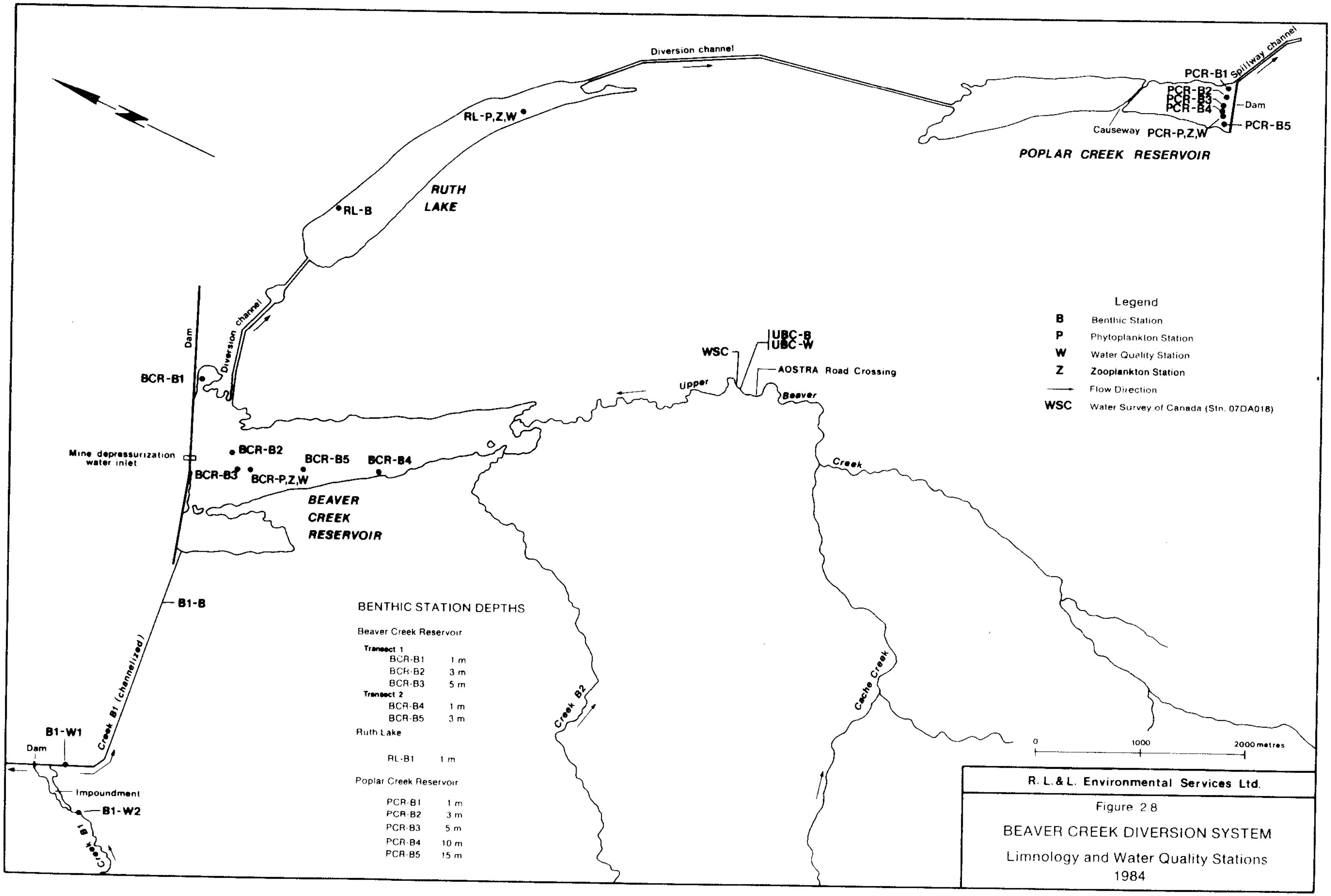

Figure 2.8

BEAVER CREEK DIVERSION SYSTEM

Limnology and Water Quality Stations

1984

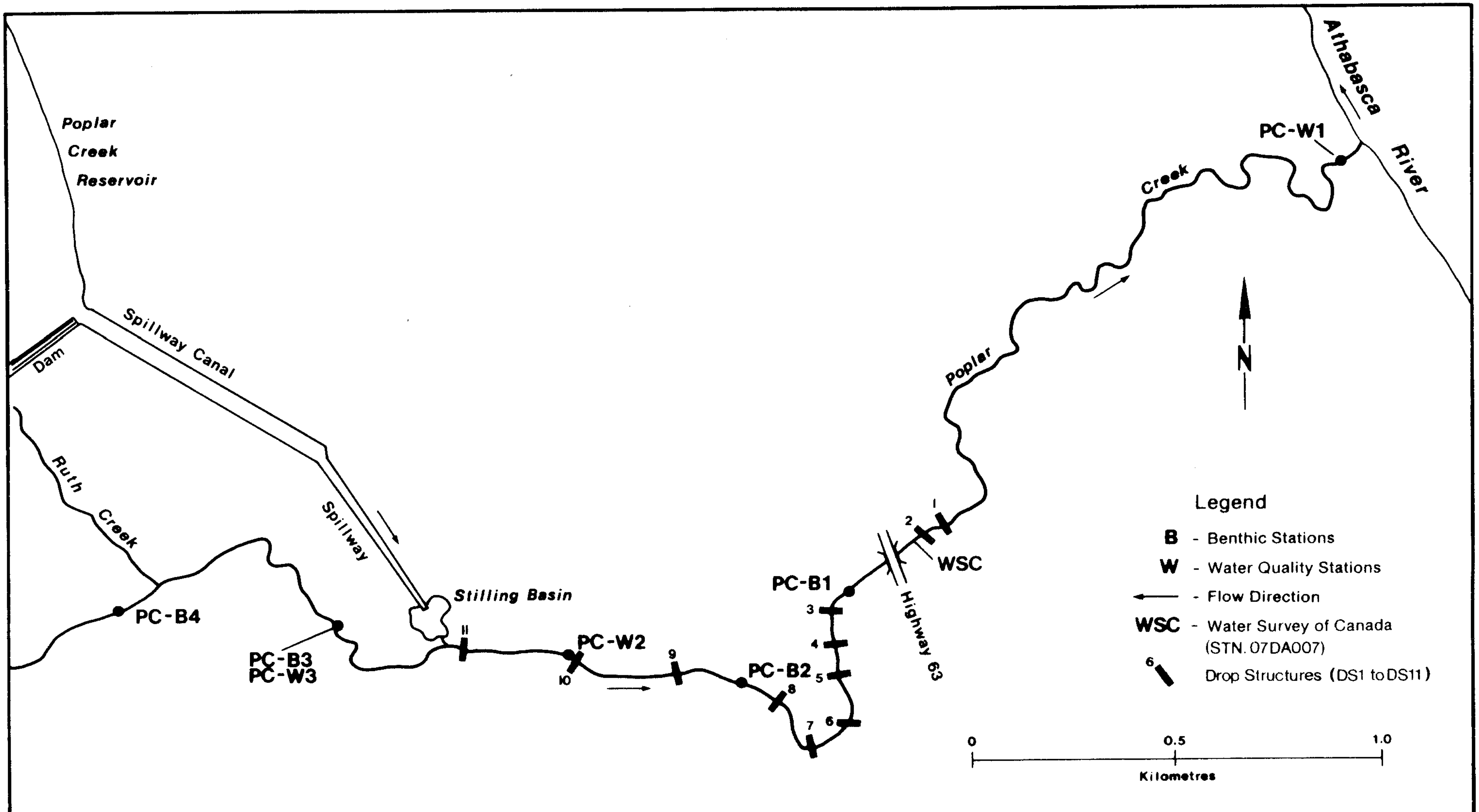

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Figure 2.9

POPLAR CREEK
Water Quality and Benthic Stations
1984

previously been examined in detail. Habitat surveys on the fluvial systems were scheduled during base flow periods to ensure that habitat features were recognizable and that low-flow limitations were evident (Table 2.1).

2.3.1 FLUVIAL SYSTEMS

2.3.1.1 Pre-typing

Fourteen drainage basins within Lease 17 and Lease 22 were identified by Syncrude Canada Ltd. Information on various drainage features was obtained for each of these systems using a 1:20 000 airphoto mosaic (lease area only) and 1:50 000 NTS maps (area outside lease). Drainage area was determined with a polar planimeter. Major beaver ponds along the streams (within the lease area only) were enumerated from the 1:20 000 airphoto mosaic. The surface area of the ponds was estimated using a dot grid matrix. Stream order ratings were assigned (from 1:50,000 NTS maps) for the mainstems of study streams according to the method of Strahler (1957). First-order streams are defined as those that have no tributaries; second-order streams receive only first-order channels, and so on. Stream lengths were measured using the method described by Herrington and Tocher (1967). Stream gradient profiles were based on the intersection of 2 m (1:20 000 map) and 10 m (1:50 000 maps) contour intervals. Stream discharge was estimated using the midsection procedure as described by Church and Kellerhals (1970). Velocities were recorded, using a Marsh-McBirney Model 201 electronic current meter, at

0.6 of the water column depth where channel depths were less than 0.76 m; at deeper stations the two-point method was employed (0.2 d, 0.8 d).

Prior to conducting habitat field surveys, the major study streams were delineated into discrete habitat reaches. Necessary pre-typing information was obtained from initial mapping data, from previous studies, and from information obtained during the fishery investigation program. To characterize pertinent habitat variables, sample stations were established in each of the discrete habitat reaches. The habitat stations were pre-designated in the office to minimize bias at the station selection stage. Randomness with respect to location of individual transects was achieved by using a pre-determined interval approach (e.g., first transect established at station marker; second transect 50 m upstream of first transect, etc.)

2.3.1.2 Field Procedures

Habitat stations generally consisted of multiple transects (transect cluster). The number of transects was determined by the degree of homogeneity of the habitat in the reach. Generally, only three to five transects were necessary to ensure that all habitat types were encountered. It was not feasible (due to logistic and time constraints) to sample multiple transects at habitat stations on the MacKay River, Dover River, and Upper Beaver Creek. Transect data were supplemented by habitat observations recorded during the downstream float survey on the MacKay River. An aerial habitat reconnaissance was undertaken on the Dover River (lower 40 km), and habitat observations were recorded. The spacing between transects was dependent upon the recurrence pattern of habitat features in that particular reach (i.e., wide enough spacing to ensure that all cover types had an equal opportunity of being sampled). In the present study, intervals between transects were set at either 25 m or 50 m (depending on stream size). Stations were marked or located in relation to visible landmarks to facilitate future sampling. Where feasible, aluminum plates were fastened to mature trees (above the high water mark) in the immediate vicinity of the initial transect (T1). The remaining transects were chained off from the preceeding transect and marked with flagging and/or fluorescent paint marks on nearby trees. A description of the various transect locations is provided in Appendix A, Table A1. Representative photographs were taken at each of the transect locations. A wide range of habitat descriptors was used to characterize conditions along each of the transects (Table 2.2). These variables were derived from several aquatic habitat methodologies which have been used extensively in previous studies in western Canada and the western United States (Platts 1979; Chamberlin 1980; U.S. Fish Wildlife Service 1981; Armantrout 1982; Nielsen and Johnson 1983), and from previous studies conducted in the tar sands area (O'Neil 1979, 1982). The system was modified, where necessary, after initial field testing in the present study area. Information obtained in the field was recorded on standardized habitat forms (Appendix B, Table B1).

2.3.2 STANDING WATERBODIES

Information on the physical habitat characteristics of standing waterbodies in the study area was collected during the course of the

Table 2.2 Aquatic habitat variables described at transect locations in the Syncrude Development Area, 1984.

Variables	General Description of Variables
Channel width	(Rooted) between rooted vegetation; (Wetted) active channel.
Gradient	Local Gradient (%) determined at habitat stations using a clinometer.
Mean Depth	Mean of depths at transect intervals (min. of 1/4, 1/2, 3/4 width).
Mean Velocity	Mean of velocities at transect intervals; 0.6d or 0.2d and 0.8d (d = depth).
Cover Type Distribution	Distribution (%) of various cover types along transect.
- Riffle	Area of increased velocity, broken water surface.
- Run	Area with rapid, non-turbulent flows (water surface unbroken).
- Flat	Area with low velocity, near laminar flow, depositional area.
- Pool	Area of increased depth and reduced velocity, more defined than Flat.
Pool Type	Distribution (%) of various types, based on depth, width, cover.
- Class 1	Low quality, diameter <1/4 a.c.w. (average channel width), depth <0.75 m, low cover.
- Class 2	Low to moderate quality, diameter <1/4 a.c.w., depth <0.75 m, moderate cover.
- Class 3	Moderate quality; diameter <1/4 a.c.w., depth >0.75 m, moderate cover.
- Class 4	Moderate to high quality, diameter >1/4 a.c.w., depth 0.75-1.0 m, low - moderate cover.
- Class 5	High quality, diameter >1/4 a.c.w., depth >1.0 m, moderate - high cover.
Macrophytes/algae	Extent of channel coverage on transect, Class 1 - 5 (<5% to >75%).
Bank Features	Description of various parameters on LUB (left bank viewed upstream) and RUB (right bank viewed upstream).
- Condition (Cond.)	Degree (%) alteration from optimal for that habitat type.
- Stability (Stab.)	Resistance to erosion (plant cover, cobble etc.), Class 1-4 (poor to excellent).
- Undercut (Under.)	Extent (cm)of bank undercutting at ends of transect.
- Overhang (Over.)	Extent (cm) of vegetation overhanging channel at ends of transect.
- Slope	Bank angle (Degrees) measured with clinometer.
- Cover	Dominant type: Class 1 (>50% bare), Class 2 (grass/forbs), Class 3 (trees), Class 4 (shrubs)
- Depth	Water depth (cm) at edge of wetted channel.
Substrate Distribution[a]	Dominant size class along transect, assigned at intervals.
- Fines	Sand, Silt
- Gravels[b]	(VFG (0.2 - 0.4cm), FG (0.4 - 0.8 cm) MG (0.8 - 1.6 cm) CG (1.6 - 3.2 cm), VCG (3.2 - 6.4 cm)
- Larges[c] (cobble, boulder)	SC (6.4 - 12.8 cm), LC (12.8 - 25.6 cm), SB (25.6 - 51.2), LB (57.2 cm+)
- Bedrock (BR)	Bedrock
- Embeddedness (EMB)	Extent Surface area of coarse substrate surrounded/covered by silt.

[a]Modified Wentworth Classification

[b]VFG = very fine gravel; FG = fine gravel; MG = medium gravel; CG = coarse gravel; VCG = very coarse gravel.

[c]SC = small cobble; LC = large cobble; SB = small boulder; LB = large boulder.

Note: local gradient may differ from average gradient (i.e., determined for reach) due to specific variation in slope, or imprecise site measurements; useful for general comparison between stations only.

fishery, water quality, and benthic invertebrate component studies, and from descriptions provided in previous studies. This included information on depth distribution, substrate type and aquatic macrophytes. The macrophyte survey was carried out from a canoe, surveying the entire periphery of each waterbody. At irregular intervals, observations of aquatic macrophyte distribution were made along transects perpendicular to the depth contours. Vegetation generally was located at depths less than 2.0 m of water; for this reason, most of the plants could be observed from the surface. A plant hook was pulled over the bottom to determine the presence of aquatic vegetation and the extent of dispersal into the deeper portions of the lake or reservoir. A sounding line was used to measure depth. Plant identification follows the description in the Flora of Alberta, Second Edition (Moss 1983).

2.4 WATER QUALITY

The water quality program was designed to characterize the physical and chemical parameters of streams, lakes, and reservoirs within Syncrude's Leases 17 and 22, and the Beaver Creek Diversion system. A total of 45 sampling stations was established (Figures 2.5 to 2.9); of these, 22 were primary and 23 were secondary stations. Primary stations are distinguished from secondary stations by the extended number of parameters analyzed. Primary stations generally were located on the mainstem of the streams, or in lakes and reservoirs. The secondary stations were located mainly on tributaries (Appendix A, Table A1).

2.4.1 FIELD PROCEDURES

In the fluvial systems, water samples were collected at mid-channel and mid-depth using either the hand held method or a Van Dorn waterbottle (capacity: 4.5 L), depending on depth. Water samples from standing waterbodies in the study area were collected using a Van Dorn waterbottle.

On Beaver Creek Reservoir, during each survey, composite samples (containing an equal volume of water from each of 0.3 m, 2.5 m, and 4.5 m depths) were obtained from the deepest area of the reservoir. The composite samples were analyzed for the primary set of parameters. An additional sample, obtained at the same location but from a depth of 5.0 m, was analyzed for the secondary set of parameters.

Primary and secondary samples also were obtained from Poplar Creek Reservoir. During the June and July surveys, composite samples comprised of water from 1.0 m, 10.0 m, and 15.0 m depths, were analyzed for the primary set of parameters. Additional samples obtained from 15.0 m depth were analyzed for the secondary set of parameters. During July when Poplar Creek Reservoir was stratified, two additional samples (at 2.0 m and 11.0 m, indicative of waters in the epilimnion and hypolimnion, respectively) were obtained for primary analysis. During the September survey, the composite sample was comprised of water from depths of 2.0 m, 9.5 m, and 17.0 m. The epilimnion and hypolimnion samples were obtained from 5.0 m and 15.0 m depths, respectively. The sampling location in September was changed from the previous surveys (by approximately 30.0 m) to attain a greater maximum depth.

On Ruth Lake, during the June and July surveys, composite samples contained equal portions of water from 1.0 m and 2.5 m depths. In September, because the lake was isothermal, the sample was obtained from 1.5 m depth. Samples from all periods were analyzed for the primary set of parameters. Water samples from Horseshoe Lake were collected from mid-depth (0.5 m) and analyzed for the primary set of parameters.

In the field, selected portions of the water samples were preserved according to the following:

Parameter(s)	Bottle Type	Preservative
Metals	1 L plastic	5 mL 1:1 HNO_3
T. Kjeldahl N & Phosphorus	250 mL plastic	5 mL 1:1 H_2SO_4
Oil & Grease	1 L glass	5 mL 1:1 H_2SO_4
Mercury	150 mL glass or plastic	2 mL $K_2Cr_2O_7$-HNO_3
Phenol	1 L glass	10 mL phenol preservative
Cyanide	250 mL plastic	1 mL 6N NaOH
Sulphide	250 mL plastic	2 mL 1M Zinc Acetate

Except for the samples for calcium and magnesium determinations, water samples were not filtered prior to analyses. All samples were kept refrigerated prior to air shipment to the laboratory.

Recordings of temperature, pH, specific conductance, dissolved oxygen, and turbidity were obtained in the field using the following meters:

Parameter	Meter
1) Dissolved oxygen/ temperature	IBC Dissolved Oxygen and Temperature Monitor Field Unit
2) Specific conductance	Chemtrix Type 700
3) pH	Broadley James Digital Model 10511-LCD
4) Turbidity	HF Instruments Model DRT 15

To ensure accurate readings with the meters, each was calibrated periodically with standards of known concentrations or values. For the dissolved oxygen meter, readings periodically were compared to measurements on a given sample as determined by the azide modification of the Winkler method.

On the lakes and reservoirs, the above mentioned physical parameters, except for turbidity, generally were measured at 1.0 m intervals; turbidity measurements were taken on the composite sample.

2.4.2 LABORATORY PROCEDURES

Chemical analyses of the water samples were conducted by Chemex Labs Alberta (1984) Ltd. in Calgary. The analytical methods, summarized in Table 2.3, are based on methods adopted by Environment Canada (1983), and Alberta Environment (1977).

Table 2.3 Summary of analytical methods

Parameter	NAQUADAT CODE	Method	Detection Limit
Calcium	20103L	A.A.	10.0 µg·L^{-1}
Magnesium	12102L	A.A. by Direct Aspiration	0.1 mg·L^{-1}
Sodium	11103L	Flame Photometry on Autoanalyzer	0.1 mg·L^{-1}
Potassium	19103L	Flame Photometry on Autoanalyzer	0.1 mg·L^{-1}
Chloride	17203L	Colourimetry on Autoanalyzer	0.1 mg·L^{-1}
Sulphate	16306L	Colourimetry on Autoanalyzer	1.0 mg·L^{-1}
PP-Alkalinity	10151L	Potentiometric Titration	0.5 mg·L^{-1}
Alkalinity total	10101L	Potentiometric Titration	0.5 mg·L^{-1}
Carbonate	06301L	Calculated	
Bicarbonate	06201L	Calculated	
Total Hardness	10602L	Calculated	
Silica (Reactive)	14101L	Colourimetry - Heteropoly Blue	20.0 µg·L^{-1}
Total Filterable Residue	10451L	Gravimetric	10.0 mg·L^{-1}
Total Non-Filterable Residue	10401L	Gravimetric	10.0 mg·L^{-1}
Chemical Oxygen Demand	08301L	$K_2Cr_2O_7$ method	1.0 mg·L^{-1}
Oil & Grease	06521P	Petroleum Ether Ext.	1.0 mg·L^{-1}
Total Nitrogen	07601L	UV Digestion followed by Colourimetry on Autoanalyzer	25.0 µg·L^{-1}
Nitrate + Nitrite	07110L	Colourimetry on Autoanalyzer	3.0 µg·L^{-1}
Total Kjeldahl	07015P	Colourimetry on Autoanalyzer	0.05 mg.L^{-1}
Total Ammonia	07555P	Colourimetry on Autoanalyzer	1.0 µg·L^{-1}
Total Phosphorus	15406P	Colourimetry on Autoanalyzer	2.0 µg·L^{-1}
Total Organic Carbon	06005L	Infrared Analysis	0.2 mg·L^{-1}
Total Inorganic Carbon	06052L	Infrared Analysis	0.5 mg·L^{-1}
Phenol	06537P	Automated 4-Aminoantipyrine Colourimetry	1.0 µg·L^{-1}
Ortho-Phosphorus	15256L	Colourimetry on an Autoanlyzer	2.0 µg·L^{-1}
Arsenic, T.	33004P	A.A. with H_2SO_4 + HNO_3 Digestion	0.2 µg·L^{-1}
Selenium, T.	34005P	A.A. with H_2SO_4 + HNO_3 Digestion	0.2 µg·L^{-1}
Boron, T.	05106L	Colourimetry on an Autoanalyzer	0.1 µg·L^{-1}
Cadmium, T.	48002P	A.A. with Solvent Ext.	1.0 µg·L^{-1}
Copper, T.	29005P	A.A. with Solvent Ext.	1.0 µg·L^{-1}
Iron, T.	26004P	A.A. by Direct Aspiration	50.0 µg·L^{-1}
Chromium, T.	24004P	A.A. with Graphite Furnace	1.0 µg·L^{-1}
Manganese, T.	25004P	A.A. with Direct Aspiration	10.0 µg·L^{-1}
Zinc, T.	30005P	A.A. with Solvent Ext.	1.0 µg·L^{-1}
Lead, T.	82002P	A.A. with Solvent Ext.	1.0 µg·L^{-1}
Vanadium, T.	23004P	A.A. Graphite Furnace	0.001 mg·L^{-1}
Nickel, T.	28002P	A.A. with Solvent Ext.	1.0 µg·L^{-1}
Mercury, T.	80011P	Flameless A.A. on an Autoanalyzer	0.05 µg·L^{-1}
Cyanide, T.	06608L	Colourimetry on an Autoanalyzer	2.0 µg·L^{-1}
Tannin & Lignin	06551L	Tungstophosphoric and Molybdophosphate acid Colourimetry	0.1 mg·L^{-1}
Sulphide	16101L	Spectrophotometer	±10%
Fluoride	09105L	Specific Ion electrode	0.05 mg·L^{-1}
Threshold Odour Number	02001L	Sniff Test	1.0 unit
Colour	02021L	Colourmetric Platinum·Cobalt Technique	5.0 units
Surfactants	10701L	Automated Solvent Ext.	0.02 mg·L^{-1}
Carbon Chloroform Extraction		Concentration by Activated Carbon and Chloroform Ext.	0.2 mg·L^{-1}
Biochemical Oxygen Demand	08202L	Measuring oxygen demand producted by carbonaceous and Nitrogenous material	1.0 mg·L^{-1}
Silver, T.	47302L	A.A. with Solvent Ext.	1.0 µg·L^{-1}
Cobalt, T.	27302L	A.A. with Solvent Ext.	1.0 µg·L^{-1}
Titanium, T.	92500L	A.A. Furnace Technique	10.0 µg·L^{-1}
Aluminum, T.	13302L	A.A. using graphite furnace	1.0 µg·L^{-1}
Barium	56001L	A.A. using graphite furnace	0.01 mg·L^{-1}
Methyl Mercaptan		Gas chromatograph	0.1 mg·L^{-1}

Notes: A.A. - Atomic Absorption; Ext. - Extraction; T. - Total

2.4.3 DATA ANALYSIS

The description of the water quality includes a comparative evaluation (description of similarities and dissimilarities) among sampling stations for each monitoring period within each of the drainage systems. The evaluation focuses on four major groups of parameters. These include: physical parameters (temperature, pH, dissolved oxygen, specific conductance), major ions, nutrients, and metals. The behaviour of the parameters and their possible sources (i.e., whether natural or anthropogenic) are discussed. The evaluation addresses the hydrological influence on water quality. Where possible, concentrations of parameters are compared to the Alberta Surface Water Quality Objectives (Alberta Environment 1977) and the Environment Canada - Water Quality Sourcebook (McNeely et al. 1979). Where possible, characterization of the waterbodies is substantiated with references.

2.5 PHYTOPLANKTON

2.5.1 FIELD SAMPLING

Discrete vertical samples were collected on a seasonal basis at one location in each of Beaver Creek Reservoir, Ruth Lake, and Poplar Creek Reservoir (Figure 2.8). Samples were collected with a Van Dorn waterbottle (capacity: 4.5 L) at 1 m depth intervals, and composited for the water column, to compensate for vertical stratification. Samples were preserved with 5% acid-Lugol's solution.

2.5.2 LABORATORY PROCEDURES

Prior to analysis, the phytoplankton samples were agitated vigorously, and 10 mL subsamples (50 mL for Ruth Lake, 24 September 1984) were dispensed into 22 mm I.D. glass sedimentation chambers (Lund et al. 1958) and allowed to sediment for 24 h (two stage sedimentation was utilized for the 50 mL sample). After sedimentation, half the basal area was scanned qualitatively with a Prior (Model 29331) inverted microscope to measure and record cell dimensions of species present for subsequent cell volume estimates. Species encountered at this level, but not enumerated, were recorded as present (P). Taxonomic keys of Prescott (1970), Taft and Taft (1971) and Webber (1971) were used for species identifications. Counts of individual cells were made at a magnification of 775X on horizontal transects of the chamber's diameter; a minimum of 200 algal units were enumerated. Individual mean cell volume estimates obtained in this manner were used to calculate total cell volumes for each enumerated species.

2.6 ZOOPLANKTON

2.6.1 FIELD PROCEDURES

Six vertical hauls were taken at a single station near the deepest point in each sampled waterbody (Figure 2.8). Zooplankton hauls were made with a Wisconsin style net of Nitex mesh (net mouth diameter 133.4 mm; mesh aperture 0.080 X 0.080 mm), combined, and preserved in 5% formalin.

2.6.2 LABORATORY PROCEDURES

Zooplankton counts were made under a Wild M5 stereomicroscope; identifications were made using Wild M11 or M40 compound microscopes equipped with phase-contrast.

The basic taxonomic keys used for crustacean plankton were those of Brooks, Wilson and Yeatman (**in** Edmondson 1959), supplemented by the keys of Brooks (1957), Smirnov (1971), Brandlova et al. (1972), Flössner (1972) and Kiefer (1978). The basic taxonomic key used for rotifers was the Voigt revision by Koste (1978), supplemented by the keys of Ahlstrom (1943) and Ruttner-Kolisko (1974). The keys used for the Chaoboridae were those of Cook (1956) and Saether (1970).

In comparison with previous investigations in the study area, some different taxonomic nomenclature has been used during the present study. **Diacyclops thomasi** is considered by Dr. F. Kiefer, the leading expert in the field, to be the correct designation of **Cyclops bicuspidatus thomasi** (Kiefer 1978) and, therefore, has been used throughout this report. Similarly, and for consistency, **Acanthocyclops vernalis** has been used in preference to **Cyclops vernalis**, and **Diacyclops navus** in preference to **Cyclops navus**.

The combined samples (i.e., six hauls) from each waterbody for each sampling date were subsampled using a modified Folsom-style splitter.

For the reservoirs, from one to three sixteenths of the original sample was counted until approximately 400 mature or identifiable organisms (excluding nauplii, early copepodids, and rotifers) were processed. For Ruth Lake, the total number counted was sometimes less than 400 because of the low total numbers of identifiable forms encountered (e.g. in the September sample, a count of the total combined sample gave less than 100 mature or identifiable crustaceans). Replication in the aliquots was very good, based on counts of certain mature forms in three aliquots or in the total sample (see Appendix C, Tables C1 to C3). Total zooplankton numbers calculated for the combined samples for each station and date were converted to numbers per cubic metre by determining the total theoretical volume filtered (i.e., net mouth area · depth of haul · six hauls), assuming a net efficiency of 100%. Although the latter assumption probably results in an underestimate of actual numbers, especially for small nauplii and rotifers, it has been retained in this study to allow data comparisons with previous studies (i.e., Syncrude Canada Ltd. 1975; Noton and Chymko 1978).

Nets cannot be considered adequately quantitative for sampling rotifers, because coarser mesh sizes (especially those greater than 0.065 mm) may allow small forms to escape, or because clogging of the net may occur; consequently, numbers derived from net hauls should at best be considered as an "order of magnitude" indication of abundance (Green 1977). Because all 1984 samples were similar in having relatively low accumulations of phytoplankton and detritus which could contribute to net aperture blockage and variable efficiency, it is likely that plankton net efficiency was similar for all samples.

Body sizes of crustacean plankton other than nauplii were determined according to the scheme employed by Noton and Chymko (1978) in order to derive a biomass estimate permitting a comparison of the 1984 data with the data gathered in 1977. Conversion formulae and rationale were the same as those employed by Noton and Chymko (1978).

Because only three samples were taken during the open water period in this study, comments on seasonal changes in zooplankton species composition and abundance and comments on changes since previous studies, will be general rather than detailed.

2.7 BENTHIC INVERTEBRATES

2.7.1 LENTIC SAMPLES

2.7.1.1 Field Procedures

Benthic invertebrate samples were collected from each of Beaver Creek Reservoir, Ruth Lake, and Poplar Creek Reservoir (Figure 2.8) during the spring, summer, and fall survey periods (Table 2.1). Sampling depth varied with lake morphology as shown below:

	Season			Sample Depth (m)				
Waterbody	Spring	Summer	Fall	1	3	5	10	15
Beaver Creek Reservoir								
Transect 1 (Stations B1, B2, B3)	X	X	X	X	X	X		
Transect 2 (Stations B4 and B5)		X	X	X	X			
Ruth Lake	X	X	X	X				
Poplar Creek Reservoir	X	X	X	X	X	X	X	X

Three replicate Ekman grab samples (area: 0.023 m^2) were taken at designated sampling depths. Each sample was washed through a sieve bucket (0.250 mm square mesh) to remove silt and fine debris. Stones, twigs, leaves and large plant fragments were discarded after examination for adhering animals. The remaining sample was placed in a tray and repeatedly flooded with lake water. The water and organic material were poured through a 0.250 mm square mesh sieve. Remaining inorganic material was inspected for molluscans and stonecased caddisflies, and then discarded. The organic fraction was placed in a collection jar (to which was added 1.2 mL lignin pink dye; saturated solution in 95% ethanol) and preserved in 10% formalin.

In order to obtain a more extensive taxonomic list of invertebrates from each waterbody, qualitative dip net samples (0.250 mm square mesh) were taken from shoreline areas in summer and fall, when macrophyte growth was abundant.

2.7.1.2 Laboratory Procedures

In the laboratory, samples were rinsed through a graded series of sieves (mesh aperture 4.00, 2.00, 1.00, 0.500, 0.250 mm). Fractions retained in each sieve were sorted and invertebrates identified using a dissecting microscope. Fractions that contained large amounts of organic material were subsampled. Identifications were made to the lowest practical taxonomic level. Taxonomic keys used for identification included Edmondson (1959), Clarke (1973), Edmunds et al. (1976), Baumann et al. (1977), Wiggins (1977), Merritt and Cummins (1978) and Pennak (1978). Because of the possibility of contamination of the samples by planktonic forms during sample collection and processing, entomostracan crustaceans (Cladocera, Copepoda, Ostracoda) were not included in the analyses.

2.7.2 LOTIC SAMPLES

2.7.2.1 Field Procedures

Invertebrate samples were collected from the streambed of flowing waterbodies during each of the spring, summer and fall surveys (Table 2.1) at the stations identified by Syncrude Canada Ltd. (Figures 2.6 to 2.9; Appendix A, Table A1). An additional station (on Creek B1) was added during the summer and fall periods after consultation with Syncrude Canada Ltd. Triplicate samples were taken at each lotic sampling station.

A Neill cylinder sampler (Neill 1938), enclosing an area of 0.1 m^2 (mesh aperture 0.210 mm), was used to collect invertebrates from erosional habitats. Two of 18 stations (Upper Beaver Creek and Creek W3) were characterized by depositional habitats and were too deep to be sampled with a cylinder sampler. At these stations, an Ekman grab sampler was employed following the procedures used in lentic habitats. A third station (West Interception Ditch, WID-B2) also was depositional, but was shallow enough to permit use of the cylinder sampler.

The cylinder sampler was pushed 10 cm into the streambed. Cobbles were removed by hand and rubbed to dislodge adhering invertebrates. The remaining substrate was thoroughly disturbed with a metal rod and by hand to a depth of 20 cm. A sampling effort of two to three minutes was expended per sample. Contents of the catchment net were emptied into plastic trays. Trays were repeatedly flooded with water and agitated to suspend organic material. The slurry was poured through a 0.250 mm square mesh sieve. Remaining inorganic material was examined for stonecased invertebrates and then discarded. Organic material was placed in a collection jar (to which was added 1.2 mL of lignin pink dye) and preserved in 10% formalin.

Qualitative samples also were taken at each sample station, using a dip net (0.250 mm square mesh). Aquatic sweep and/or kick samples were taken from adjacent pools, riffles, along banks, and among submerged wood and vegetation. Material collected from each habitat was placed in a water-filled tray. Each tray was examined for two to three minutes. Representatives of all visibly distinct taxa were removed and preserved in 10% formalin.

2.7.2.2 Laboratory Procedures

Sorting and identification techniques for the stream sampling program usually were identical to those used in lake surveys; however, samples containing large quantities of bitumen were pretreated prior to fractioning and sorting. This involved draining the sample, flooding with butanol and draining off this fluid. The sample was then repeatedly flooded with mineral spirits (i.e., varsol) to dissolve the bitumen. A final butanol wash was used to remove residual thinner before fractioning and sorting.

2.7.3 ESTIMATION OF BIOMASS

Reger et al. (1982) demonstrated a very precise relationship between ash-free dry mass (AFDM) of a wide variety of lentic and lotic invertebrates, and the mesh aperture of sieves that would retain them. That study used a graded series of nine sieves with apertures ranging from 0.250 to 4.0 mm. Data from Reger et al. (1982) were reanalyzed to produce a regression equation suitable for use with the sieve series employed in the present study. The resultant equation provided an excellent fit to the data (r^2 = 0.996; Figure 2.10). The regression equation was used to interpolate expected AFDM of an organism retained by a sieve of given aperture as shown below:

Sieve Aperture (mm)	AFDM (mg)
0.250	0.013
0.500	0.049
1.00	0.189
2.00	0.729
4.00	2.819

Total biomass of organisms was estimated by multiplying the number of organisms retained per sieve by the appropriate interpolated AFDM value, then summing the products.

2.7.4 SPECIES DIVERSITY

Species diversity (H') at all lotic and lentic stations was estimated using the Shannon-Weaver function as expressed by Lloyd et al. (1968).

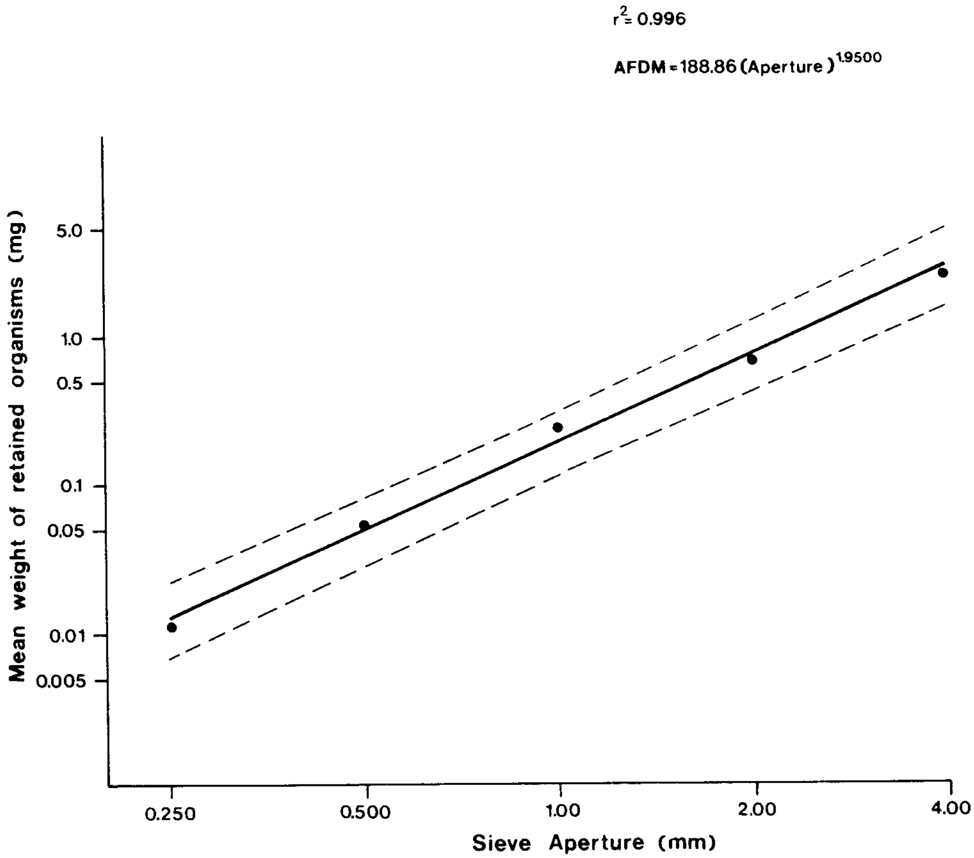


Figure 2.10 Relationship between mean ash free dry mass (AFDM) of aquatic organisms retained in sieves and sieve aperture. Dashed lines represent 95% prediction limits. Data from Reger et al. (1982). Data points are means of composite measurement of at least 7000 animals.

This was calculated according to the formula:

$$H' = -\Sigma p_i \mathrm{Log}_2 p_i$$

where: p_i was the decimal fraction of total individuals in all replicates belonging to the i^{th} taxon.

To avoid bias induced by over-representation of taxa identifiable to lower taxonomic categories, taxa were considered only at the family level.

A second measure of diversity, taxonomic richness (i.e., total number of taxa present in all collections at a station), also was determined, to make maximum use of the additional information gained from the qualitative sweep samples.

2.7.5 MULTIVARIATE ANALYSIS

Multivariate analysis techniques such as cluster analysis (CA) and principal component analysis (PCA) are frequently used in the assessment of water quality (Green 1979). These techniques summarize data sets (matrices) into graphical forms that are relatively easy to interpret.

Cluster analysis graphically illustrates the degree of similarity among pairs of groups of similar sites, but distorts the relationships among members of larger (i.e., more dissimilar) clusters (Sneath and Sokal 1973). In contrast, PCA is characterized by faithful representation of similarity between major groups or clusters, but is notorious for distorting apparent similarity between (compositionally) close neighbours (Sneath and Sokal 1973).

In this study, cluster analysis (Wishart 1978) was used to group river sampling stations that were similar in macroinvertebrate composition. Dendrograms were used to display station groupings.

Seasonal progression in running water systems induces marked changes in zoobenthic composition independently of most habitat characteristics. Because interstation similarities and differences were of primary interest in this study, data from each sampling season were analysed independently.

Principal component analysis (PCA) was used to estimate which taxa were most responsible for differences in taxonomic composition of invertebrate communities among lotic sampling stations. The details of PCA have been outlined by several authors including Davis (1973) and Orloci (1975). Briefly, PCA summarizes the information from a covariance matrix (for abundance data) or correlation matrix (for presence/absence data) in terms of new components. The first principal component accounts for the greatest proportion of total variation among stations. Successive components contribute progressively smaller portions of the total variation. The first two or three principal components usually account for most of the variability in the original data.

Further analysis may then be performed to evaluate the relationship between abundance of individual taxa among sites, and each principal component. A correlation between a taxon and a principal component implies that differences in the abundance of that particular taxon among stations are largely responsible for the observed overall differences in composition. This information, together with knowledge of the ecological requirements of these taxa, permits speculation as to what environmental features (natural or otherwise) may be controlling zoobenthic distribution among stations in the study area.

In this study, the abundance data were transformed to logarithms (Ln(X+1)) before the statistical analysis was performed. To eliminate the potential undue influence of rare species, only taxa that constituted at least 10 % of the total number in any one sample were included in the analysis.

Detailed results of the multivariate analyses are presented in Appendix H; general findings are summarized in the Discussion (Section 8.4).

2.8 FISHERIES

Fisheries sampling stations were established in 1984 on the waterbodies indicated by Syncrude Canada Ltd. (Figures 2.1 to 2.5; Table 2.1). The sampling method employed was dictated by the physical characteristics of the system. At sample stations established during previous studies (i.e., O'Neil 1979, 1982), and sampled again in the present study, similar sampling gear and procedures were employed. The designations of these stations also were retained. Sample stations established in 1984 (i.e., those without a prior station designation) were generally coded in a consistent manner, with station numbers increasing with increased upstream distance. In some systems, however, the inclusion of a new station between established stations resulted in non-sequential station codes.

2.8.1 FIELD PROCEDURES

Four fish sampling techniques were employed in the present study: boat electroshocking (ES), backpack electrofishing (EF), seining (S) and gill netting (G). Of these, only boat electrofishing had not previously been employed in the study area. A description of each of the sampling methods is provided below.

2.8.1.1 Gill Netting

In standing waterbodies, standardized gill net gangs were used as the primary method for sampling larger fish. These gangs consisted of 15.2 m by 2.4 m net panels of the following mesh sizes: 3.8 cm, 6.4 cm, 8.9 cm, and 10.2 cm (stretched measure). All nets were of monofilament construction.

In all instances, nets were set overnight. Catch per unit effort (CUE) was calculated on a standard unit of effort, namely, the application of one net-unit over a 12 h (overnight) period. The combined surface area of the 3.8 cm, 6.4 cm, and 8.9 cm mesh panels constituted one net-unit. The 10.2 cm mesh was excluded from the calculations as this mesh size failed to catch fish. In addition, CUE values were calculated from a net-unit applied overnight (regardless of time set) with no indexing to a standard 12 h sampling duration.

Gill nets were set at or near the surface of the water column. Water depth of set locations generally ranged from 3.5 m to 6.0 m (Beaver Creek Reservoir), 2.0 m to 2.5 m (Ruth Lake), and 3.0 m to 4.0 m (Poplar Creek Reservoir). In each waterbody, test-gangs were set at locations sampled in previous studies (Figure 2.3).

2.8.1.2 Seining

An 8.6 m by 1.7 m seine was used to collect smaller fish (i.e. cyprinids and young-of-the-year) in standing waterbodies and in the MacKay and Dover rivers. The main body of the seine was constructed of 1.0 cm mesh (stretched measure), with a centre mounted collection bag constructed of 0.3 cm mesh (stretched measure).

Seine hauls in standing waterbodies were conducted at stations established during previous studies (Figure 2.3). Three seine hauls were conducted at each station to account for localized differences in habitat type and the habitat preferences displayed by the various fish species present. At seine stations on the MacKay and Dover rivers (Figure 2.1), the number of hauls at each station varied from one to three, depending on the availability of shoreline area suitable for sampling by this method.

Haul length in standing waterbodies was set at 25 m; in flowing waterbodies, haul lengths ranged from 20 m to 35 m. Maximum water depth at sample stations varied from 30 cm to 120 cm. Median depth (i.e. the depth at a point midway between shore and the offshore end of haul) was recorded for each haul to allow characterization of the depth profile. Other parameters recorded at each haul location included extent of aquatic vegetation, substrate type, and fish distribution-habitat preferences.

Sampling efficiency during each haul was rated on a scale of one to four, with one representing the highest level of efficiency. Only data from hauls assessed ratings of one or two were considered valid for CUE calculations. In some cases, this involved conducting additional hauls to obtain three efficient replicates. CUE calculations were based on the number of fish per unit area (i.e., number of fish per 10 m^2 of sampled surface area).

2.8.1.3 Backpack Electrofishing

Backpack electrofishing was conducted in streams and rivers within the study area using a Smith-Root Type VII backpack electrofisher. The majority of sampling was conducted with the unit producing 300 VDC (pulsed) at 0.5 to 1.5 A. Pulse rate and pulse width were normally set at 60 Hz and 6 ms, respectively.

Stream reaches selected for replicate sampling were flagged during the spring survey. On Poplar Creek, sampling was conducted at stations previously sampled in 1978 and 1981 (Figure 2.4). The primary sample sections (i.e., sampled during each of the spring, summer, and fall periods) ranged from 150 m to 300 m in length. Catch per unit effort values were based on a standard unit of effort, in this case, electrofisher operating time in minutes. Operating time rather than stream length or area was selected as the unit of sampling effort because it was more readily quantifiable and allowed comparison of catch between stations. Length and area of stream sampled varied considerably between stations in response to seasonal changes in stream flow and/or wading conditions. Sampling efficiency was rated at each station on a scale of one to four, with one representing the highest efficiency level. Also recorded was information describing fish distribution-habitat preferences, stream habitat conditions, water clarity, and water temperature.

2.8.1.4 Boat Electroshocking

Boat electroshocking was conducted on the MacKay River in 1984. Three sample stations (each approximately 5 km in length) were sampled during the spring and summer periods (Figure 2.1). Low water levels prevented the use of this method during the fall period. Boat electroshocking also was conducted during the spring on Beaver Creek Reservoir, Ruth Lake, the diversion channel connecting Beaver Creek Reservoir and Ruth Lake, and the lower section of Upper Beaver Creek (Figure 2.3).

Boat electroshocking was conducted using a Smith-Root Type V1-A boat electroshocking unit powered by a 4000-watt gas-powered generator. The electroshocking apparatus was operated from a 4.6 m aluminum work boat, modified for safe and efficient sampling (i.e., flat bowdeck with safety rail, mounted anodes, etc.). A three-person crew was utilized (i.e., boat operator and two netters) during the spring survey on the MacKay River. A two-person crew (i.e., one operator and one netter) was employed during the summer MacKay River survey and the spring reservoir surveys as insufficient numbers of fish were present to warrant the use of two netters.

The Smith-Root Type V1-A electroshocking system operates at an input voltage of 230 VAC at approximately 15 A; output voltages of 0-1000 VAC (in 166V increments) at 0.1-10.0 A are available to the operator. Most effective fish capture occurred with the unit set between 336-504 VDC and outputting between 5 to 7 A. A pulse rate of 60 Hz and a pulse width of 7 ms were utilized.

The electroshocking procedure consisted of moving in a downstream direction (at motor idle) and alternating from bank to bank to allow sampling of all habitat types. Captured fish were placed in holding tubs; when holding capacity was reached (approximately 20 fish), electro-shocking was suspended and fish sampling undertaken. Fish escaping the electric field or avoiding the netter were enumerated by crew members and recorded as observed. At each stop, pertinent data were recorded on standardized catch record forms, including: number of fish captured and observed, section length (km), sampling time (s), sampling efficiency (on a one to four rating scale with one as the most efficient rating), habitat conditions (depth, velocity, substrate, cover type, water temperature, visibility, etc.), and electroshocker settings.

2.8.2 LIFE HISTORY ANALYSIS

All sport fish species and a representative sample of coarse fish (i.e., sucker) and forage fish (i.e., cyprinid) species were measured (fork length to the nearest millimetre) and weighed. Sex and state of maturity were determined either externally from the extrusion of gametal products or by dissection. Appropriate aging materials were collected from all sport fish species. Fin-rays and scales were collected from a representative sample of sucker species; aging was carried out largely to complement the length-frequency analysis (i.e., the assignment of age-classes to modal peaks) for these species. Scales (from goldeye, whitefish and yellow perch) were mounted between glass microscope slides and read using a 3M, Model SRC816 microfiche reader. Fin-rays (first two left pelvic rays from walleye) were sectioned with a jewellers' saw (7/0 blade). Fin sections were mounted in Diatex mounting medium and viewed under a dissecting microscope. Cleithra (from northern pike) and otoliths (from burbot) were aged using a dissecting microscope.

Life history data (i.e., age, length, weight, sex, maturity, etc.) collected during the study were entered onto standard fish data forms suitable for computer analysis using R.L. & L. Environmental Services Ltd. software package (FISHPAK).

SECTION 3.0

MACKAY RIVER SYSTEM

3.1 AQUATIC HABITAT

3.1.1 DESCRIPTION OF DRAINAGE AREA

The MacKay River (and associated tributaries) drains an area of 5550 km^2 and is the largest system within the Syncrude Development Area (Appendix B, Table B2). The lower reaches of the river (approximately 60 km) pass through the northwest corner of Syncrude Lease 17 and bisects Syncrude Lease 22 (Figure 1.1). At present, mining activities do not occur within the MacKay River watershed.

The MacKay River originates in the Algar Plains of the Birch Mountains Upland and flows in a generally northeastern direction for approximately 200 km before entering the Athabasca River near the village of Fort MacKay. Two major tributaries, the Dover River (drainage area 963 km^2) and the Dunkirk River (drainage area 2183 km^2) drain areas to the west of the MacKay River, entering the mainstem approximately 27 km and 147 km, respectively, upstream from the mouth.

The majority of the MacKay River drainage basin consists of mixed spruce and sparsely treed muskeg terrain. The river water is coloured due to the presence of dissolved organic matter; however, suspended sediment levels generally are low.

The study area on the MacKay River extended from the mouth upstream to km 76.0 (Figure 2.1). Numerous smaller drainages, some ephemeral, enter the MacKay River within the study area. Eleven of these systems (M1-M11) were sampled for water quality parameters and discharge characteristics in the present study. The 1984 study area on the Dover River extended from the mouth upstream for 40 km.

3.1.2 STREAMFLOWS DURING STUDY PERIOD

In 1984, the peak flow event in the MacKay River occurred on 2 June at which time a discharge of 116.0 $m^3 \cdot s^{-1}$ was recorded (Water Survey of Canada, preliminary data, 1984). Prior to this, during the first three weeks of May, flows were in the order of 3 to 4 $m^3 \cdot s^{-1}$ (Figure 3.1). Minor peaks also occurred on 16 July (48.6 $m^3 \cdot s^{-1}$), 15 August (24.4 $m^3 \cdot s^{-1}$), and 13 September (12.6 $m^3 \cdot s^{-1}$). Relatively low flows (4 to 8 $m^3 \cdot s^{-1}$) were recorded during the late July to mid-August period. Discharge data for the three major seasonal sampling periods on the MacKay River, Dover River, and minor tributaries are provided in Appendix B, Table B2.

3.1.3 MAINSTEM MACKAY RIVER

Physical habitat characteristics of the mainstem MacKay River have been evaluated by several previous investigators. Griffiths (1973), in a study for the Alberta Fish and Wildlife Division, described and rated the system according to the Canada Land Inventory (C.L.I.) classification scheme. R.R.C.S. (1975) reviewed the information presented by Griffiths

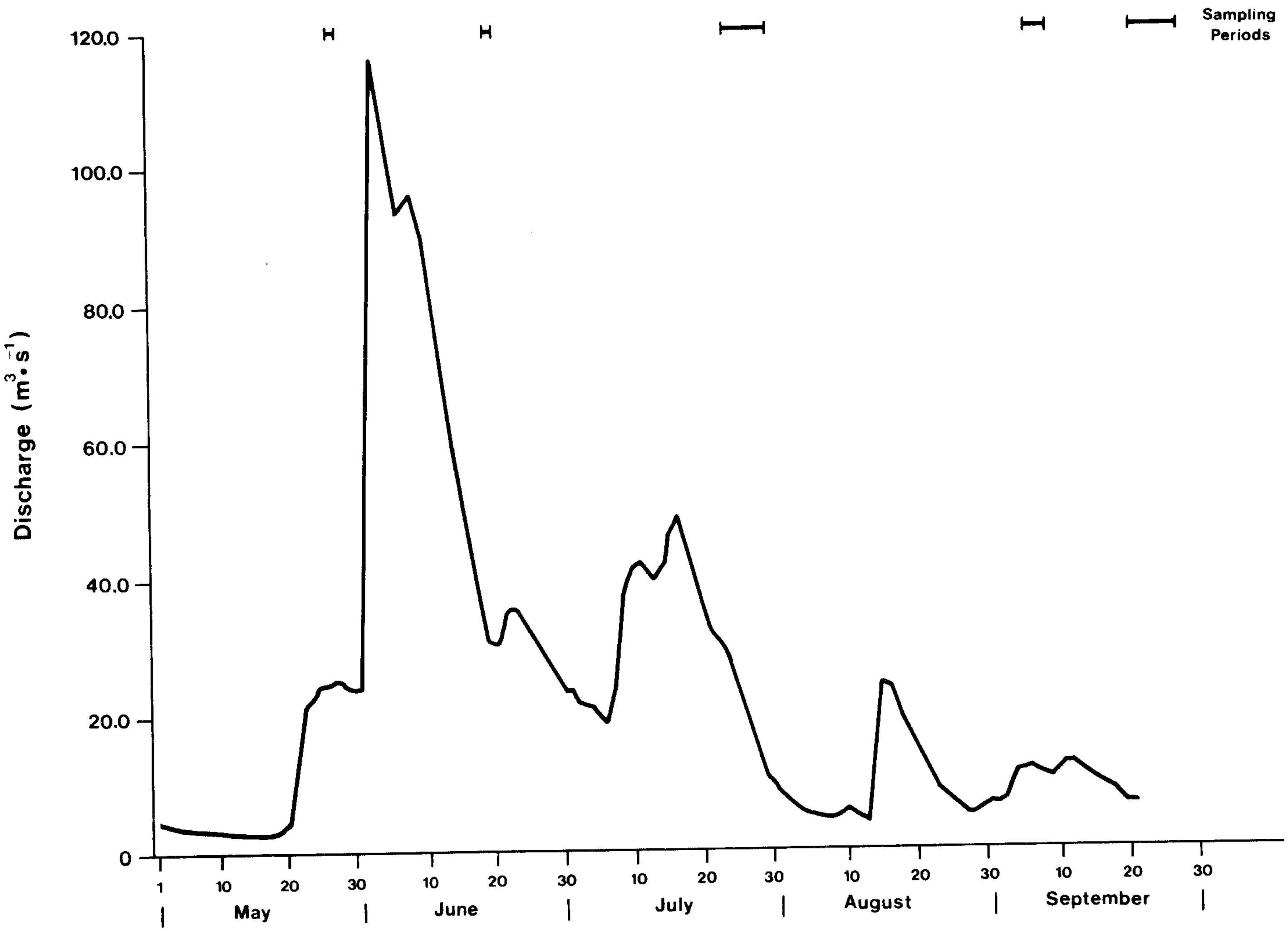


Figure 3.1 MacKay River hydrograph, 1 May to 21 September 1984 (based on preliminary Water Survey of Canada data for Station No. 07DB001).

(1973) during a study conducted for the North East Alberta Regional Plan. Gradient profiles were developed which identified major habitat zones. In a study for Syncrude Canada Ltd., McCart et al. (1978) recorded habitat information at 13 sites distributed from km 61 to the mouth. These data, which were general in nature, pertained to channel width and depth, substrate type, riffle, bank type and stability, and species distribution of aquatic macrophytes. Machniak et al. (1980) characterized the habitat in the MacKay River under the regional A.O.S.E.R.P. studies using a preliminary application of the methodology outlined by Brown et al. (1978). This involved establishing habitat reach boundaries using 1:50 000 N.T.S. maps and available gradient information (R.R.C.S. 1975). General descriptions of each reach were acquired during aerial surveys, and site specific information was collected at point sample locations. A.O.S.E.R.P. investigators conducted a more systematic evaluation of aquatic habitat during 1979 (Walder et al. 1980). The system of reach classification and biophysical measurements used was based on the approach devised by the Resource Analysis Branch, B.C. Ministry of Environment (Chamberlin and Humphreys 1977). Reaches were defined and site specific information was obtained at point sample locations.

3.1.3.1 Habitat Zonation

Four major reaches based on gradient differences are represented within the Syncrude development area (Figure 3.2). Reach designations follow the classification of Walder et al. (1980); however, kilometreage intervals and gradients determined in the two studies (1979 and 1984) do

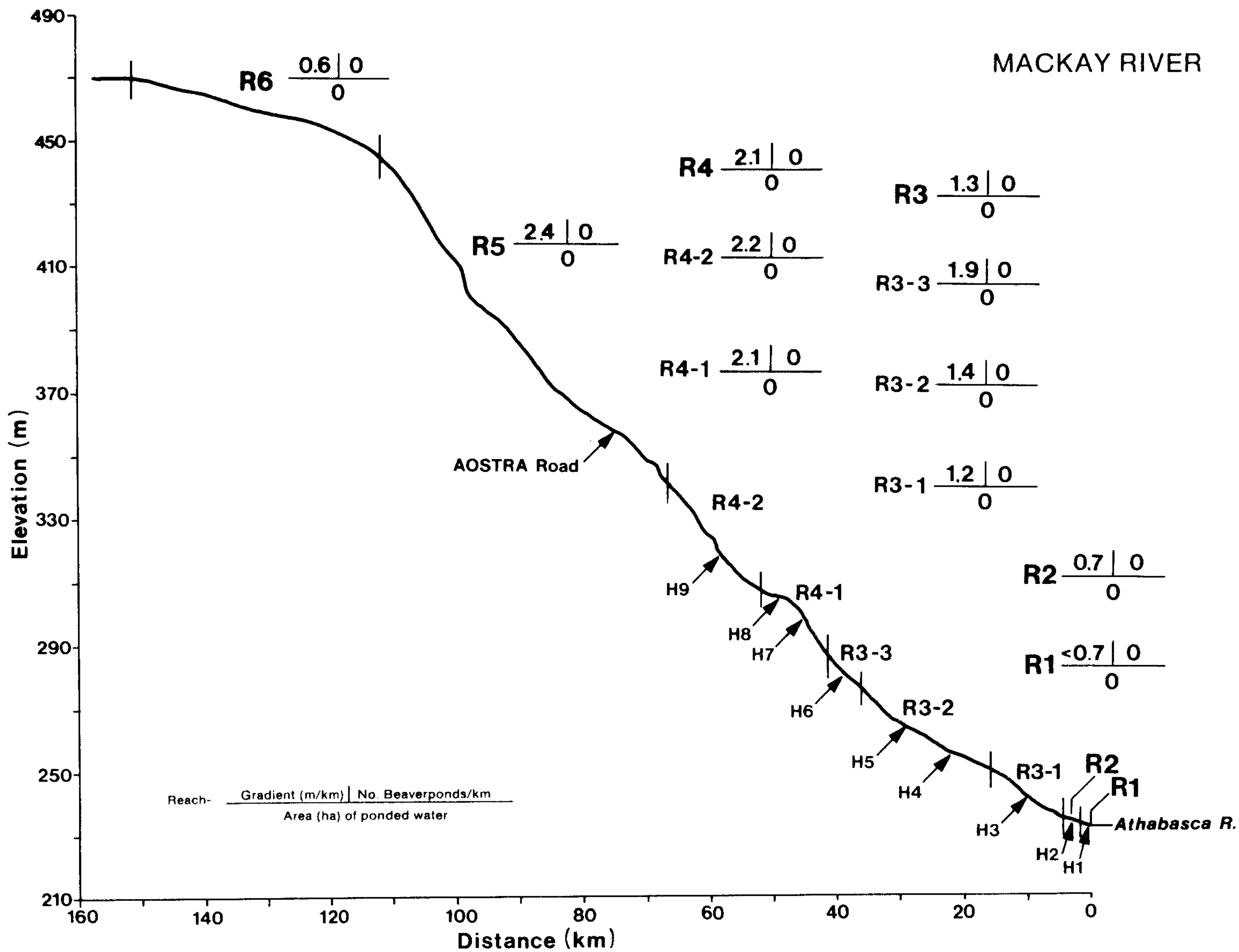


Figure 3.2 Longitudinal profile and habitat zonation, MacKay River.

not correspond in all cases. More detailed mapping was available in the present study (1:20 000 airphoto mosaics with 2 m contour intervals as opposed to 1:50 000 N.T.S. maps with 10 m contour intervals in the earlier study).

In 1984, detailed habitat sampling was conducted at nine stations (H1-H9) situated at specified intervals throughout section km 58 to km 0 (confluence with Athabasca River). The results obtained at stations H1-H9 are provided in Table 3.1. Additional sampling of a synoptic nature (49 stations) was conducted at each kilometre location.

<u>Reach 1</u> (km 0.0-1.4)

Reach 1 is situated within the Athabasca River flood plain; as such, it is subject to inundation due to back-flooding. The channel exhibits a relatively straight pattern. The average gradient for the reach was estimated to be less than that determined for the adjacent upstream reach ($0.7\ m \cdot km^{-1}$) based on flow characteristics and substrate composition; however, accurate data on the elevation of the MacKay River-Athabasca River confluence was not available so the actual gradient could not be determined. The wetted channel width at the primary habitat station (H1) was 45 m (Table 3.1); the mean depth at this station was 65 cm (range: 45-74 cm). Current velocities (mean of $33\ cm \cdot s^{-1}$) were low, reflecting the low gradient nature of the reach. The habitat at H1 was predominantly Flat (i.e., 100% at transect H1); as such, it was relatively homogeneous with little habitat diversity (Table 3.1).

Table 3.1 Summary of physical habitat characteristics at sampling stations on the MacKay River and Dover River, September 1984.

			Channel Features at Transect						Cover Type Distribution (%)							
		Water Temp(°C) (Time)(h)										Pool Type				
Station	Date		Rooted Width (m)	Wetted Width (m)	Local Gradient (%)	Mean Depth (cm)	Mean Velocity ($cm \cdot s^{-1}$)	Discharge ($m^3 \cdot s^{-1}$)	Riffle	Run	Flat	1	2	3	4	5
MacKay River																
H1	9 Sept.	9 (1700)	52	45	0.25	65 (45-74)	33 (22-43)	9.0	-	-	100	-	-	-	-	-
H2	9 Sept.	9 (1549)	48	25	0.25	119 (88-173)	36 (30-42)	-	-	52	48	-	-	-	-	-
H3	9 Sept.	9 (1305)	42	34	0.50	68 (20-118)	56 (15-84)	10.3[a]	-	74	2	-	-	24	-	-
H4	9 Sept.	9 (0940)	41	22	0.75	64 (38-103)	77 (70-86)	-	-	100	-	-	-	-	-	-
H5	8 Sept.	9 (1414)	36	27	0.5	70 (44-105)	54 (40-62)	-	-	100	-	-	-	-	-	-
H6	8 Sept.	9 (1056)	34	27	0.75	120 (96-135)	34 (16.5-52)	-	-	85	15	-	-	-	-	-
H7	7 Sept.	10 (1626)	63	32	1.0	54 (15-89)	57 (20-104)	-	-	100	-	-	-	-	-	-
H8	7 Sept.	9 (1327)	38	34	0.5	135 (58-200)	48 (26-60)	-	-	48	16	-	-	36	-	-
H9	7 Sept.	9 (0955)	36	33	2.0	45 (30-63)	79 (58-124)	9.2	64	36	-	-	-	-	-	-
Dover River																
H1	8 Sept.	9 (1623)	16	10	1.0	27 (9-52)	43 (19-66)	1.2	-	100	-	-	-	-	-	-
H2	24 Sept.	7 (1528)	17	8	2.0	24 (10-40)	67 (48-82)	-	65	11	16	8	-	-	-	-
H3-T1	24 Sept.	6 (1235)	16	14	0.5	43 (36-52)	8 (3-17)	-	-	66	34	-	-	-	-	-
-T2	24 Sept.	6 (1317)	22	14	1.0	24 (16-32)	27 (15-34)	-	37	28	3	32	-	-	-	-
H4	24 Sept.	6 (1049)	20	14	0.5	44 (13-65)	6 (1-14)	0.5	-	42	58	-	-	-	-	-

	Bank Features (RUB/LUB)							Substrate Distribution (%)											Aquatic Veg.	
Station	Cond. (%)	Stab. (No.)	Under. (cm)	Slope (Deg.)	Cover (No.)	Depth (cm)	Over. (cm)	Sand	Silt	FG	MG	CG	VCG	SC	LC	SB	LB (BR)	EMB. (No.)	Macro. (No.)	Algae (No.)
MacKay River																				
H1	90/40	2/2	0/0	145/145	2/4	0/0	0/0	58	-	-	-	-	-	14	-	-	(28)[b]	3	1	1
H2	5/90	3/2	0/0	170/160	4/1	0/0	0/0	52	-	-	-	-	-	24	24	-	-	3	1	1
H3	15/40	2/3	0/0	165/105	2/2	0/0	0/10	-	-	-	-	-	36	44	18	-	(2)[b]	3	1	1
H4	10/5	3/4	0/0	145/160	1/1	0/42	0/0	-	-	-	-	-	-	75[c]	-	-	(25)[b]	3	1	1
H5	100/40	4/1	0/0	140/90	1/2	0/24	0/25	-	-	-	-	-	-	-	-	-	(100)[b]	N/A[d]	1	1
H6	90/40	2/2	0/0	130/95	4/2	0/62	0/20	32	-	-	-	-	-	-	-	68	-	1	1	1
H7	100/100	1/1	0/0	140/140	1/1	0/0	0/0	-	-	-	-	-	-	-	38	62	-	3	0	3
H8	100/100	2/2	0/0	95/130	1/4	0/0	0/0	18	11	-	-	-	-	-	71	-	-	3	1	ND[d]
H9	0/100	4/1	0/0	160/145	4/1	0/0	0/0	-	-	-	-	-	-	-	63	37	-	4-5	0	2
Dover River																				
H1	90/0	1/4	0/0	150/160	1/2	0/0	0/0	-	-	-	-	-	-	19	28	37	(16)	3	1	2-3
H2	10/20	4/4	0/0	165/145	1/1	0/0	0/0	-	-	-	-	-	-	51	49	-	-	4	1	3
H3-T1	30/10	3/4	0/0	90/125	4/2	47/0	80/70	-	-	-	-	-	-	-	-	100		2-3	1	5
-T2	60/85	2/2	0/60	160/150 (47)[e]	4/3	0/0	0/0	-	28	-	-	-	-	22	20	20	(10)	2	3	4
H4	20/15	3/3	0/0	90/115	2/2	11/0	5/50	-	-	-	-	-	-	-	100	-	-	3-4	1	5

[a]WSC Station No. 07DB001 (preliminary data)
[b]Bitumen bedrock.
[c]Cobble embedded in bitumen.
[d]ND - data unavailable; N/A - not applicable.
[e]Angle of undercut in parentheses.
Note: Description of terms in Table 2.2.

The results of the synoptic survey (Table 3.2) show similar trends. Substrate in the reach consists primarily of gravels, with some areas of sand (Walder et al. 1980). The substrate distribution at station H1 was as follows: 58% sand, 28% bitumen bedrock, and 14% small cobble (6.4-12.8 cm).

Reach 2 (km 1.4-4.5)

Reach 2, which is 3.1 km in length, lies just above the Athabasca River floodplain. The river flows in a sinuous channel through a narrow valley (Walder et al. 1980). The average gradient in the reach was 0.7 $m \cdot km^{-1}$. Channel width was considerably less than in the downstream section. A wetted channel width of 25 m was recorded at H2 (9 September). The mean channel depth at this location was 119 cm (range: 88 to 173 cm). Current velocities (mean of 36 $cm \cdot s^{-1}$) were slightly higher than those obtained in Reach 1. The increased gradient in Reach 2 resulted in reduced presence of Flat habitat and increased availability of Run cover type. At transect H2 (Table 3.1), the cover type distribution was as follows: 52% Run and 48% Flat. For the combined H2 and synoptic transects (Table 3.2), Run habitat accounted for 63% of the habitat; Flat contributed the remaining 37% (Plate 1). Three major pools were recorded (in intervening sections between primary transects) during the float survey. Two pools were in the Class 3 (moderate quality) category and one was in the Class 5 (high quality) category. The substrate at H2 consisted of 52% sand and 48% cobble; the cobble was distributed evenly between the small (6.4 to 12.8 cm) and large (12.8 to 25.6 cm) category.

Table 3.2. Distribution of cover types at habitat transects[a] on the MacKay River within the Syncrude Development Area, 1984.

		Cover Type Distribution(%)				Major Pool Distribution[b]			
						Class			
Reach (Sub-reach)	**Location (km)**	**Riffle**	**Run**	**Flat**	**Pool**	**3**	**4**	**5**	**Total**
R1	0-1.4	-	-	100	-	0	0	0	0
R2	1.4-4.5	-	63	37	-	2	0	1	3 (1.0)
R3(1)	4.5-15.3	14	56	28	2	1	4	3	8 (0.7)
R3(2)	15.3-36.3	11	65	22	2	1	5	4	10 (0.5)
R3(3)	36.3-41.2	20	41	29	10	0	3	0	3 (0.6)
R4(1)	41.2-52.9	29	40	28	3	1	3	3	7 (0.6)
R4(2)	52.9-59.0+	15	48	36	1	0	0	0	0

[a]Data collected during downstream float survey (km 58-0) on 7-9 September; 58 transects (H1-H9 and 49 synoptic).
[b]Total number; the number per kilometre is given in brackets.

Reach 3 (km 4.5-41.2)

The channel in Reach 3 is characterized by a tortuous, meandering pattern; it is entrenched within a canyon incised 40 to 50 m deep into the McMurray Oil Sands formation. The high, near-vertical stream banks are predominantly unstable; exposed oil sands deposits are common (Walder et al. 1980).

Reach 3 is 36.7 km in length and exhibits an average gradient of 1.3 $m \cdot km^{-1}$ which is substantially higher than that exhibited by the downstream situated Reach 2 (Figure 3.2). The section was subdivided into three sub-reaches owing to localized differences in channel form and habitat characteristics. These differences were not major enough to warrant separate reach status. Wetted channel widths at stations H3 to H6 ranged between 22 m and 34 m. Mean depths varied from 64 cm (H4) to 120 cm (H6); mean velocities also showed considerable variability, ranging between 34 $cm \cdot s^{-1}$ (H6) and 77 $cm \cdot s^{-1}$ (H4). The distribution of habitat cover types was fairly similar in all sub-reaches. Both primary habitat station data (Table 3.1) and synoptic transect data (Table 3.2) indicate a preponderance of Run type habitat and a corresponding decrease in Flat type habitat. This reflects the higher gradient in Reach 3 relative to Reach 2. Reach 3 also possesses a higher diversity of habitats (i.e., presence of all four major habitat cover types) relative to downstream sections. A total of 21 major pools were enumerated in Reach 3, with the majority of these being located in the lower two sub-reaches. The frequency of occurrence, however, was similar in all three sub-reaches, being in the order of 0.6 pools per kilometre. Granular substrates, ranging from very coarse gravel (3.2 to 6.4 cm) to small boulder (25.6 to 51.2 cm), were prevalent at each of the primary habitat transects. Bitumen bedrock and small cobble (6.4 to 12.8 cm) embedded in bitumen also were noted, particularly in Sub-reaches 1 and 2.

Reach 4 (km 41.2-60.0+)

The channel in Reach 4 is characterized by an irregular meander pattern and is confined by the valley walls; however, there is considerable evidence of previous lateral channel movement (i.e., oxbows and meander scars). Outside meander bends are frequently steep and slumping, although the proportion of unstable banks in this reach is noticeably lower than in Reach 3 (Walder et al. 1980).

Reach 4 is 25.5 km in length; of this, 18.8 km are situated within the Syncrude Development Area (i.e., upper lease boundary at km 60). The average gradient in Reach 4 is 2.1 $m \cdot km^{-1}$ which is considerably higher than downstream sections (Figure 3.2). Two sub-reaches were identified by Walder et al. (1980). Sub-reach 1 extends from km 41.2 to 52.9; the remaining section up to and beyond the lease boundary is contained within Sub-reach 2. Wetted channel widths at primary habitat stations were very similar (about 33 m) (Table 3.1). Depths and velocities at the transects were variable. Riffle and Run habitats were predominant in the reach, a reflection of the high gradient. High quality pools were well represented in Sub-reach 1 (frequency of 0.6 pools per km) but were absent in the upper section (Table 3.2). Numerous small, shallow pools were noted in Sub-reach 2.

3.1.4 MINOR TRIBUTARIES TO MACKAY RIVER

Numerous small, unnamed tributaries enter the MacKay River within the Syncrude Development Area. Eleven of these systems (M1-M11) were investigated in this study. Six of the streams (M3, M4, M5, M8, M9, M11) were assigned to the first-order category according to Strahler (1957) (Appendix B, Table B2). The mean drainage area for these systems was 4.2 km^2 (range: 2.1 to 6.4). Three second-order streams were identified (M1, M7, M10); the mean drainage area for these systems was 19.1 km^2 (range: 11.1 to 28.1). The remaining two streams (M2, M6) were given a third-order rating; the drainage area for these systems was 72.4 km^2 and 52.4 km^2, respectively.

Discharges in first-order streams during the June measurement period ranged from less than 0.01 to 0.06 $m^3 \cdot s^{-1}$. In July, no measurable flow was recorded in M9; the remaining five were flowing at less than 0.01 $m^3 \cdot s^{-1}$. In September, measurable flow did not occur in three of six first-order streams. Discharge in the remaining three was less than 0.01 $m^3 \cdot s^{-1}$. June flows in second and third-order streams were higher than in first-order systems, ranging from 0.02 to 0.17 $m^3 \cdot s^{-1}$. By September, all but M2 (the largest third-order stream) were flowing at less than 0.01 $m^3 \cdot s^{-1}$. A discharge of 0.05 $m^3 \cdot s^{-1}$ was recorded in M2 in September.

All streams exhibited a steep gradient in the lower reaches (Figures 3.3 to 3.8; Plate 3). These sections correspond with the descent of the stream into the incised MacKay River valley. Control of these sections by beaver activity was neglible to non-existent, depending on the system. Gradients in upstream reaches were low to moderate, with an increased frequency of beaver control and pondage. Of all systems, Creek M2 exhibited the greatest ponded area (Figure 3.3). Muskeg was the dominant terrain type in all of the systems except M1 which featured predominantly highland terrain.

Due to the presence of numerous severe habitat limitations (unacceptable minimum flows, steep gradients, access blockage, etc.), Creeks M1-M11 were not considered to have any significant value as fish habitat other than for non-game or forage species (e.g., fathead minnow, brook stickleback).

3.1.5 MAINSTEM DOVER RIVER

Physical habitat conditions in the Dover River have been examined previously. Griffiths (1973), in a preliminary assessment, assigned a low suitability rating to the Dover River (Canada Land Inventory Classification). In 1978, Machniak et al. (1980) divided the Dover River into four discrete habitat reaches based on differences in gradient, flow characteristics, substrate, and channel form. Site specific habitat sampling was conducted at two locations. More detailed habitat investigations were undertaken by A.O.S.E.R.P. in 1979

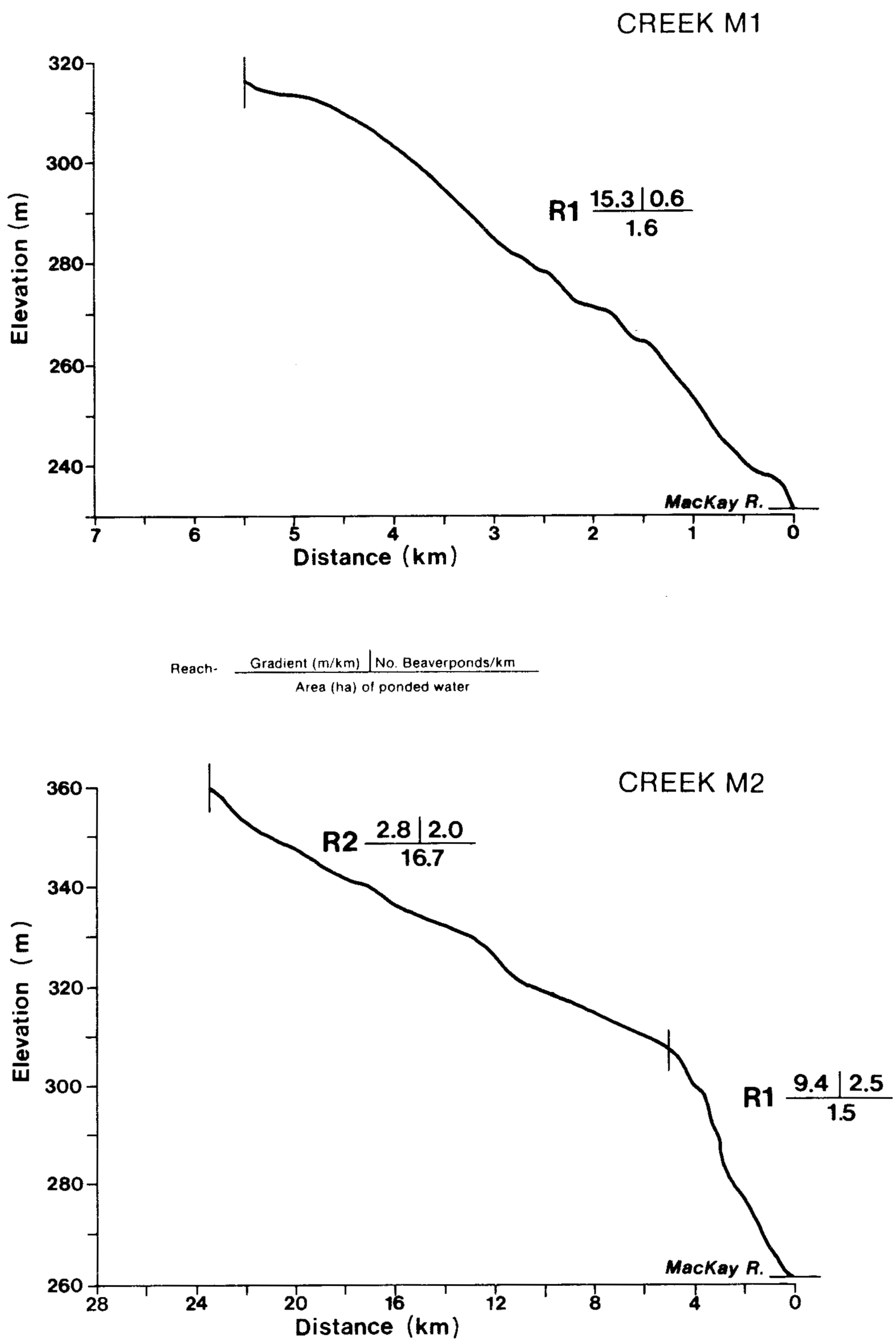


Figure 3.3 Longitudinal profile and habitat zonation, Creek M1 and Creek M2.

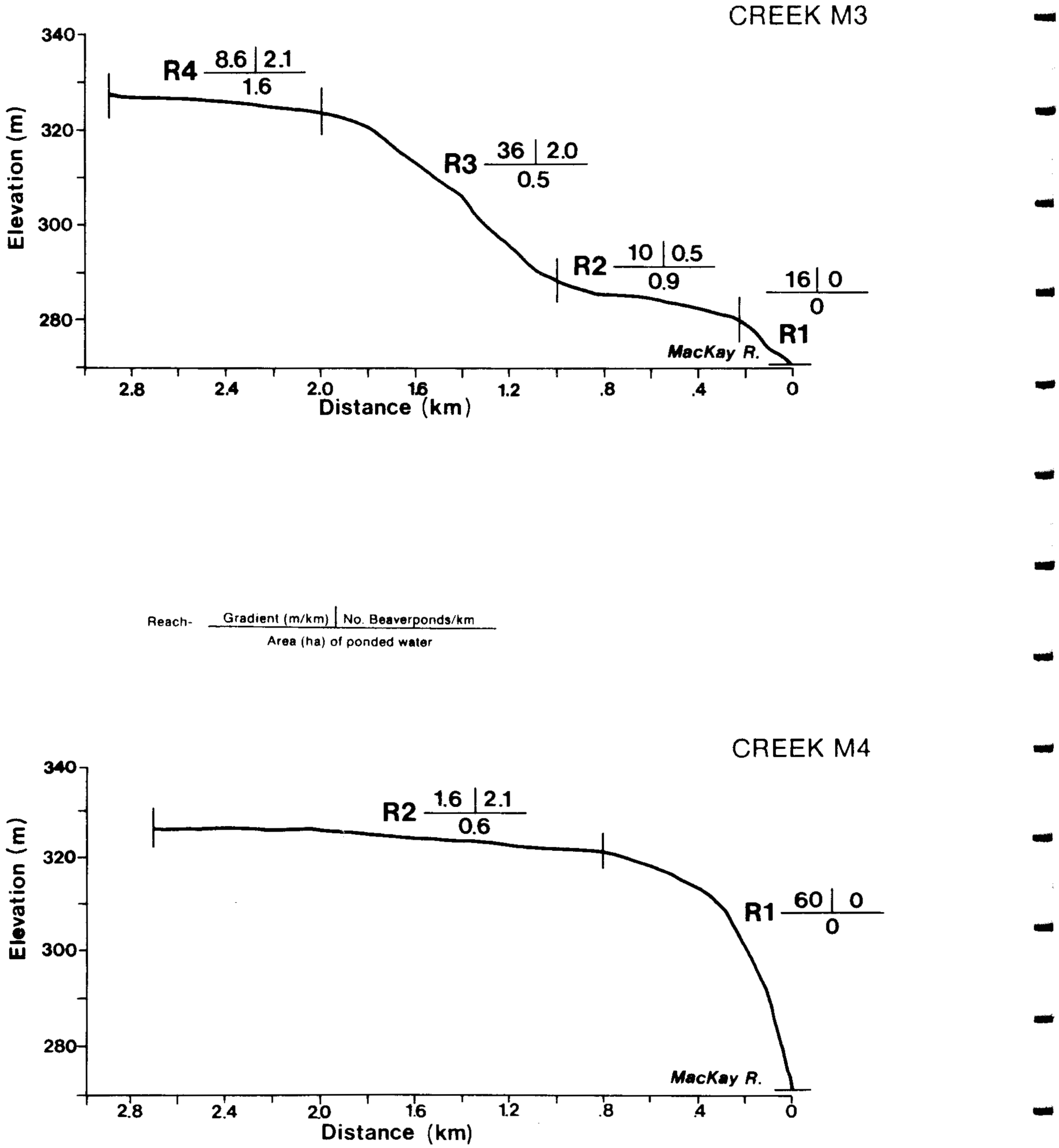


Figure 3.4 Longitudinal profile and habitat zonation, Creek M3 and Creek M4.

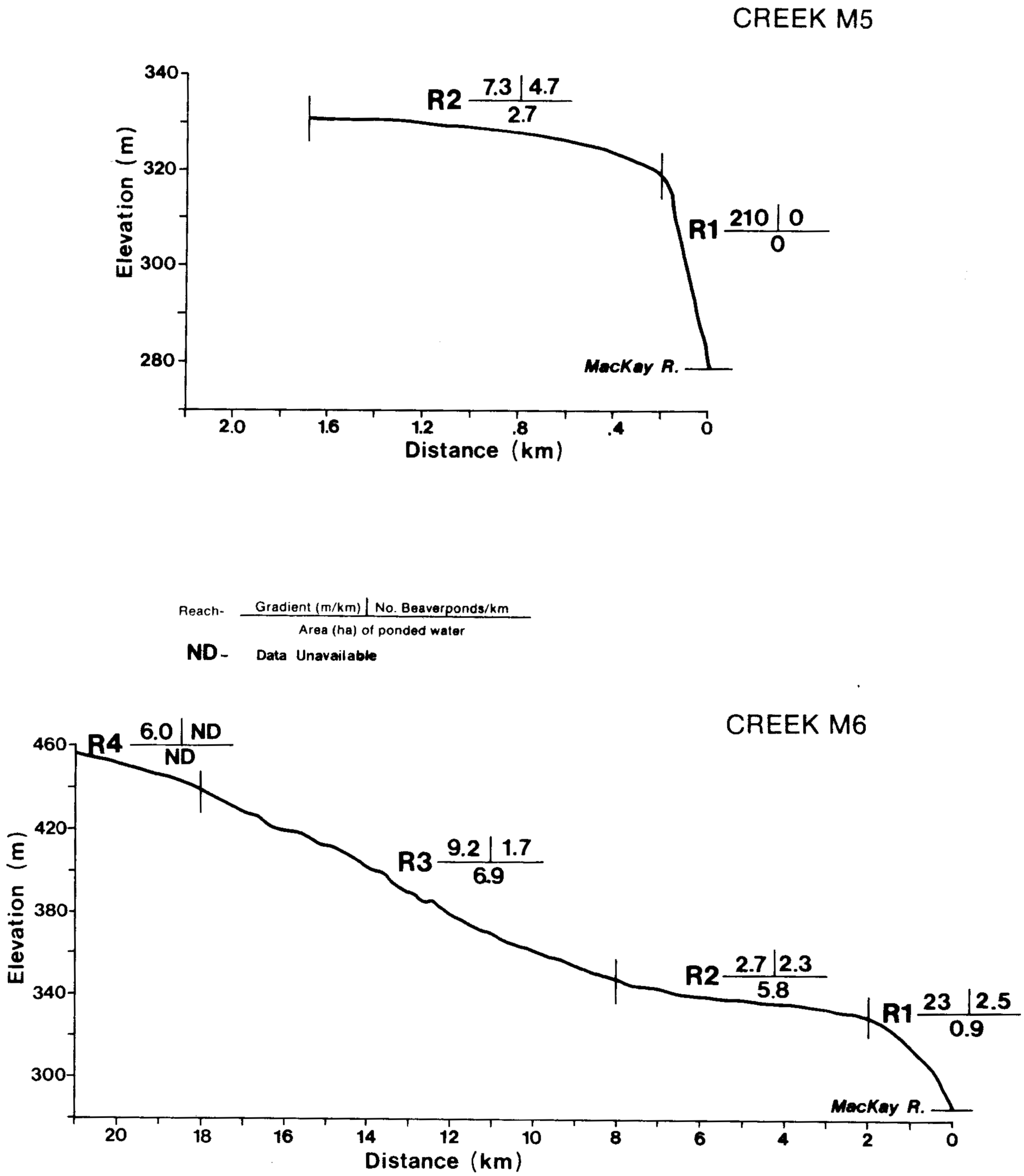


Figure 3.5 Longitudinal profile and habitat zonation, Creek M5 and Creek M6.

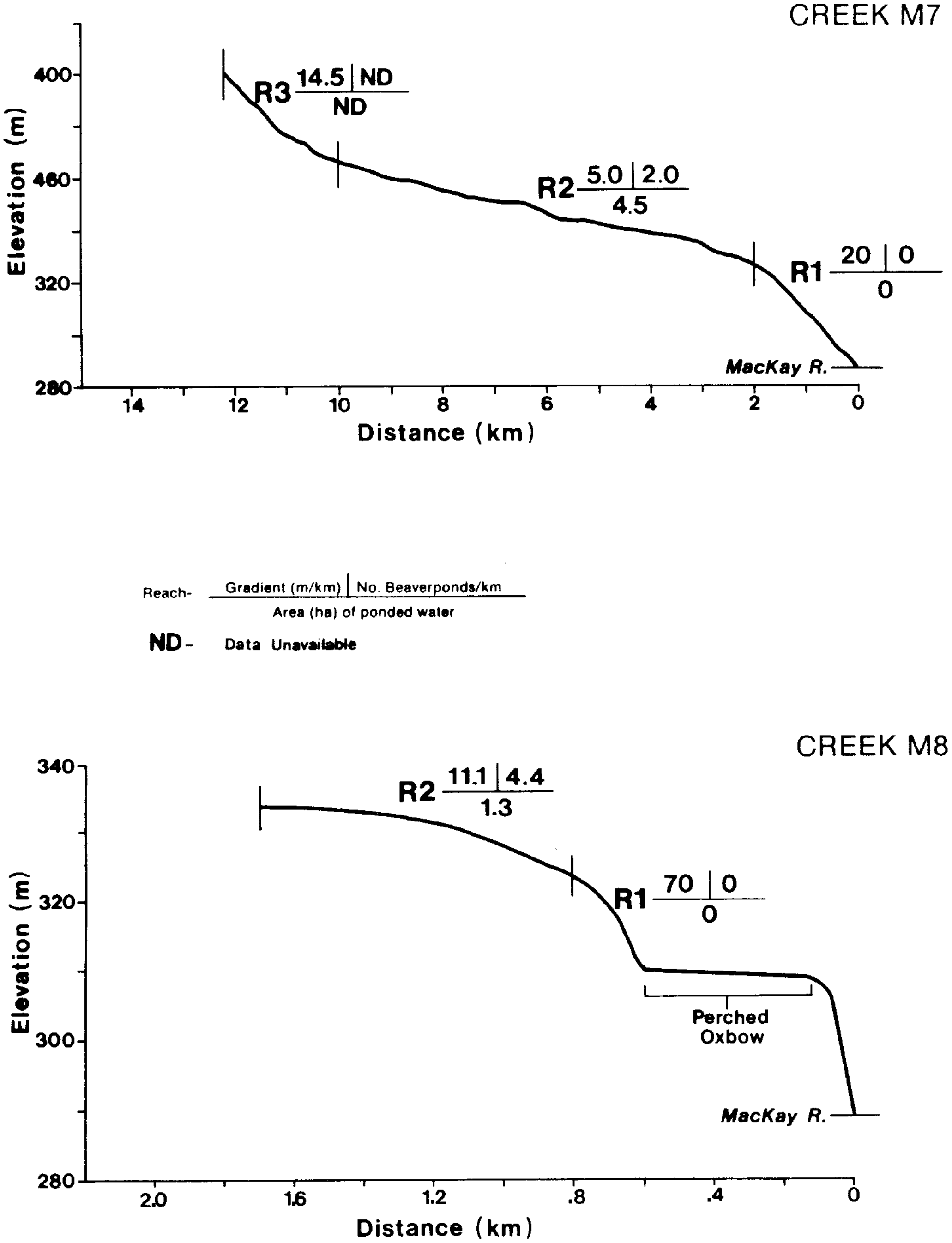


Figure 3.6 Longitudinal profile and habitat zonation, Creek M7 and Creek M8.

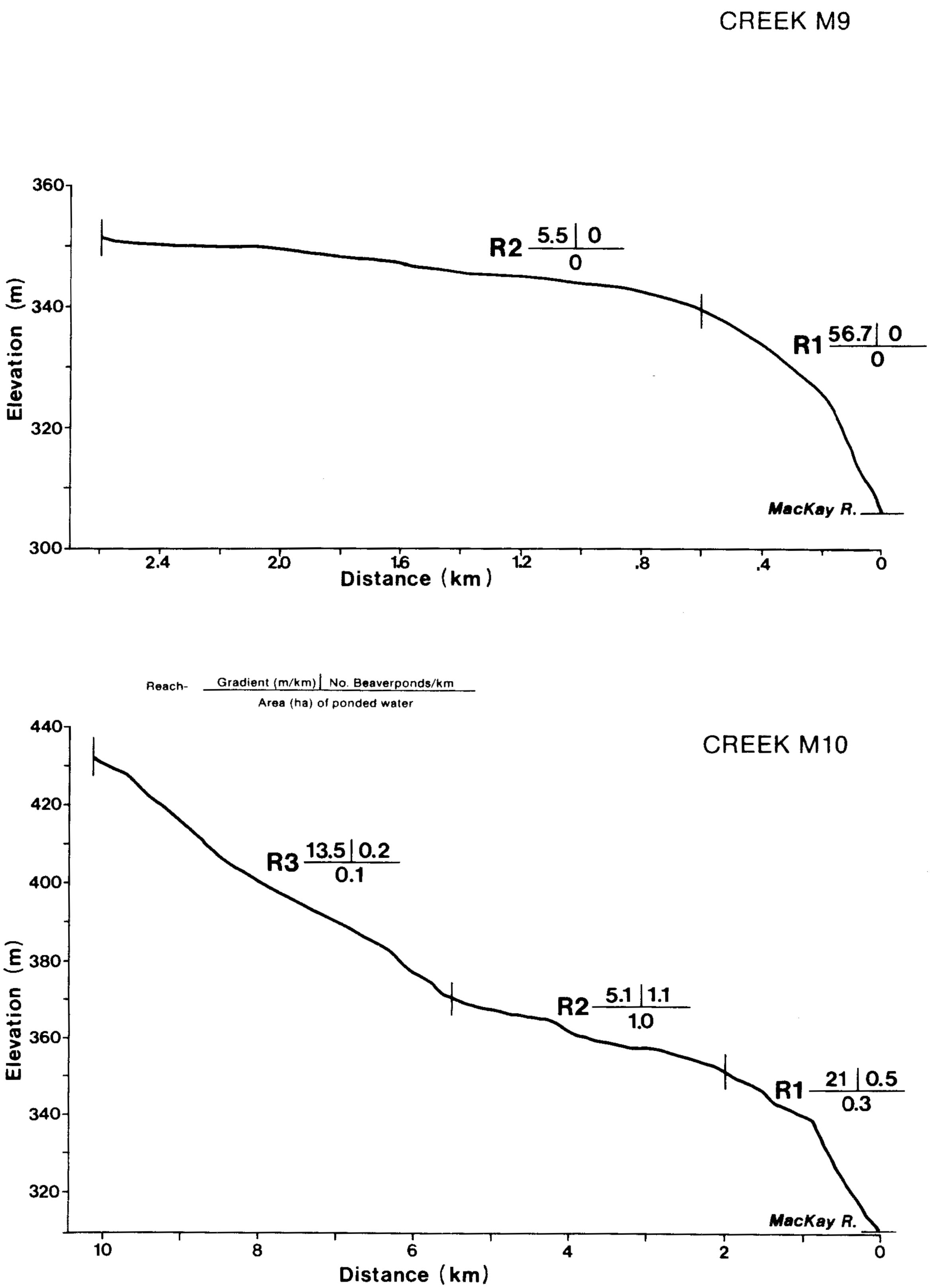


Figure 3.7 Longitudinal profile and habitat zonation, Creek M9 and Creek M10.

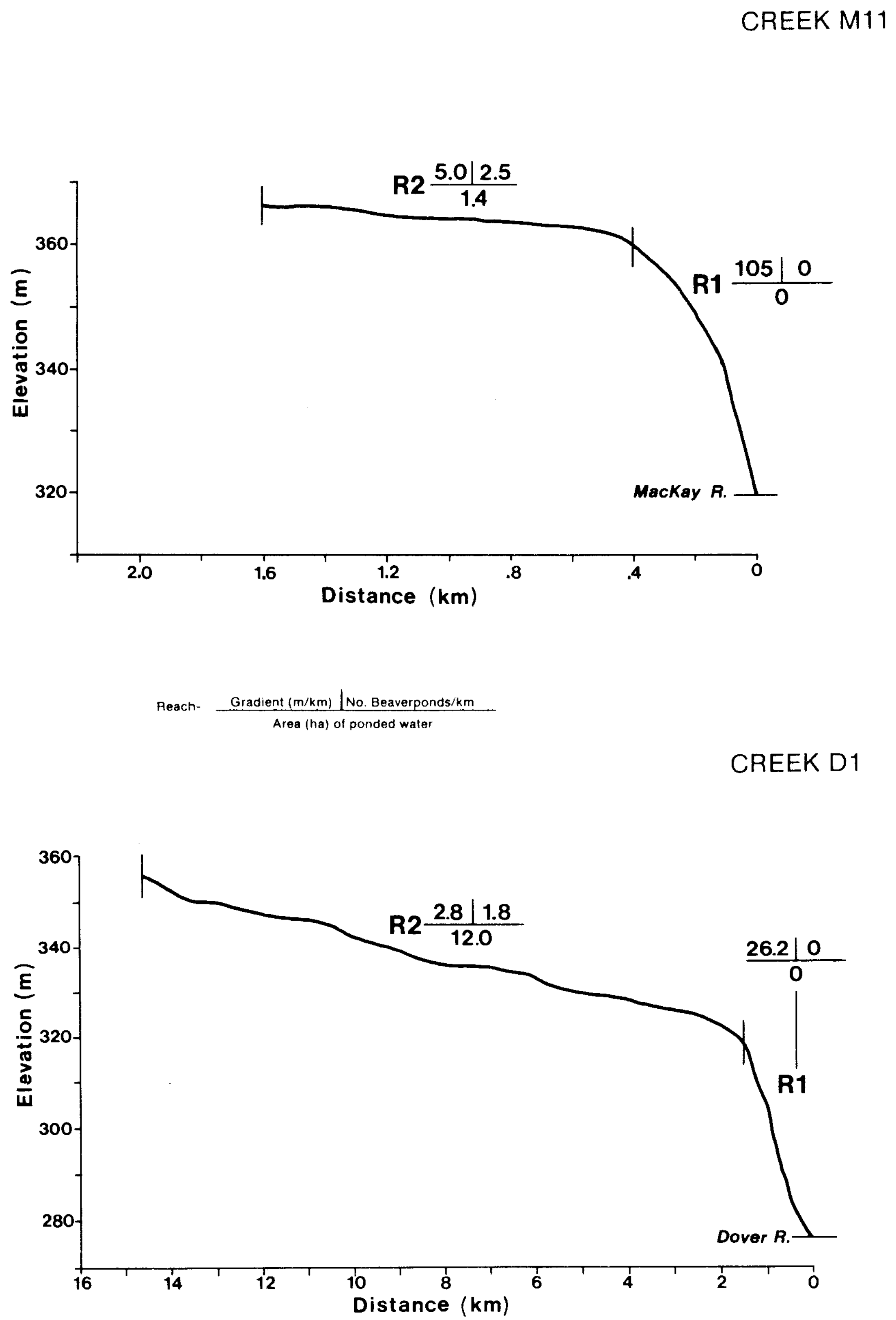


Figure 3.8 Longitudinal profile and habitat zonation, Creek M11 and Creek D1.

(Walder et al. 1980). On the basis of the additional information provided, the Dover River was further subdivided (i.e., total of six habitat reaches). Both A.O.S.E.R.P. studies concluded that habitat in the Dover River was of poor quality and that the system was rarely utilized by sport fish. Major limiting factors identified were low overwintering potential, limited spawning habitat, and high frequency of beaver dams impeding access. The habitat reaches identified by Walder et al. (1980) were maintained in the present study, although actual kilometreage at reach boundaries may differ slightly due to differences in map scales used (i.e., 1:20 000 airphoto mosaics used in 1984; 1:50 000 NTS maps used in 1979).

3.1.5.1 Habitat Zonation

The lower two habitat reaches (R1, R2) and a portion of Reach 3 are situated within the Syncrude Development area; they provide a total stream length of 29.0 km. During the present study, detailed habitat mapping was undertaken at four locations on the Dover River (H1-H4) (Figure 2.1). The results of the survey, which was conducted on 8 September (H1) and 24 September (H2-H4), are provided in Table 3.1.

Reach 1 (km 0-12.5)

Reach 1 is a high gradient section extending 12.5 km upstream from the MacKay River confluence (Figure 3.9). The channel features an irregular, meandering pattern. Stream banks generally consist of silt, sand, and gravel, and are predominantly unstable (Walder et al. 1980).

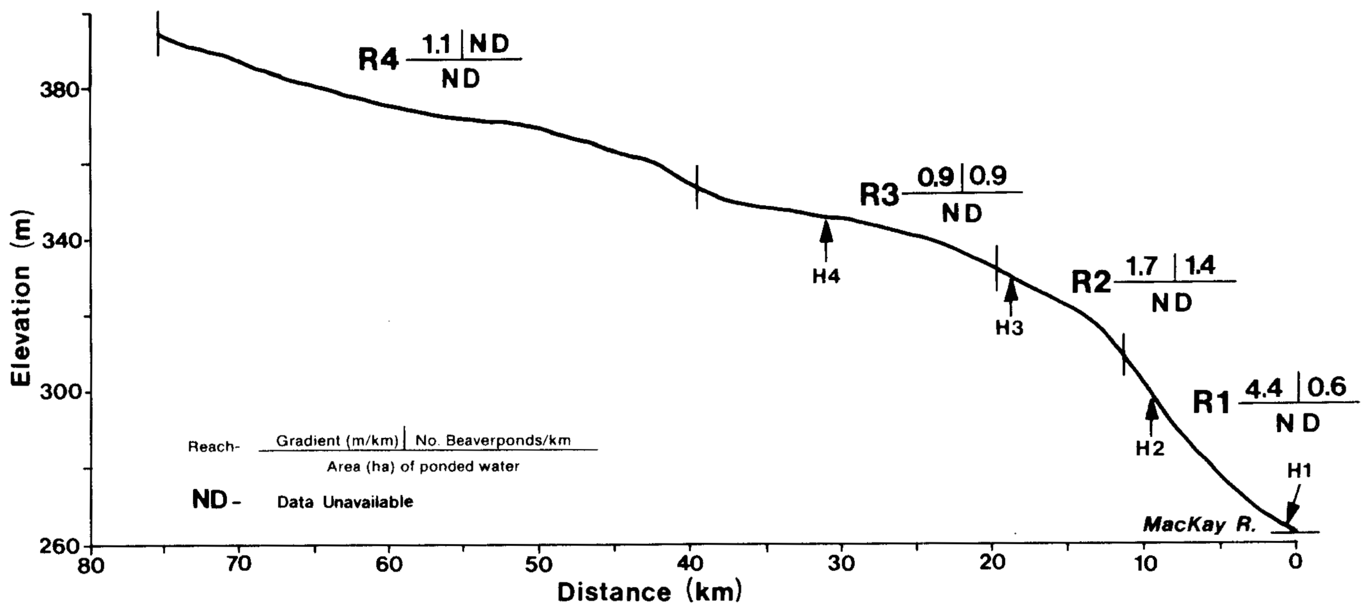


Figure 3.9 Longitudinal profile and habitat zonation, Dover River.

The average gradient in Reach 1 (4.4 m·km^{-1}) is high due to the descent of the Dover River into the incised MacKay River valley. Riffle and Run habitat were the dominant habitat cover types at stations H1 and H2 (Table 3.1). The substrate was predominantly small cobble (6.4 to 12.8 cm), large cobble (12.8 to 25.6 cm), and small boulder (25.6 to 51.2 cm).

Reach 2 (km 12.5-19.5)

Reach 2 is a transition zone between the high gradient habitat in Reach 1 and the lower gradient conditions in Reach 3. The average gradient in Reach 2 is moderate (1.7 m·km^{-1}). The habitat was diverse in this section; all habitat cover types were represented (Table 3.1). Pool quality in the reach was notably low.

Reach 3 (km 19.5-29.0+)

Reach 3 is a low gradient section (0.9 m·km^{-1}). This is reflected in the low habitat diversity (i.e., dominated by Flat cover type), and the high incidence of beaver activity (Plate 2).

3.1.6 TRIBUTARIES TO DOVER RIVER

Creek D1 is the major tributary entering the Dover River within the study area (Figure 2.1). It is a second-order stream with a drainage area of 27.6 km^2. Discharge was recorded on three occasions during the study

(Appendix B, Table B2). Values ranged from 0.05 to 0.01 $m^3 \cdot s^{-1}$ from the June to the September survey. Creek D1 features a steep gradient in the lower reach (Figure 3.8); beaver control of this reach is negligible. Reach 2 displays a moderate gradient and frequency of beaver activity, and pondage increases correspondingly. Due to the presence of severe habitat limitations (low flow, restricted access, etc.), Creek D1 is unlikely to have any important value as fish habitat.

3.2 WATER QUALITY

3.2.1 PHYSICAL PARAMETERS

Water temperatures in the MacKay River ranged from 7.0 to 24.5°C with the lowest and the highest values occurring in September and July, respectively (Table 3.3). A longitudinal temperature gradient was not apparent. In 1979, a maximum summer water temperature of approximately 26°C was recorded in the MacKay River by Charlton and Hickman (1984). The high summer water temperatures recorded in previous studies and during the present survey reflect the relatively shallow, exposed nature of the MacKay River mainstem. Water temperatures of sampled tributaries ranged from 5.0 to 20.0°C, with the highest value recorded at the Dover River in July.

The pH values recorded at all sample stations within the MacKay River drainage system ranged from neutral (pH 7.0) to alkaline (pH 8.6). Generally, pH was highest during the September sample period. Similar

Table 3.3. Summary of water quality data for the MacKay River system, 1984.

Site/Date	MR-W3			M11-W			M10-W			M9-W	M8-W		M7-W		
Parameter	20 June	30 July	21 Sept.	20 June	30 July	21 Sept.	20 June	30 July	21 Sept.	20 June	20 June	30 July	20 June	30 July	21 Sept.
Temperature °C	16.0	24.5	8.0	15.0	15.0	7.5	16	18.5	7.0	14.0	16.0	16.5	15	19.0	7.5
pH	7.3	7.4	7.6	7.1	7.5	8.2	8.1	8.0	8.6	7.1	7.5	7.9	7.6	8.2	8.3
Specific Conductance $\mu S \cdot cm^{-1}$	180	200	220	190	300	350	680	900	1000	225	450	470	455	525	575
Dissolved Oxygen	10.5	8.2	11.1	10.9	11.6	10.3	10.7	7.8	10.5	11.0	8.4	8.0	10.0	8.7	9.4
Oxygen % Saturation	100	97	93	107	112	85	107	82	86	105	85	80	97	93	77
Turbidity N.T.U.	18.0	9.0	4.4	21.0	8.5	1.7	15.5	7.0	7.0	13.0	1.1	20.0	31.5	23.0	30.0
Calcium	18.80	23.20	23.80	18.80	39.80	44.30	44.90	63.50	69.00	20.40	28.90	50.60	27.50	45.40	50.00
Magnesium	6.60	9.70	8.80	7.00	14.70	18.00	20.20	27.00	29.10	9.00	14.10	18.60	12.60	18.10	23.30
Sodium	9.60	10.20	16.30	8.50	21.50	24.70	75.00	122.00	158.00	17.80	40.50	45.50	48.00	50.50	58.00
Potassium	1.19	0.77	0.62	2.12	2.58	2.68	3.37	3.93	4.08	1.26	3.41	3.18	2.14	2.66	2.87
Chloride	1.70	1.60	1.70	1.10	1.50	1.30	6.70	11.00	15.30	3.50	3.20	3.30	5.30	5.00	5.40
Sulphate	18.4	17.9	13.5	24.9	37.6	38.6	70.0	102.0	126.0	24.7	88.0	60.0	46.5	19.4	25.5
Oil & Grease	1.0	0.9	L0.1												
PP. Alkalinity as $CaCO_3$	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	31.0	L0.1	L0.1	L0.1	L0.1	L0.1	7.4	L0.1
Alkalinity, T. as $CaCO_3$	72.0	96.2	107.0	61.0	168.0	192.0	264.0	433.0	501.0	91.0	112.0	238.0	155.0	267.0	326.0
Bicarbonate	88.0	117.5	130.5	74.5	205.0	234.0	322.0	452.0	610.5	111.0	137.0	290.0	189.0	307.5	397.5
Carbonate								37.0						9.0	
Hardness, T. as $CaCO_3$	74.0	98.0	96.0	76.0	160.0	185.0	195.5	270.0	292.0	88.0	130.0	203.0	121.0	188.0	221.0
Silica (Reactive)	4.67	5.31	4.20	3.10	5.00	5.64	7.45	9.44	12.50	7.50	2.55	7.60	3.93	8.00	8.60
Total Filterable Residue	110	122	140												
Total Non-Filterable Residue	32.0	6.0	2.0												
Chemical Oxygen Demand	87	94	124												
Nitrogen, T. as N	1.04	1.13	1.19	1.11	1.17	0.67	1.07	1.28	0.63	1.21	0.98	1.19	1.21	1.46	1.28
Nitrate + Nitrite Nitrogen as N	0.040	0.007	0.006	0.006	0.167	0.010	0.005	0.051	0.010	0.008	0.003	0.006	0.008	0.156	0.022
Kjeldahl Nitrogen, T. as N	1.00	1.12	1.18	1.10	1.00	0.66	1.06	1.23	0.62	1.20	0.98	1.18	1.20	1.30	1.26
Ammonia Nitrogen, T. as N	0.05	L0.01	L0.01	0.05	L0.01	L0.01	0.05	0.03	L0.01	0.07	0.03	0.10	0.05	0.10	0.03
Phosphorus, T. as P	0.124	0.126	0.053	0.078	0.027	0.025	0.250	0.042	0.132	0.070	0.029	0.355	0.102	0.089	0.057
Ortho-Phosphorus as P	0.049	0.074	0.034												
Total Organic Carbon	35.5	32.5	37.0	33.7	26.2	25.0	34.2	26.8	26.9	54.0	26.5	27.3	41.5	35.6	35.7
Total Inorganic Carbon	14.0	18.0	21.0	12.0	35.0	43.0	60.0	91.0	109.0	18.0	24.0	56.0	34.0	57.0	71.0
Phenol	0.009	0.022	0.012												
Cyanide, T.	0.005	0.006	0.009												
Arsenic, T.	0.0011	0.0016	0.0007												
Selenium, T., $\mu g \cdot L^{-1}$	L0.2	L0.2	0.4												
Boron, T.	0.20	0.17	0.15												
Cadmium, T.	L0.001	L0.001	L0.001												
Copper, T.	0.001	0.001	L0.001												
Iron, T.	1.05	2.21	1.00												
Chromium, T.	0.001	0.001	0.001												
Manganese, T.	0.080	0.070	0.020												
Zinc, T.	0.002	0.002	0.004												
Lead, T.	L0.002	0.004	L0.002												
Vanadium, T.	L0.001	L0.001	L0.001												
Nickel, T.	0.006	0.001	L0.001												
Mercury, T. $\mu g \cdot L^{-1}$	L0.1	0.1	L0.1												
Tannin & Lignin	3.6	4.1	3.4												
Ion Balance	1.03	1.03	1.06	1.09	1.00	1.03	1.05		0.98	1.05	1.07	1.00	1.08	1.03	0.97

Continued ...

Notes: All values are reported in $mg \cdot L^{-1}$ unless otherwise stated.
L - Less Than; T. - Total; N - Nitrogen; P - Phosphorus.

Table 3.3. Continued.

Site/Date	M6-W			M5-W			MR-W2			M4-W			M3-W		
Parameter	**19 June**	**30 July**	**21 Sept.**	**19 June**	**30 July**	**21 Sept.**	**19 June**	**30 July**	**21 Sept.**	**19 June**	**30 July**	**21 Sept.**	**19 June**	**30 July**	**21 Sept.**
Temperature ^{o}C	15	17.5	8.0	14	19.0	6.0	17.0	23.5	8.0	16.0	16.0	6.5	16.0	14.0	7.0
pH	7.8	7.5	8.0	8.1	8.2	8.3	8.0	7.7	7.5	7.5	7.9	8.2	7.7	7.7	7.9
Specific Conductance $\mu S{\cdot}cm^{-1}$	260	330	340	280	380	380	175	190	225	225	250	300	220	375	340
Dissolved Oxygen	10.7	8.1	9.8	10.5	8.8	11.1	9.8	8.2	11.4	10.6	8.8	10.8	10.5	7.9	9.0
Oxygen % Saturation	105	84	82	100	94	88	100	95	96	106	88	87	105	76	73
Turbidity N.T.U.	4.3	25.0	30.0	5.0	3.0	3.2	22.0	7.8	4.3	9.8	17.0	51.0	3.3	2.7	1.6
Calcium	18.60	26.00	26.30	20.20	32.60	34.80	18.80	29.10	24.50	16.30	27.30	22.80	20.70	71.10	57.00
Magnesium	9.50	9.90	12.40	8.40	13.70	14.30	6.60	6.60	9.00	5.90	8.90	8.80	8.10	20.70	19.50
Sodium	31.10	40.00	39.00	34.60	55.00	53.50	10.00	10.60	17.00	26.00	42.50	42.50	28.50	57.00	47.00
Potassium	2.25	2.20	2.62	1.68	2.15	1.67	1.27	0.82	0.62	0.70	0.95	1.35	1.33	2.10	1.69
Chloride	8.60	9.50	8.40	9.40	14.40	16.40	2.20	2.40	2.60	15.20	21.00	20.00	10.10	32.70	24.40
Sulphate	21.8	15.0	15.4	21.7	47.5	50.0	19.1	17.9	14.5	28.1	14.8	15.1	16.5	20.2	11.6
Oil & Grease							0.7	1.1	0.6						
PP. Alkalinity as $CaCO_3$	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1
Alkalinity, T. as $CaCO_3$	110.0	163.0	162.0	116.0	205.0	173.0	71.0	93.8	108.0	67.0	136.0	129.0	106.0	310.0	263.0
Bicarbonate	134.0	199.0	197.5	141.5	250.0	211.0	87.0	114.5	132.0	82.0	166.0	157.5	129.0	378.0	321.0
Carbonate															
Hardness, T. as $CaC0_3$	86.0	106.0	117.0	85.0	138.0	146.0	74.0	100.0	98.0	65.0	105.0	93.0	85.0	263.0	223.0
Silica (Reactive)	5.55	6.20	6.45	4.50	6.80	6.84	4.75	5.30	4.12	3.04	3.60	5.75	6.35	8.60	7.50
Total Filterable Residue							110	124	140						
Total Non-Filterable Residue							63.2	11.0	2.4						
Chemical Oxygen Demand							107	94	104						
Nitrogen, T. as N	1.24	1.45	1.23	1.55	1.42	1.32	1.14	1.15	1.08	1.47	1.49	1.44	1.63	1.25	1.10
Nitrate + Nitrite Nitrogen as N	0.055	0.151	0.014	0.006	0.062	0.018	0.34	0.006	0.004	0.008	0.067	0.022	0.006	0.114	0.015
Kjeldahl Nitrogen, T. as N	1.18	1.30	1.22	1.54	1.36	1.30	1.10	1.14	1.08	1.46	1.42	1.42	1.62	1.14	1.08
Ammonia Nitrogen, T. as N	0.06	0.01	L0.01	0.06	0.01	L0.01	0.05	0.05	L0.01	0.07	0.05	L0.01	0.07	0.02	L0.01
Phosphorus, T. as P	0.124	0.192	0.080	0.089	0.077	0.051	0.119	0.109	0.049	0.112	0.142	0.145	0.066	0.035	0.030
Ortho-Phosphorus as P							0.046	0.070	0.034						
Total Organic Carbon	38.0	38.0	37.0	53.0	50.0	46.0	36.2	33.0	37.7	65.0	66.5	66.0	59.0	36.5	36.5
Total Inorganic Carbon	23.0	33.0	35.0	23.0	43.0	36.0	14.0	19.0	21.0	11.0	28.0	26.0	21.0	67.0	57.0
Phenol							0.012	0.009	0.010						
Cyanide, T.							0.005	0.007	0.008						
Arsenic, T.							0.0015	0.0012	0.0008						
Selenium, T. $\mu g{\cdot}L^{-1}$							L0.2	L0.2	0.5						
Boron, T.							0.19	0.17	0.15						
Cadmium, T.							L0.001	L0.001	L0.001						
Copper, T.							0.001	0.001	L0.001						
Iron, T.							1.52	2.13	0.96						
Chromium, T.							0.001	0.002	0.001						
Manganese, T.							0.070	0.080	0.030						
Zinc, T.							0.003	0.012	0.004						
Lead, T.							L0.002	L0.002	L0.002						
Vanadium, T.							0.004	L0.001	0.001						
Nickel, T.							0.006	L0.001	L0.001						
Mercury, T. $\mu g{\cdot}L^{-1}$							L0.1	L0.1	L0.1						
Tannin & Lignin							3.7	4.4	3.4						
Ion Balance	1.08	1.02	1.08	1.07	0.95	1.06	1.04	1.07	1.07	1.04	1.09	1.08	1.08	1.03	1.06

Continued ...

Notes: All values are reported in $mg{\cdot}L^{-1}$ unless otherwise stated.
L - Less Than; T. - Total; N - Nitrogen; P - Phosphorus.

Table 3.3. Continued

Site/Date Parameter	D1-W 20 June	D1-W 30 July	D1-W 21 Sept.	DR-W 19 June	DR-W 30 July	DR-W 21 Sept.	M2-W 19 June	M2-W 30 July	M2-W 21 Sept.	M1-W 19 June	M1-W 28 July	M1-W 21 Sept.	MR-W1 20 June	MR-W1 24 July	MR-W1 22 Sept.
Temperature °C	13.0	13.5	6.0	18.0	20.0	8.0	12.0	16.0	7.0	12.0	18.0	5.0	16.0	24.0	7.0
pH	7.1	7.6	8.1	8.0	7.9	8.0	7.6	7.5	8.0	7.4	7.7	7.7	7.1	7.0	7.1
Specific Conductance $\mu S \cdot cm^{-1}$	260	440	275	325	300	380	250	580	300	325	475	540	220	200	225
Dissolved Oxygen	11.2	8.5	10.2	9.7	8.0	9.3	9.8	7.7	10.0	10.5	8.3	9.0	10.3	8.4	11.5
Oxygen % Saturation	105	80	81	100	87	77	90	77	82	96	86	70	102	100	94
Turbidity N.T.U.	7.1	3.0	1.9	8.5	10.0	6.4	21.0	21.0	9.2	6.5	4.4	3.3	21.0	8.5	4.2
Calcium	20.30	41.90	26.00	26.80	34.10	41.20	22.20	43.70	27.20	26.00	46.00	54.00	19.80	20.00	27.10
Magnesium	9.10	16.60	12.30	11.50	9.20	16.80	10.50	16.70	12.60	9.90	15.60	22.00	7.10	6.50	9.70
Sodium	21.00	39.00	25.50	27.40	24.00	37.50	24.70	42.50	26.50	41.50	50.00	57.00	11.50	10.50	19.20
Potassium	1.06	2.00	1.37	1.83	1.13	2.00	1.80	2.38	1.60	1.75	2.75	2.52	1.27	0.65	0.73
Chloride	8.70	9.30	7.50	5.00	3.90	6.20	7.00	15.00	7.70	17.20	19.30	16.70	2.50	1.80	3.40
Sulphate	38.0	91.0	33.2	20.0	13.6	20.5	23.0	37.5	18.4	28.2	14.0	16.6	19.6	15.1	15.0
Oil & Grease				1.1	0.4	0.9							1.4	0.4	L0.1
PP. Alkalinity as $CaCO_3$	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1
Alkalinity, T. as $CaCO_3$	76.0	142.0	117.0	145.0	148.0	217.0	125.0	201.0	140.0	132.0	233.0	287.0	78.0	84.5	119.0
Bicarbonate	93.0	173.0	143.0	177.0	180.5	265.0	152.5	245.0	171.0	161.0	284.0	350.0	95.0	103.0	145.0
Carbonate															
Hardness, T. as $CaCO_3$	88.0	173.0	116.0	114.5	123.0	172.0	99.0	178.0	120.0	106.0	179.0	225.5	79.0	77.0	108.0
Silica (Reactive)	2.76	4.70	4.00	2.40	2.90	3.23	2.10	3.50	3.75	6.75	9.70	9.00	4.52	4.75	4.00
Total Filterable Residue				195	176	265							120	115	155
Total Non-Filterable Residue				4.8	4.0	3.6							28.4	23.6	1.6
Chemical Oxygen Demand				78	94	79							87	83	104
Nitrogen, T. as N	1.27	1.17	1.03	1.14	1.25	1.00	1.15	1.24	1.01	1.63	1.85	1.01	1.08	1.22	1.11
Nitrate + Nitrite Nitrogen as N	0.005	0.032	0.007	0.006	0.017	0.005	0.005	0.057	0.010	0.005	0.111	0.012	0.036	0.023	0.006
Kjeldahl Nitrogen, T. as N	1.26	1.14	1.02	1.08	1.24	1.00	1.14	1.18	1.00	1.62	1.74	1.00	1.04	1.20	1.10
Ammonia Nitrogen, T. as N	0.05	0.02	L0.01	0.05	0.02	L0.01	0.05	0.03	L0.01	0.09	0.15	0.01	0.05	0.19	L0.01
Phosphorus, T. as P	0.066	0.034	0.037	0.120	0.142	0.068	0.086	0.086	0.064	0.064	0.103	0.065	0.129	0.105	0.049
Ortho-Phosphorus as P				0.051	0.078	0.048							0.052	0.060	0.034
Total Organic Carbon	51.5	46.5	49.5	35.2	36.0	28.8	40.0	35.0	37.3	64.0	64.0	50.5	35.0	36.7	36.3
Total Inorganic Carbon	15.0	29.0	22.0	30.0	27.0	48.0	24.0	42.0	29.0	27.0	55.0	65.0	15.0	16.0	23.0
Phenol				0.007	0.007	0.005							0.009	0.011	0.011
Cyanide, T.				0.004	0.006	0.006							0.005	0.006	0.008
Arsenic, T.				0.0009	0.0011	0.0008							0.0010	0.0008	0.0007
Selenium, T. $\mu g \cdot L^{-1}$				L0.2	L0.2	0.3							L0.2	L0.2	0.2
Boron, T.				0.30	0.24	0.22							0.20	0.19	0.17
Cadmium, T.				L0.001	L0.001	L0.001							L0.001	L0.001	L0.001
Copper, T.				0.001	0.001	L0.001							0.001	0.001	L0.001
Iron, T.				1.52	2.21	1.23							1.31	1.85	0.91
Chromium, T.				L0.001	0.002	0.001							0.001	0.002	0.001
Manganese, T.				0.040	0.060	0.020							0.060	0.050	0.010
Zinc, T.				0.002	0.001	0.005							0.005	0.004	0.003
Lead, T.				L0.002	L0.002	L0.002							L0.002	L0.002	L0.002
Vanadium, T.				0.005	L0.001	0.003							L0.001	L0.001	L0.001
Nickel, T.				0.005	L0.001	L0.001							0.007	0.001	L0.001
Mercury, T. $\mu g \cdot L^{-1}$				L0.1	L0.1	L0.1							L0.1	L0.1	L0.1
Tannin & Lignin				3.0	4.2	2.3							3.6	4.1	3.5
Ion Balance	1.09	1.04	1.06	1.02	1.05	1.04	0.98	1.05	1.05	1.07	1.06	1.08	1.03	0.98	1.08

Notes: All values are reported in $mg \cdot L^{-1}$ unless otherwise stated.
L - Less Than; T. - Total; N - Nitrogen; P - Phosphorus

pH levels were reported by Akena et al. (1981) in the MacKay River during the summer. The pH levels recorded in the present study were within the Alberta Surface Water Quality Objectives (ASWQO) of 6.5 to 8.5 (Table 3.4).

In the MacKay River, total non-filterable residue concentrations ranged from 1.6 to 63.2 $mg \cdot L^{-1}$; the concentrations were notably higher in June than in the subsequent sample periods, and exhibited a positive relationship to discharge rates.

A brown colouration was exhibited by MacKay River drainage waters due to the presence of dissolved organic matter.

Dissolved oxygen concentrations in the MacKay River drainage ranged from 7.7 to 11.6 $mg \cdot L^{-1}$ and were above the ASWQO of 5.0 $mg \cdot L^{-1}$, which is generally considered adequate for the survival of fish. The dissolved oxygen levels recorded in June and September were similar while the July values generally were lower. The percent saturation values ranged from 70 to 112% with the highest values recorded in June. Supersaturation probably was a result of increased oxygen production by photosynthesizing plants. McCart et al. (1978) recorded similar dissolved oxygen levels in the MacKay River in 1977, although supersaturated conditions were not recorded until August and September.

Table 3.4 Summary of water quality objectives for the protection of aquatic life.

Parameter[a]	**ASWQO**[b]	**Environment Canada**[c]
pH	6.5 - 8.5	
Dissolved Oxygen	5.0 (minimum)	
Total Nitrogen as N	1.0	
Total Phosphorus as P	0.05	0.100[d]; 0.025[e]
Aluminum, T.		0.100 (tentative)
Cyanide, T.	0.01	
Arsenic, T.	0.01	
Selenium, T.	0.01	
Boron, T.	0.5	
Cadmium, T.	0.01	0.0002
Copper, T.	0.02	0.005
Iron, T.	0.30	
Chromium	0.05	0.040
Manganese, T.	0.05	
Zinc, T.	0.05	0.030
Lead, T.	0.05	0.030
Nickel, T.		0.025
Mercury, T.	0.0001	
Silver, T.	0.05	
Fluoride	1.5	
Threshold Odour Number (20°C)	8	
Phenol	0.005	0.001
Surfactants	0.05	
Carbon Chloroform Extraction	0.2	
Sulphide	0.05	
Methyl Mercaptan	0.05	

[a] All values are reported as $mg \cdot L^{-1}$ unless stated otherwise.

[b] ASWQO - Alberta Surface Water Quality Objectives by Alberta Environment (1977).

[c] Environment Canada by McNeely et al. (1979).

[d] Value for flowing water.

[e] Value for lakes and reservoirs.

3.2.2 MAJOR IONS

The MacKay River water was of the calcium bicarbonate type with an ionic dominance of $HCO_3^- > Ca^{++} > Mg^{++} > Na^+ > SO_4^= > Cl^- > K^+$ (Figure 3.10). Although the concentrations of each ion generally were similar at each sampling station, slight seasonal variation was exhibited by most ions, with concentrations increasing from June to September. This was confirmed by the specific conductance values which showed a similar pattern. Charlton and Hickman (1984) also reported summer peaks of specific conductance. Sodium concentrations exhibited the greatest increase in September, relative to the previous sampling periods. This increase likely resulted from an increase in the proportion of groundwater, which is common during periods of low flow. Similar conditions were reported by McCart et al. (1978). In addition, these authors indicated that water in the MacKay River shifted to a sodium chloride type during the winter period. However, in 1978 and 1979 sodium concentrations in the MacKay River during the summer periods nearly equalled those recorded in the winter (Charlton and Hickman 1984). These authors indicated that the summer flows during 1978 and 1979 were similar except that in 1978 the September flows were three times higher. The 1984 summer flows were similar to those in 1979 except that the June flows in 1984 were two times higher. In 1978 and 1979, the mean flows for July and September were approximately three to four times less than the long term means for those months (Water Survey of Canada 1983). In 1979, the mean flow in June was similar to the long term mean, while in the same month the 1978 monthly mean was approximately one-half of the long term mean.

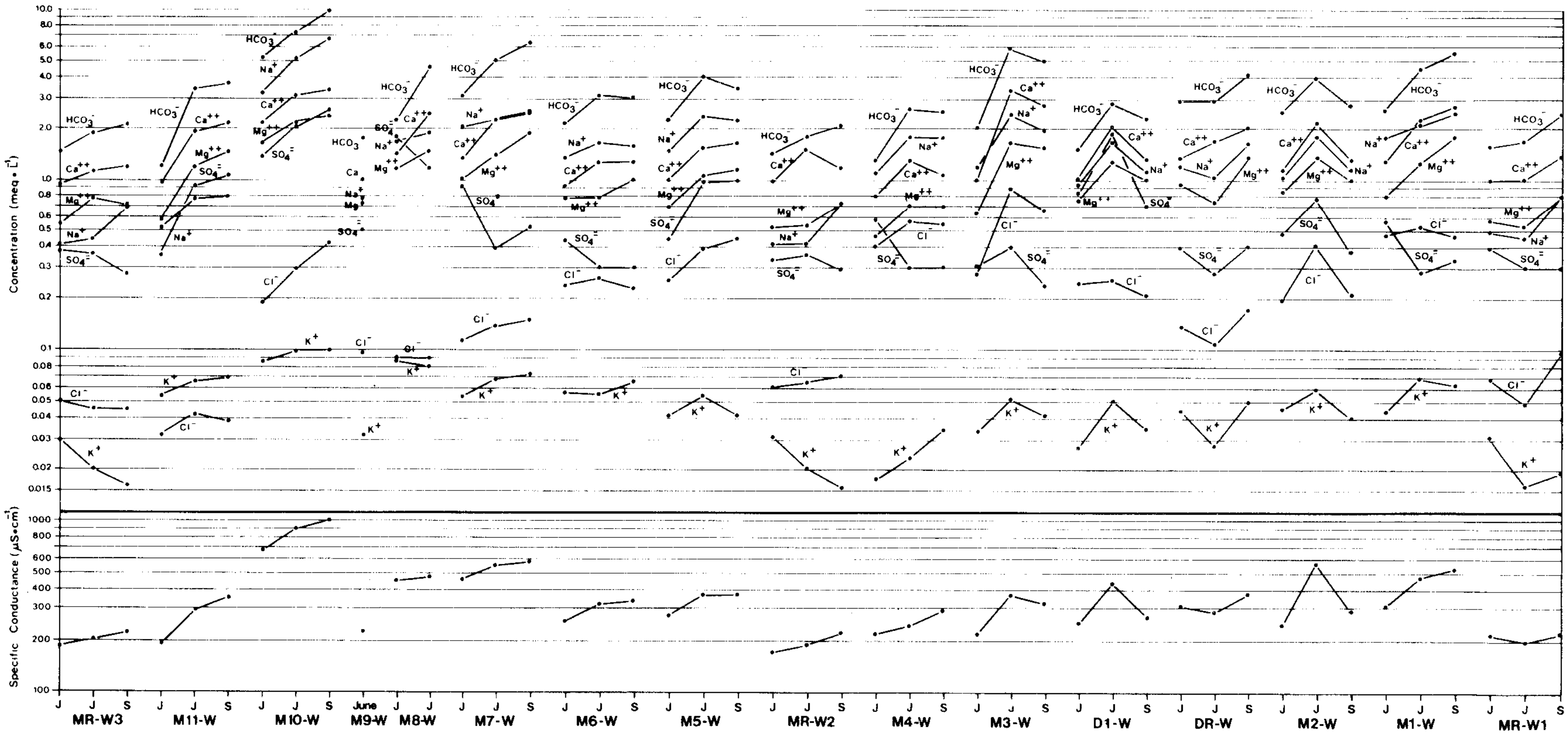


Figure 3.10 Ionic dominance of the major ions, and specific conductance profiles for the MacKay River System in June, July and September, 1984.

In general, the tributaries exhibited higher concentrations of total filterable residue than the MacKay River mainstem. Highest concentrations of total filterable residue among the tributaries was recorded at station M1-W. The ionic dominance varied considerably among the tributaries. At stations M11-W, M9-W, M2-W, D1-W, and DR-W (Dover River), the water was of the calcium bicarbonate type; at the remaining stations, water of the sodium bicarbonate type was present during at least one sampling period. At the majority of stations, the concentrations of most ions were inversely related to discharge rates, with the highest concentrations generally recorded in September. At stations M3-W, D1-W, and M2-W, however, concentrations of major ions exhibited a decrease in this period. The flows in these creeks during September were equal to or greater than those present during the July survey. Normally, concentrations of most major ions increase during low flow periods, particularly in fall and winter due to increased influence from groundwater. Groundwater generally has higher concentrations of total filterable residue than waters originating from surface runoff. The data suggest that the groundwater to surface runoff ratio has an important role in determining the ionic composition of the waters in this drainage system.

Although notable differences existed in ionic composition between tributary and mainstem MacKay River waters, the tributaries, because of their low discharges, did not contribute to a discernible change in the water quality of the mainstem.

3.2.3 NUTRIENTS

Nitrogen, phosphorus, and reactive silica are the major nutrients required by plants: of these, the dissolved fractions of total nitrogen and total phosphorus are most important in determining primary productivity in streams. Reactive silica is particularly important to diatoms. Total organic carbon is used as an energy source by bacteria and other heterotrophic organisms.

3.2.3.1 Nitrogen

The total nitrogen concentrations among the stations in the MacKay River system were similar and ranged from 0.63 mg $N \cdot L^{-1}$ at M10-W to 1.85 mg $N \cdot L^{-1}$ at M1-W. Most values exceeded the ASWQO of 1.0 mg $N \cdot L^{-1}$. Lowest concentrations generally occurred in September, showing a direct relationship to stream discharge. Important seasonal changes in nitrogen concentrations normally occur between early spring, summer, and winter periods. Logan (1977) reported that maximum transport of nitrogen occurs during storm runoff and early spring, and that during summer low flow, sediment transport of nitrogen is minimal. McCart et al. (1978) reported that total nitrogen in the MacKay River ranged from approximately 0.55 to 0.75 mg $N \cdot L^{-1}$ during the June to September period. The nitrate + nitrite concentrations in the MacKay River ranged from 0.006 to 0.340 mg $N \cdot L^{-1}$, with the highest concentrations occurring in June. Similar concentrations were evident in the tributaries. Normally, maximum inorganic nitrogen levels occur during the winter and spring periods as a result of nitrification (Hutchinson 1957). Ammonia concentrations in the MacKay River system were low, ranging from less than 0.01 to 0.19 mg $N \cdot L^{-1}$. Natural waters generally contain ammonia with concentrations less than 0.1 mg $N \cdot L^{-1}$. Levels greater than 0.1 mg $N \cdot L^{-1}$ may be indicative of anthropogenic inputs.

3.2.3.2 Phosphorus

In the MacKay River, total phosphorus concentrations ranged from 0.049 to 0.129 mg $P \cdot L^{-1}$. A general decrease in phosphorous concentrations occurred from June to September. Considerable seasonal fluctuations in concentrations normally occur between spring, summer, and winter periods. A strong correlation often is found between total phosphorus and suspended sediment concentrations, and both parameters closely parallel a natural hydrograph. Cahill (1977) reported that mass transport during storms tends to contribute a very large proportion of total annual phosphorus loading. He also indicated that unlike total phosphorus, ortho-phosphorus concentrations do not always have a positive association with stream discharge, and may be inversely related to discharge during the lower flow range. This relationship was exhibited in the MacKay River where the ortho-phosphorus levels (0.034 to 0.074 mg $P \cdot L^{-1}$) were notably higher in July, a period when the discharge was considerably lower than in June. McCart et al. (1978) found that total phosphorus concentrations in the MacKay River ranged from 0.030 to 0.100 mg $P \cdot L^{-1}$ during the June to September period with the lowest value reported in September. For the same period they also reported mean ortho-phosphorous concentrations of 0.015 to 0.035 mg $P \cdot L^{-1}$ with the highest value in July. Among the tributaries, the relationship between total phosphorus and discharge was less defined than in the MacKay River. The total phosphorus levels in MacKay River system generally exceeded the ASWQO limit of 0.05 mg $P \cdot L^{-1}$. McNeely et al. (1979) reported that total phosphorous levels should not exceed 0.10 mg $P \cdot L^{-1}$ in order to not accelerate eutrophication of water systems.

3.2.3.3 Reactive Silica

In the MacKay River drainage system, concentrations of reactive silica (SiO_2) ranged from 2.10 to 12.50 $mg \cdot L^{-1}$. Most natural waters contain concentrations of silica from 1 to 30 $mg \cdot L^{-1}$ (McNeely et al. 1979). Concentrations in the MacKay River were lower in September than in previous months, a relationship similar to that found by McCart et al. (1978). In the tributaries, the highest reactive silica values generally were found in September; this probably was the result of increased influence by groundwater. Concentrations of silica in groundwater may range from 1000 to 4000 $mg \cdot L^{-1}$ (McNeely et al. 1979).

3.2.3.4 Total Organic Carbon

Concentrations of total carbon in the MacKay River system ranged from 25.0 to 66.5 $mg \cdot L^{-1}$. Trends among sampling stations and among monitoring periods were not evident. McCart et al. (1978), however, reported that in the MacKay River, highest values were found in mid-winter with lower values in mid-summer. The total organic carbon content in natural waters may vary from 1 to 30 $mg{\cdot}L^{-1}$, with higher values considered to be the result of anthropogenic input (McNeely et al. 1979).

3.2.4 TRACE METALS AND OTHER SUBSTANCES

The concentrations of trace metals and elements in the MacKay River generally were below the detection limits. Iron (0.91 to 2.21 $mg{\cdot}L^{-1}$) and manganese (0.010 to 0.080 $mg{\cdot}L^{-1}$) concentrations frequently exceeded the ASWQO limits of 0.30 and 0.050 $mg{\cdot}L^{-1}$, respectively. The sources of these parameters were natural since no anthropogenic inputs were apparent. McCart et al. (1978) reported that boron, iron, lead, mercury and cadmium exceeded the ASWQO most frequently during the winter period. During the present study, phenol concentrations ranged from 0.009 to 0.022 $mg{\cdot}L^{-1}$, and also exceeded the ASWQO of 0.005 $mg{\cdot}L^{-1}$. Values exceeding the ASWQO also were reported in McCart et al. (1978). The source of phenol was likely natural, originating mainly from hydrocarbon and decaying vegetation. Oil and grease (<0.1 to 1.4 $mg{\cdot}L^{-1}$) present in the MacKay River probably were derived from the natural hydrocarbon present in the substrate.

3.3 ZOOBENTHOS

3.3.1 MACKAY RIVER

Changes in physical structure along the length of the MacKay River were reflected in the composition of zoobenthos. The downstream sample station (MR-B1; Figure 2.6) was located within a reach of the river characterized by slow flow and homogeneous substrate comprised mainly of sand and silt. The fauna at B1 was composed primarily of Oligochaeta, Chironomidae and, to a lesser extent, Ephemeroptera (**Ephemerella**, **Tricorythodes**, Baetidae). Relative composition was stable over the three seasons sampled (Figure 3.11); however, densities increased markedly in fall.

At upstream stations, water velocities increased, and the substrate exhibited a greater proportion of gravels and cobble. Simuliidae, which require hard substrates for attachment, constituted the most prevalent taxon at upstream stations B2, B3 and B4 during spring and summer, and almost completely dominated spring samples from B4 (Figure 3.11). Diversity at this station was 40% lower than that of any other MacKay River station in spring (H' = 0.626), even though more taxa were collected at this station than at the others (Table 3.5). Simuliidae remained abundant at the three upstream stations in summer, but all had emerged by fall (Figure 3.11). At this time all four MacKay River stations were dominated by Oligochaeta, Ephemeroptera and Chironomidae.

Benthic densities were variable within stations and seasons. Animals were much more abundant at station B4 in spring and fall, but densities were reduced in summer. At stations B2 and B3 the trend was reversed, with greatest densities (primarily Simuliidae) observed in summer. At station B1, relatively low densities were recorded except in the fall.

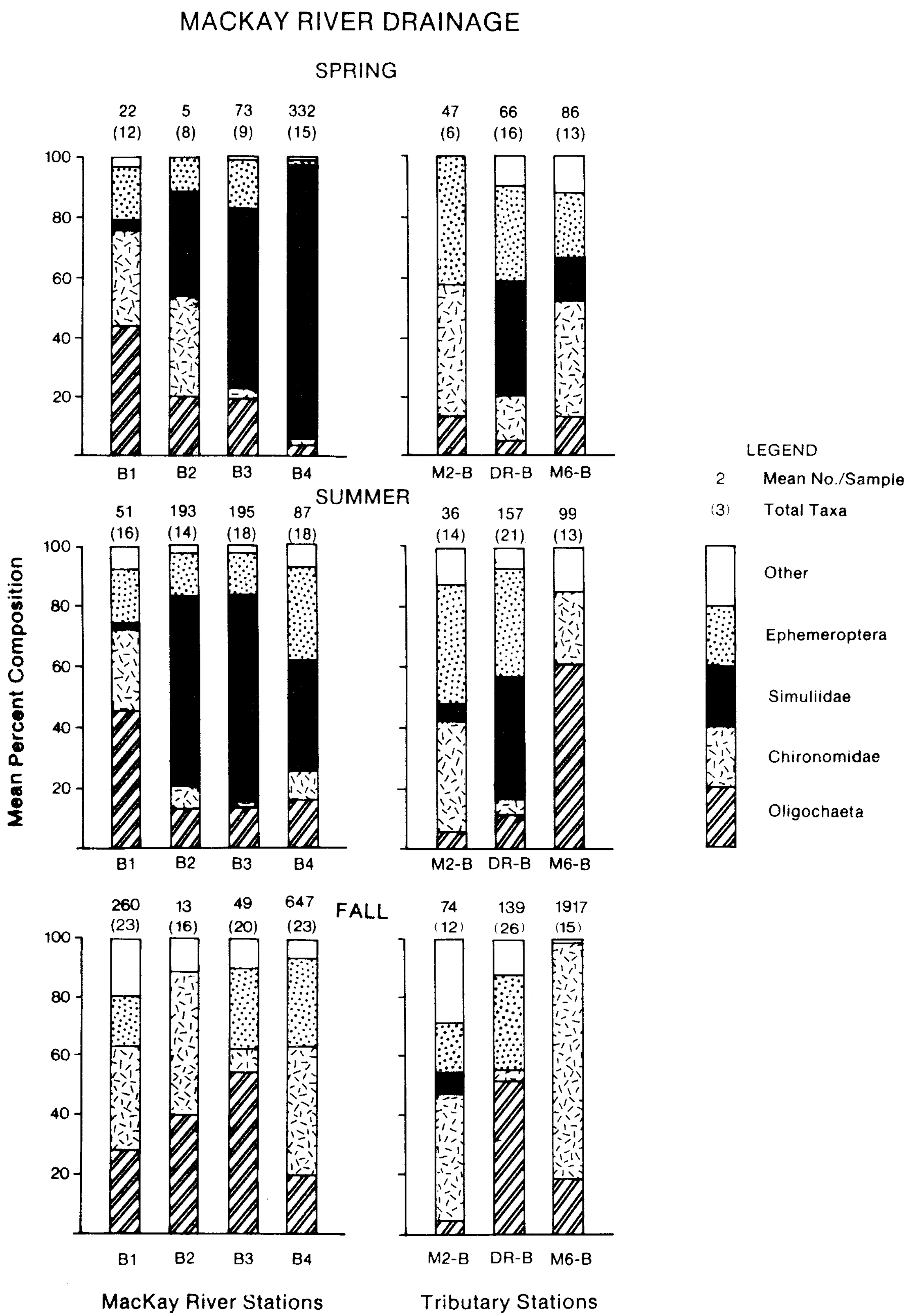


Figure 3.11 Relative abundance of major taxonomic groups of benthic invertebrates in the MacKay River drainage area, 1984.

Table 3.5 Mean density (no. per 0.1 m^2), mean biomass (mg per 0.1 m^2), diversity, and taxonomic richness of zoobenthos at MacKay River mainstem and tributary stations, 1984.

Station		Spring	Summer	Fall
MR-B1	Density	21.9	50.9	260.0
	Biomass	3.5	4.0	16.9
	Diversity	2.051	2.214	2.632
	Richness	12	16	23
MR-B2	Density	5.0	193.1	12.9
	Biomass	0.7	11.6	2.4
	Diversity	1.890	1.757	2.059
	Richness	8	14	16
MR-B3	Density	73.3	194.9	49.3
	Biomass	7.0	16.7	3.3
	Diversity	1.677	1.727	2.180
	Richness	9	18	20
MR-B4	Density	331.8	87.1	647.1
	Biomass	60.1	7.9	50.7
	Diversity	0.626	2.729	2.252
	Richness	15	18	23
M2-B	Density	47.3	35.9	73.9
	Biomass	6.9	6.5	10.0
	Diversity	1.535	2.326	2.228
	Richness	6	14	12
DR-B	Density	66.1	157.3	139.2
	Biomass	11.1	19.7	11.9
	Diversity	2.404	2.324	2.177
	Richness	16	21	26
M6-B	Density	85.8	99.2	1919.4
	Biomass	11.6	15.3	76.7
	Diversity	2.510	1.644	0.852
	Richness	13	13	15

Biomass estimates roughly paralleled those of benthic density; however, because the modal size class of individuals at all stations decreased through the year, summer and fall increases in biomass were not as great as density increases (Table 3.5). Most organisms collected in the fall were early stages of species that overwinter as immatures. Diversity and taxonomic richness generally increased at all stations throughout the year (Table 3.5). The upper and lower stations had highest diversity and richness in the fall. Detailed tables of taxonomic composition and abundance are presented in Appendix D, Tables D1 to D4.

3.3.2 TRIBUTARIES TO MACKAY RIVER

3.3.2.1 Creek M2

During the June sample period, Creek M2 was 3 m wide at station M2-B, with moderate current flowing over substrate of sand and fine gravel impregnated with bitumen (Figure 2.6). Benthic densities were fairly constant among seasons, ranging from 35.9 to 73.9 animals per 0.1 m^2 (Table 3.5).

The ephemeropteran **Baetis** was the most abundant organism in spring and summer. Simuliidae was codominant in spring, but was replaced by Chironomidae in summer and fall (Figure 3.11). Diversity and richness were low in spring (six taxa, H' = 1.535, Table 3.5), but increased in summer and fall. Trends in biomass paralleled those reported for the MacKay River (Appendix D, Table D31).

Detailed tables of taxonomic composition and abundance of the benthos at MacKay River tributary stations are presented in Appendix D, Tables D5 to D7.

3.3.2.2 Dover River

At station DR-B (100 m upstream of the confluence), the Dover River was approximately 7 m wide and had a shallow, rapid flow over coarse limestone talus (Figure 2.6).

In spring and summer, **Baetis** and Simuliidae were the most abundant organisms. Oligochaeta replaced Simuliidae as the most common taxon in fall (Figure 3.11). Fauna were substantially richer and more abundant in the Dover River than in Creek M2. Richness also consistently exceeded that of any station in the MacKay River drainage, although other stations were more diverse (Table 3.5).

Biomass in fall was equivalent to that in spring even though animals were twice as abundant (Table 3.4). This reflected the small size of most individuals at this time (Appendix D, Table D31).

3.3.2.3 Creek M6

Creek M6 was sampled downstream of a beaver dam where the creek descends sharply into the MacKay River valley (Figure 2.6). The creek at M6-B was less than 1 m wide and very shallow, flowing over coarse cobble embedded in sand, and through deadfall snags. Aspen overstory provided dense shading.

Chironomidae and Oligochaeta were the dominant taxa present, although **Baetis** and Simuliidae were common in spring (Figure 3.11). Taxonomic richness was intermediate in comparison to M2-B and DR-B (Table 3.5). The fall sample contained very high densities of Chironomidae and Oligochaeta, and this produced estimates of density and biomass greater than at any other sample station in the MacKay River drainage (Appendix D, Table D31).

3.4 FISH

3.4.1 MACKAY RIVER

Nineteen species of fish were recorded in the MacKay River in 1984 (Table 3.6). Of these, eight were sportfish species (i.e., species having some sport, domestic or commercial importance), two were coarsefish species (i.e., sucker), and eight were forage species (i.e., cyprinids, sculpins, etc.). Fish species previously recorded in the MacKay River (Sekerak and Walder 1980) but absent from 1984 collections were finescale dace (**Chrosomus neogaeus**), spottail shiner (**Notropis hudsonius**), spoonhead sculpin (**Cottus ricei**) and brook stickleback (**Culaea inconstans**). Species recorded in the present study but not previously reported from the MacKay River drainage were fathead minnow and northern redbelly dace.

Table 3.6. Fish species recorded in the MacKay River system, 1984.

Species	Species Code	Scientific Name
Lake whitefish	LW	**Coregonus clupeaformis** (Mitchill)
Mountain whitefish	MW	**Prosopium williamsoni** (Girard)
Arctic grayling	AG	**Thymallus arcticus** (Pallas)
Goldeye	GE	**Hiodon alosoides** (Rafinesque)
Northern pike	NP	**Esox lucius** Linnaeus
Walleye	YW	**Stizostedion vitreum** (Mitchill)
Yellow perch	YP	**Perca flavescens** (Mitchill)
Burbot	LING	**Lota lota** (Linnaeus)
Longnose sucker	LNS	**Catostomus catostomus** (Forster)
White sucker	WS	**Catostomus commersoni** (Lacepede)
Fathead minnow	FHM	**Pimephales promelas** Rafinesque
Flathead chub	FHC	**Platygobio gracilis** (Richardson)
Lake chub	LKC	**Couesius plumbeus** (Agassiz)
Longnose dace	LND	**Rhinichthys cataractae** (Valenciennes)
Pearl dace	PD	**Semotilus margarita** (Cope)
Northern redbelly dace	NRD	**Chrosomus eos** Cope
Emerald shiner	ES	**Notropis atherinoides** Rafinesque
Slimy sculpin	SS	**Cottus cognatus** Richardson
Trout-perch	TP	**Percopsis omiscomaycus** (Walbaum)

Total = 19 species

The fish species assemblage of the MacKay River has been grouped for discussion into sportfish, coarsefish and forage fish categories. Several previous fisheries studies have been conducted on the MacKay River system (Griffiths 1973; McCart et al. 1978; Machniak et al. 1980; Walder et al. 1980); however, a detailed comparison between these and present study results is beyond the scope of this report. Comparisons, when made, will be general in nature and limited to species for which a sufficient data base is available.

3.4.1.1 Sportfish Species

The majority of sportfish species in the MacKay River were recorded during boat electroshocking surveys in the spring and summer periods (Appendix E, Table E1). Yellow perch, Arctic grayling, northern pike, and walleye were the only species recorded by other capture methods (seine and backpack electrofisher; Appendix E, Tables E1 and E2).

Goldeye

Goldeye was the most abundant sportfish species encountered during electroshocking surveys, contributing 22.6% to the total catch from all stations and periods combined (Table 3.7). This species was present in catches from all stations and sample periods. During the summer survey at stations ES1, ES2, and ES3, goldeye contributed 42.2%, 41.5%, and 37.0%, respectively, to the total catch. Capture rates (fish per electroshocking minute) for this species at these stations were 0.6, 0.4, and 0.2

Table 3.7 Percentage composition of fish species at repetitive boat electrofishing stations on the MacKay River, spring and summer 1984.

Species[a]	Boat Electroshocking (ES) Stations											
	MR-ES1			MR-ES2			MR-ES3			All Stations		
(n)[b]	Spring (120)	Summer (64)	Combined (184)	Spring (29)	Summer (41)	Combined (70)	Spring (24)	Summer (27)	Combined (51)	Spring (173)	Summer (132)	Combined (305)
LW	0	3.1	1.1	0	0	0	0	0	0	0	1.5	0.7
MW	1.7	6.3	3.3	0	4.9	2.9	4.2	0	2.0	1.7	4.6	3.0
GE	10.7	42.2	21.7	3.4	41.5	25.7	4.2	37.0	21.6	8.7	40.9	22.6
NP	0.8	3.1	1.6	0	4.9	2.9	8.3	3.7	5.9	1.7	3.8	2.6
YW	15.8	7.8	13.0	3.4	4.9	4.3	33.3	7.4	19.6	16.2	6.8	12.1
LING	0	0	0	3.4	0	1.4	0	0	0	0.6	0	0.3
LNS	4.2	0	2.7	17.2	12.2	14.3	0	14.8	7.8	5.8	6.8	6.2
WS	55.0	32.8	47.3	51.7	24.4	35.7	25.0	33.3	29.4	50.3	30.3	41.6
FHC	1.7	4.7	2.7	10.4	7.3	8.6	0	3.7	2.0	2.9	5.3	3.9
LKC	10.0	0	6.4	3.4	0	1.4	25.0	0	11.8	11.0	0	6.2
TP	0	0	0	6.9	0	2.9	0	0	0	1.2	0	0.7

[a]For species code explanation see Table 3.6.

[b]Number of fish captured and observed.

fish·min.$^{-1}$, respectively (Appendix E, Table E1), indicating a decreased abundance with increased distance from the Athabasca River.

The majority of the goldeye captured were juveniles although adults also were represented in the catch, particularly in the July period. Evidence of spawning by this species in the MacKay River was not obtained; those individuals present in the system likely were migrants from the Athabasca River, moving into the MacKay River to forage. This is supported by the findings of Machniak et al. (1980). Results of the 1980 study, however, indicated a lower abundance of goldeye in the MacKay River than found during the present study. In addition, trapping and gillnetting operations in 1980 captured only juvenile fish, whereas in 1984, 47% of the aged fish were adults or sub-adults (i.e., age six or older). This indicates that the present use of summer feeding habitat in the MacKay River for both adults and juveniles of this species is greater than previously observed.

Goldeye (n=32) captured in the MacKay River in 1984 ranged in fork length from 135 to 395 mm with a relatively even representation from all size-classes within this range (Appendix E, Table E2). In previous studies on the MacKay River, McCart et al. (1978) reported goldeye from 232 to 287 mm fork length, and Machniak et al. (1980) reported a range of 258 to 318 mm for this species. During studies on the Athabasca River in the Mildred Lake area, a similar size range was found (Bond and Berry 1980). In 1984, 15 (47%) of the goldeye captured were over 300 mm in length and ranged from age six to eight. Of the 17 goldeye aged and sexed, eight were mature. Seven of the mature goldeye were females six to eight years-of-age. McCart et al. (1978) and Machniak et al. (1980) found all goldeye captured in the MacKay River (for which sex and age were determined) were immature four to six year-old fish. In the Athabasca River, 99% of all goldeye examined were sexually immature (Bond 1980).

Walleye

Thirty-eight walleye were collected from the MacKay River. Walleye were present at all electroshocking stations during each of the sample periods (Table 3.7). This species was second in abundance and contributed 12.1% to the total electroshocking catch. Most walleye were taken during the spring period, from stations ES1 and ES3, with the latter station contributing 33.3% to the total electroshocking catch.

Although representing a major component of the sportfish assemblage, walleye exhibited low densities and a sporadic distribution in the MacKay River. The highest capture rate recorded for walleye was 0.3 fish·min^{-1} from ES1 during the spring period. The majority of these individuals were present below the bridge crossing at Highway 63, suggesting a close association with the Athabasca River. A localized concentration of walleye also was present at the mouth of the Dover River (in ES3) during the spring. Presence in these confluence areas likely indicates preferred feeding habitat for this species.

Direct evidence of walleye spawning in the MacKay River was not obtained in the present study. Most adult walleye captured in the late

May survey were spent males. Only one spent female was recorded. Machniak and Bond (1979) reported a similar preponderance of spent males and low numbers of female walleye in the Steepbank River, and attributed their presence to a post-spawning migration into the system for feeding.

McCart et al. (1978) captured young-of-the-year (y-o-y) walleye 20 km upstream in the MacKay River; however, based on the low numbers (n = 39) of y-o-y walleye captured, these authors suggested only a limited spawning use of the river. Availability of spawning habitat, however, does not appear to be a limiting factor. Surveys conducted in the fall of 1984, indicated numerous areas of good potential spawning habitat are present in the MacKay River.

Machniak et al. (1980) indicated that walleye leave the MacKay River drainage during the summer and suggested that few, if any, overwinter in the system. McCart et al. (1978) reported that walleye were most abundant in the lower reaches of the MacKay River in May, with catches declining by late September. In the present study, walleye abundance decreased from the May to July period (Appendix E, Table E1) indicating movements out of the area had occurred.

Walleye captured in the MacKay River in 1984 ranged in fork length from 247 to 484 mm, with those in the 385 to 443 mm size range accounting for 42% of the catch (Appendix E, Table E2). Most (95%) of walleye sexed were males. Machniak et al. (1980) reported 73%

of the MacKay River walleye were between 300 to 460 mm in length, with 94% of walleye captured being males. A similar dominant size range and a preponderance of males also were reported for MacKay River walleye by McCart et al. (1978).

Fin-ray age was determined for 24 walleye in the present study. Lengths of these fish ranged from 247 mm (age three) to 484 mm (age nine). Most walleye were age seven (42%) although age three (21%) and age four (17%) fish also were well represented in the catch. McCart et al (1978) reported scale ages for MacKay River walleye ranged from 0+ to 14. Machniak et al. (1980) reported scale ages ranged from 0+ to nine, with the majority (96%) being age two to age seven, inclusive. The age-length relationship for MacKay River walleye in 1984 (Appendix E, Table E2) is similar to that recorded by Machniak et al. (1980).

Northern Pike

In 1984, eight northern pike were captured by boat electroshocking in the MacKay River. This species occurred infrequently, contributing 2.6% to the total electroshocking catch (Table 3.7). The highest contribution of northern pike (8.3%) was recorded during spring surveys in ES3. At stations ES1 and ES2, the highest percentage composition in catches occurred during the summer survey. Capture rates of northern pike at all stations and during all surveyed periods were less than 0.1 fish·min^{-1}. The majority of northern pike captured in 1984 were adults.

Within the study area, the MacKay River contained few areas of suitable pike spawning habitat. This, combined with the absence of y-o-y and the low abundance of juvenile northern pike, indicated a limited spawning use of the system. Only one spent male was captured (at ES3) in the spring survey.

In 1978, Machniak et al. (1980) recorded an upstream post-spawning migration of northern pike into the lower MacKay River in the spring and a return downstream movement, possibly to the Athabasca River, in the fall. These movements suggest the primary use of the lower MacKay River by northern pike was for summer foraging. McCart et al. (1978) indicated a resident population of northern pike was present in the upper reaches of the MacKay River.

The seven northern pike examined in the present study ranged in length from 336 to 679 mm. The largest individual was eight years of age. McCart et al. (1978) reported a maximum age of 11 years for MacKay River northern pike, with most (81%) ranging from four to seven years. Machniak et al. (1980) reported a range in ages from 0+ to nine years with the majority (75%, excluding y-o-y) of pike aged being three to six years of age.

Mountain Whitefish

Mountain whitefish were a minor component in the 1984 electroshocking catch. They were most frequently encountered in stations ES1 and ES2 during the summer survey, contributing 6.3% and 4.9%, respectively, to the total catch from these stations (Table 3.7). Of the seven mountain whitefish captured in 1984, five were juveniles. The occurrence of this species primarily at the lower sample stations and the absence of y-o-y mountain whitefish in all sampled areas indicates that the source of this population was probably the Athabasca River, with individuals undertaking feeding movements into the MacKay River during the spring and summer periods. Previous studies (McCart et al. 1978; Machniak et al. 1980) also indicated a low, seasonal use of the MacKay River by mountain whitefish.

In 1984, mountain whitefish (n=7) captured in the MacKay River ranged from 136 to 336 mm in length with the majority (71%) being in the 136 to 146 mm size range (Appendix E, Table E2). The dominant size class (n=5) consisted of age one fish. A single age three fish (a mature female) and one age four fish (a mature male) were the only other mountain whitefish recorded. Machniak et al. (1980) captured only two mountain whitefish (299 and 319 mm fork length) in the MacKay River; both fish were five-year-old males.

Lake Whitefish

Only two lake whitefish (i.e., one captured and one observed) were recorded in 1984. Both individuals were adults, collected at station ES1 during the summer survey (Table 3.7). Results of this and previous studies (McCart et al. 1978; Machniak et al. 1980) indicate that lake whitefish utilize the MacKay River only during short feeding excursions from the Athabasca River.

The one lake whitefish captured in the present study was a six-year-old (scale age), mature female, measuring 359 mm in length. In 1978, Machniak et al. (1980) collected five lake whitefish ranging in length from 333 to 376 mm, and in scale age from six to eight years.

Arctic Grayling

Arctic grayling were absent from boat electroshocking and seining samples in 1984. One Arctic grayling (a y-o-y) was captured by backpack electrofishing at EF9, near the upstream limit of the study area (Appendix E, Table E1).

Trapping operations on the lower MacKay River in 1978 (Machniak et al. 1980) recorded the presence of a small (n=45), upstream spawning migration of Arctic grayling in late April to early May. Although the location of spawning areas was not identified, the authors indicated the most suitable spawning areas in the MacKay River were situated above the Dover River confluence, upstream to approximately km 125. They also recorded one y-o-y Arctic grayling in the vicinity of EF9.

One Arctic grayling was captured in the MacKay River in 1984. This individual, taken in late September, was 113 mm in length and age 0+. Machniak et al. (1980) recorded Arctic grayling ranging in fork length from 66 to 378 mm and in scale age from 0+ to age seven with the majority being ages two, three, and five.

Yellow Perch

Nine yellow perch (all y-o-y) were collected from the MacKay River in the present study; all were recorded at seine stations located within 3 km of the mouth (Appendix E, Table E3). Yellow perch y-o-y also were recorded at the mouth of the MacKay River in 1978 (Machniak et al. 1980).

All yellow perch captured in the MacKay River (n=9) during the present study were age 0+ (scale age). These individuals, captured in late September, ranged in length from 47 to 52 mm, with a mean length of 50.7 mm. Machniak et al. (1980) collected y-o-y perch (n=62) from the mouth of the MacKay River. These individuals ranged in length from 33 to 53 mm. Mean lengths were 36.1 and 44.0 mm on 22 July and 26 August, respectively.

Burbot

One burbot (an adult) was recorded in electroshocking captures (Table 3.7); none were taken by other sampling methods during the present study. Low numbers of burbot have been found in the lower reaches of the MacKay River during previous studies (McCart et al. 1978; Machniak et al. 1980). Burbot likely utilize the lower reaches of the MacKay River for feeding. Spawning use of the system by this species is unknown.

The burbot captured in the present study was a mature male, 610 mm in total length and age seven (otolith age). Machniak et al. (1980) captured 16 burbot, ranging in length from 134 to 589 mm, in 1978. The oldest burbot aged in 1978 were five years of age and were maturing males, 496 and 499 mm in total length.

3.4.1.2 Coarsefish Species

Two species of coarsefish, white sucker and longnose sucker, were recorded in the MacKay River during the present study. These species were present at the majority of sample stations within the study area and were collected by all sampling methods.

White Sucker

In 1984, white sucker was the most abundant species in electroshocking captures, contributing 41.6% to the total catch (Table 3.7). Adult and juvenile white suckers were most common at the lower two sample stations (ES1 and ES2) in the spring, contributing 55.0 and 51.7% to the total catch at those respective stations. Capture rates (CUE) in this period exhibited a decline with increased upstream distance from the Athabasca River (Appendix E, Table E1). White sucker juveniles were present in low numbers in seine collections during the spring survey, being recorded only from the two lowermost stations (Table 3.8). White sucker y-o-y were absent from spring collections.

Table 3.8 Percentage composition of fish species at repetitive seine stations on the MacKay River, spring and summer 1984.

Species[a] (n)	MR-S1 Spring (226)	MR-S1 Summer (528)	MR-S1 Combined (754)	MR-S2 Spring (212)	MR-S2 Summer (315)	MR-S2 Combined (527)	MR-S3 Spring (146)	MR-S3 Summer (384)	MR-S3 Combined (530)	All Stations Spring (584)	All Stations Summer (1227)	All Stations Combined (1811)
NP	0.9	0	0.3	0	0	0	0	0.3	0.2	0.3	0.1	0.2
YW	0.4	0	0.1	0.5	0	0.2	0	0	0	0.3	0	0.1
YP	0.4	0	0.1	0	0	0	0	0	0	0.2	0	L 0.1[b]
LNS	3.1	0.2	1.1	1.9	1.3	1.5	0.7	0	0.2	2.0	0.4	0.9
WS	0.9	3.2	2.5	1.4	0.6	1.0	0	11.7	8.5	0.9	5.2	3.8
FHM	0	12.7	8.9	0	0.3	0.2	0	0	0	0	5.5	3.8
LKC	26.6	64.4	53.0	84.4	70.2	75.9	97.3	81.2	85.7	65.2	71.2	69.2
LND	0	11.9	8.4	3.3	18.1	12.1	0.7	1.3	1.1	1.4	10.2	7.3
NRD	0	0	0	0	0	0	0	0.3	0.2	0	0.1	L 0.1
ES	2.7	0	0.8	0	0	0	0	0	0	1.0	0	0.3
SS	0	0.2	0.1	1.4	1.3	1.3	0	0.3	0.2	0.5	0.5	0.5
TP	65.0	7.4	24.7	7.1	8.2	7.8	1.4	4.9	4.0	28.1	6.8	13.7

Seine (S) Stations

[a] For species code explanation see Table 3.6.

[b] L = Less than

In the summer, white sucker adults and juveniles were encountered in reduced numbers in electroshocking captures. Seine collections of white suckers increased in the summer surveys, reflecting the greater abundance of y-o-y, particularly in collections at stations S1 and S3 (Appendix E, Table E3).

Synoptic surveys in the fall recorded a low occurrence and sporadic distribution of white suckers. White sucker (primarily y-o-y) were recorded only from stations EF2, S1B, and EF9, with the greatest numbers recorded at the latter station (Table 3.9).

White sucker spawning in the MacKay River was not documented in 1984. Previous investigations have documented large numbers of white suckers migrating into the MacKay River to upstream spawning areas (Machniak et al. 1980). In 1978, this migration was essentially completed by 18 May; spawning was thought to have occurred during mid-May when maximum daily water temperatures of 11°C to 13°C were attained. In 1984, water temperature was 14.5°C in the MacKay River during the spring survey period (i.e., 27-28 May). The high temperatures and the capture of spent white suckers suggests spawning was completed prior to the 1984 spring surveys.

White sucker spawning areas have not been previously identified in the MacKay River; however, indirect evidence obtained by previous investigators (i.e., the capture of newly emergent fry and y-o-y) indicated this species likely spawned in the MacKay River upstream from the Dover

Table 3.9 Percentage composition of fish species recorded at synoptic backpack electrofishing and seine stations on the mainstem MacKay River, September 1984.

Species[a] (n)[b]	Electrofishing (EF) Stations										Seine (S) Stations							All Stations Combined (482)
	MR-EF1 (47)	MR-EF2 (45)	MR-EF3 (30)	MR-EF4 (14)	MR-EF5 (22)	MR-EF6 (26)	MR-EF7 (36)	MR-EF8 (11)	MR-EF9 (149)	Combined (380)	MR-S1A (5)	MR-S1B (40)	MR-S2A (12)	MR-S3A (5)	MR-S4 (10)	MR-S5 (30)	Combined (102)	
AG	0	0	0	0	0	0	0	0	0.7	0.3	0	0	0	0	0	0	0	0.2
YP	0	0	0	0	0	0	0	0	0	0	0	5.0	0	0	0	0	2.0	0.4
LNS	0	0	0	28.6	13.6	0	5.6	18.2	20.1	10.8	0	0	0	0	0	3.3	1.0	8.7
WS	0	2.2	0	0	0	0	0	0	13.4	5.5	0	10.0	0	0	20.0	0	5.9	5.6
LKC	87.2	93.3	86.7	71.4	54.5	76.9	69.4	54.5	19.5	55.5	40.0	40.0	58.3	60.0	30.0	76.7	52.9	55.0
LND	0	0	0	0	27.3	11.5	2.8	27.3	1.3	4.0	0	0	0	20.0	40.0	13.3	8.8	5.0
PD	8.5	0	0	0	0	0	0	0	14.1	6.6	0	12.5	0	0	0	0	4.9	6.2
NRD	4.3	0	0	0	0	3.8	0	0	19.5	8.4	40.0	5.0	0	0	0	6.7	5.9	7.9
SS	0	0	0	0	0	0	0	0	0	0	0	0	8.3	20.0	0	0	2.0	0.4
TP	0	4.4	13.3	0	4.6	7.7	22.2	0	11.4	8.9	20.0	27.5	33.3	0	10.0	0	16.7	10.6

[a]For species code explanation, see Table 3.6.
[b]Number of fish captured (captured and observed for electrofishing).

River, and in the Dunkirk and Dover rivers. McCart et al. (1978) found white sucker y-o-y distributed throughout the lower MacKay River during the summer, but indicated they were most abundant in the mainstem between km 80 and km 40. The distribution patterns of y-o-y white suckers recorded in the present study were similar to those recorded by previous investigators.

In 1978, Machniak et al. (1980) recorded a defined out-migration of white sucker y-o-y in the MacKay River. These authors indicated that large numbers of emergent fry left the MacKay River during June, and that by the end of June, only a small portion of the 1978 year-class remained in the system. A second out migration by y-o-y individuals was recorded during October. Movements of fry and y-o-y out of the system may account for the low abundance of y-o-y white suckers encountered in the 1984 summer and fall survey periods. A portion of the white sucker population (consisting of all age-classes) likely overwinters in the MacKay River.

Longnose Sucker

In 1984, longnose suckers were considerably less abundant in the MacKay River than white suckers. Longnose sucker adults and larger juveniles were present in greatest abundance at ES2 during both the spring and summer electroshocking surveys (Table 3.7). Smaller juveniles were taken at most seine stations sampled in the spring and summer periods (Table 3.8); however, y-o-y were absent from spring and summer collections in the lower MacKay River. During the fall survey, juvenile and y-o-y longnose suckers were present only at sample stations situated upstream from the Dover River confluence (Table 3.9).

All adult longnose suckers captured in the spring 1984 survey were spent, indicating spawning was completed by this time. Machniak et al. (1980) reported that in 1978, longnose sucker spawning in the MacKay River was essentially completed by mid-May. Trapping results in 1978 indicated the size of the longnose sucker spawning population in the MacKay River was considerably lower than the white sucker population. Although longnose sucker spawning areas were not identified by these investigators, they indicated spawning likely occurred in areas of the MacKay River upstream from the Dover River confluence. McCart et al. (1978) found sucker y-o-y to be widely distributed in the lower MacKay River but felt that most longnose suckers spawned upstream of the Lease 17 boundary. In 1984, large concentrations of fry were observed near the mouth of the MacKay River on 26 May. A dip-netted sample of these was preserved and the fry subsequently were identified as longnose suckers. These individuals ranged in length from 12 to 14 mm indicating recent hatching. The source of these y-o-y (in the MacKay River or the Athabasca River) is unkown; however, the absence of y-o-y from spring and summer collections in the lower MacKay River may indicate that the fry observed originated from mainstem Athabasca River spawning areas. Sampling in the fall of 1984 recorded longnose sucker y-o-y only from stations upstream of the Dover River, with the highest capture rate (3.3 $fish \cdot min^{-1}$) recorded from EF-9, the farthest upstream station

(Appendix E, Table E1). These results support previous conclusions that longnose sucker spawning areas are located in the upper reaches of the MacKay River above the Dover River. The presence of these age-classes during the fall indicates the MacKay River provides an important rearing habitat function. Some overwintering use of the system by all age-classes of longnose suckers is probable also.

3.4.1.3 Forage Fish Species

Lake Chub

Lake chub was the most abundant species in the MacKay River in 1984. This species was captured at all sample stations. Lake chub accounted for 69.2% of the seine collections at repetitive sample stations (Table 3.8), 55.5% of catches at synoptic backpack electrofishing stations, and 52.9% of synoptic seine collections (Table 3.9). This species was most abundant at stations S1, S2, and S3 during the summer survey; CUE values for these stations were 7.6, 4.4, and 6.9 fish per 10 m^2 of surface area, respectively (Appendix E, Table E1).

Machniak et al. (1980) found lake chub to be the most abundant species in the MacKay River watershed in 1978, accounting for 50.0% of the total seine catch. This species exhibited a ubiquitous distribution in 1978 but was most abundant in the lower 80 km of the MacKay River. Sampling in 1978 indicated the occurrence of a substantial upstream migration into the lower MacKay River during May. These fish apparently utilize the system for spawning, feeding, and rearing. A substantial downstream migration of lake chub was recorded in October, although it was not determined if these fish moved into the Athabasca River for overwintering or remained in the lower reaches of the MacKay River.

The MacKay River contains important spawning and rearing habitat for lake chub. The capture of ripe adults during the upstream migration in 1978 indicated this movement was related to spawning (Machniak et al. 1980). In 1984, lake chub y-o-y were present at most stations indicating widespread spawning and nursery use of the MacKay system. A similar distribution of y-o-y was noted in 1978.

Trout-Perch

Trout-perch was the second most abundant forage species encountered in the MacKay River and was present at the majority of sample stations in 1984. This species accounted for 13.7% of collections from repetitive seine stations (Table 3.8), and 10.6% of the combined catch at synoptic seine and electrofishing stations (Table 3.8).

Although adult trout-perch in spawning condition were not encountered in the present study, the capture of y-o-y from stations S1 and S3 in the summer survey indicates spawning use of the MacKay River in 1984.

In 1978, Machniak et al. (1980) recorded an upstream movement of trout-perch into the lower reaches of the MacKay River in early May, and a subsequent return migration in September. Spawning reportedly occurred in mid-June and y-o-y were recorded in catches during July. Numerous y-o-y trout-perch apparently drifted out of the spawning stream into the Athabasca River shortly after hatching although some remained in the MacKay River throughout the summer. A portion of the trout-perch population was thought to overwinter in the MacKay River watershed.

Other Species

Fathead minnow, flathead chub, longnose dace, pearl dace, northern redbelly dace, emerald shiner, and slimy sculpin were the other forage species recorded in the MacKay River in 1984 (Appendix E, Tables E1 and E3). Of these, flathead chub and emerald shiner were present only in the lower reaches of the MacKay River, likely a result of localized feeding movements from Athabasca River populations. Fathead minnow y-o-y were recorded in the lower MacKay River only during the summer survey (Table 3.8); adults or juveniles were absent. This species was frequently recorded from small, low gradient drainages in the present study area, and the presence of y-o-y in the MacKay River may indicate a downstream drift from the smaller associated drainages.

Northern redbelly dace have not been reported previously from the MacKay River. The species was encountered infrequently in the MacKay River, with the majority of specimens taken in the lower reaches (Table 3.9). The capture of one individual at EF6 and 29 y-o-y at EF9 in the fall period, however, may indicate the presence of a small resident population within other areas of the MacKay River.

Longnose dace and slimy sculpin likely are resident species in the MacKay River. Longnose dace were common in the lower MacKay River and also in the upper sections of the study area. Slimy sculpins were absent from upstream collections, occurring only in catches from the lower MacKay River. In 1984, longnose dace y-o-y were captured at both upstream (ES9) and downstream (S1) sample stations. Machniak et al. (1980) reported that slimy sculpins spawned in the MacKay River from mid-May to mid-June.

Pearl dace were recorded at both the farthest upstream and downstream sample stations in the MacKay River. The presence of y-o-y in September at EF9 indicates this species spawned in the MacKay River in 1984, and possibly is resident in the upper reaches of the MacKay River.

3.4.2 DOVER RIVER

Eight fish species were recorded from the Dover River in 1984. All species encountered in the Dover River also were present in the MacKay River in 1984. Previous studies on the Dover River (Sekerak and Walder 1980) captured several species (i.e., yellow perch, northern pike, finescale dace, pearl dace, brook stickleback) not recorded in the present study. Their absence likely is due to the limited sampling, particularly in upper reaches of the Dover River, in 1984.

3.4.2.1 Sportfish Species

Burbot was the only sportfish species found in the Dover River in 1984 (Table 3.10). One individual (an adult) was observed in EF1 during the spring survey (Figure 2.1). This species has not previously been recorded in the Dover River; its presence in 1984 likely represents a feeding incursion from the MacKay River.

Resident populations of yellow perch and northern pike have been reported from the headwater lakes of the Dover River (Machniak et al. 1980).

3.4.2.2. Coarsefish Species

Both white sucker and longnose sucker were recorded in the Dover River in 1984. White suckers were the most abundant coarsefish, accounting for 14.7% of the combined catch (Table 3.10). White suckers were present at all sample stations on the Dover River; longnose suckers were present at all stations except EF2. Adults of both sucker species were absent from captures. White sucker y-o-y were captured at EF1 in July and at EF4 in September; longnose sucker y-o-y were found at EF4 in September. The presence of y-o-y confirms the occurrence of spawning by these species in the Dover River in 1984. Machniak et al. (1980) reported similar findings in 1978.

Table 3.10 Percentage composition of fish species recorded at backpack electrofishing and seine stations on the Dover River, 1984.

Species[a] (n)[c]	Electrofishing (EF) Stations					Seine Stations			All Stations Combined
	DR-EF1[b] (171)	DR-EF2 (86)	DR-EF3 (96)	DR-EF4 (137)	Combined (490)	DR-S1 (11)	DR-S2 (10)	Combined (21)	(511)
LING	0.6	0	0	0	0.2	0	0	0	0.2
LNS	0.6	0	6.3	5.8	3.1	0	0	0	2.9
WS	26.9	9.3	5.2	11.7	15.3	0	0	0	14.7
LKC	49.7	59.3	57.3	59.9	55.7	63.6	70.0	66.7	56.2
LND	2.9	3.5	5.2	0	2.6	0	0	0	2.5
NRD	0.6	2.3	0	0	0.6	0	0	0	0.6
SS	4.1	3.5	10.4	4.4	5.3	0	0	0	5.1
TP	14.6	22.1	15.6	18.2	17.1	36.4	30.0	33.3	17.8

[a]For species code explanation, see Table 3.6.

[b]DR-EF1 sampled during each of the spring, summer, and fall survey periods; remainder of electrofishing and seine stations sampled only during the fall survey period.

[c]Number of fish captured (captured and observed for electrofishing).

The high incidence of beaver dams found on the Dover River during the fall 1984 suggests that some individuals of both sucker species may become temporarily entrapped and overwinter in the Dover River. A certain portion of the spawning population likely originates from outside the Dover River (i.e., MacKay or Athabasca rivers) during the spring freshet and vacates the system after spawning. In years with low spring flows (e.g., 1984), however, some beaver dams may remain intact, preventing access by upstream migrants to spawning areas. The presence of y-o-y suckers in upstream locations in 1984 indicates successful overwintering by mature adults within these areas.

3.4.2.3 Forage Species

Five forage fish species were collected from the Dover River in 1984. All species present were considered to be resident and completing all life history functions within the system. Lake chub were the most abundant species recorded, accounting for 56.2% of the combined 1984 captures; the majority of fish captured at all Dover River stations were lake chub (Table 3.9). This species was most abundant at EF4 where a CUE of 6.8 fish·min^{-1} was recorded in September (Appendix E, Table E1).

Trout-perch also were abundant in Dover River collections, contributing 17.8% to the combined catch (Table 3.10). Highest capture rate for this species was 2.1 fish·min^{-1} at EF4 (Appendix E, Table E1). This species was present in catches from all stations.

Slimy sculpins were present at all stations in 1984, and accounted for 5.1% of the combined catch (Table 3.10). This species exhibited a similar abundance at all stations.

Northern redbelly dace and longnose dace exhibited a more sporadic distribution and lower abundance in the Dover River, relative to the other forage species. Both dace species were recorded only from the lower reaches of the Dover River.

SECTION 4.0

WEST INTERCEPTION DITCH/LOWER BEAVER CREEK SYSTEM

4.1 AQUATIC HABITAT

4.1.1 DESCRIPTION OF DRAINAGE AREA

The West Interception Ditch (W.I.D.) was constructed in 1976 to divert stream flow and surface runoff from the Syncrude Canada Ltd. mine site. It presently drains an area of approximately 73 km^2 (Appendix B, Table B2). Situated approximately 2.5 km west of the plant site, the W.I.D. originates in the southwestern corner of the mine site (Figure 2.2). An earthen dam forms the headwaters of the W.I.D., and separates the W.I.D. from Creek B1, diverting flow from Creek B1 into Beaver Creek Reservoir. From the dam, the W.I.D. flows north for approximately 14 km before entering Bridge Creek. Four main tributaries (Creeks W2, W3, W4 and W5) and several ephemeral drainages (draining a large muskeg area to the west) flow into the W.I.D. prior to its confluence with Bridge Creek. The drainage areas for these systems range from 1.8 km^2 (W2) to 26.0 km^2 (W3).

Bridge Creek originates in a muskeg area to the northwest of the mine site and drains directly (i.e., not including W.I.D. system) an area of approximately 14 km^2 (Appendix B, Table B2). From the headwaters, Bridge Creek flows in a southeasterly direction for 3.0 km before it is joined by the W.I.D. (Figure 2.2). From this confluence, Bridge Creek flows east for 3.5 km before emptying into Lower Beaver Creek. The total drainage area of Bridge Creek (including the W.I.D. system) is 86.3 km^2 (Appendix B, Table B2).

The remaining section of Lower Beaver Creek originates below the North Starter Dike and flows in a northeasterly direction for 5.5 km to the confluence with Bridge Creek, and then east for 2.5 km to the Athabasca River (Figure 2.2). Seepages and springs provide the majority of the flow in Lower Beaver Creek. The present drainage area for this system (excluding input from Bridge Creek) is approximately 4 km^2 (Appendix B, Table B2).

4.1.2 STREAMFLOWS DURING STUDY PERIOD

Discharges in the W.I.D. and Lower Beaver Creek system were measured on three occasions (June, July, September) during the study period (Appendix B, Table B3). Highest discharges were recorded in all systems during the June survey. In most systems, flow rates were similar during the July and September surveys. Discharge in the West Interception Ditch (WID-W) ranged seasonally from 0.10 $m^3 \cdot s^{-1}$ in June to 0.06 $m^3 \cdot s^{-1}$ in September. Tributaries to the W.I.D. experienced the following seasonal fluctuation: W3 - 0.07 $m^3 \cdot s^{-1}$ in June to less than 0.01 $m^3 \cdot s^{-1}$ in September; W4 - 0.02 $m^3 \cdot s^{-1}$ in June to less than 0.01 $m^3 \cdot s^{-1}$ in September; W5 - less than 0.1 $m^3 \cdot s^{-1}$ on all three occasions. Discharge in Lower Beaver Creek (LBC-W1) in June was 0.26 $m^3 \cdot s^{-1}$ compared to 0.02 $m^3 \cdot s^{-1}$ in September. Bridge Creek (BRC-W1) also displayed lower discharges during the fall (0.16 $m^3 \cdot s^{-1}$ in June; 0.01 $m^3 \cdot s^{-1}$ in September).

4.1.3 WEST INTERCEPTION DITCH (W.I.D.)

A study of the various forms of aquatic biota and the physical habitat characteristics of the W.I.D. was undertaken in 1977, one year after its construction (Tsui et al. 1977). Physical habitat conditions were recorded at four locations in the ditch. Tsui et al. (1977) described the W.I.D. as a shallow, slow-moving stream varying in width from 4 m (upstream) to 12 m (downstream). They noted that the substrate was predominantly mud except where gravel had been placed for stream bed protection. In 1977, maximum discharge occurred in June; streamflow was negligible by August. Visible erosion of the non-vegetated sloping banks was evident in June. By August, the banks were completely revegetated and apparently stabilized.

During the present study, habitat stations were established in the lower (H1), middle (H2), and upper reaches (H3) (Figure 2.2). The location of these stations in relation to the habitat zonation on the W.I.D. is shown in Figure 4.1. A summary of the data collected at the habitat stations is presented in Table 4.1.

Three major habitat reaches on the W.I.D. are evident. Reach 1, which originates at the confluence with Bridge Creek, is approximately 1.0 km in length. This section features a high gradient (8.0 $m \cdot km^{-1}$) in relation to upstream reaches. Reach 2 (km 1.0-2.2), with a gradient of 2.9 $m \cdot km^{-1}$, constitutes a transition zone between the high gradient conditions in Reach 1 and the low gradient conditions in the upper reach. Reach 3 (km 2.2-13.0) is characterized by a low gradient (1.9 $m \cdot km^{-1}$).

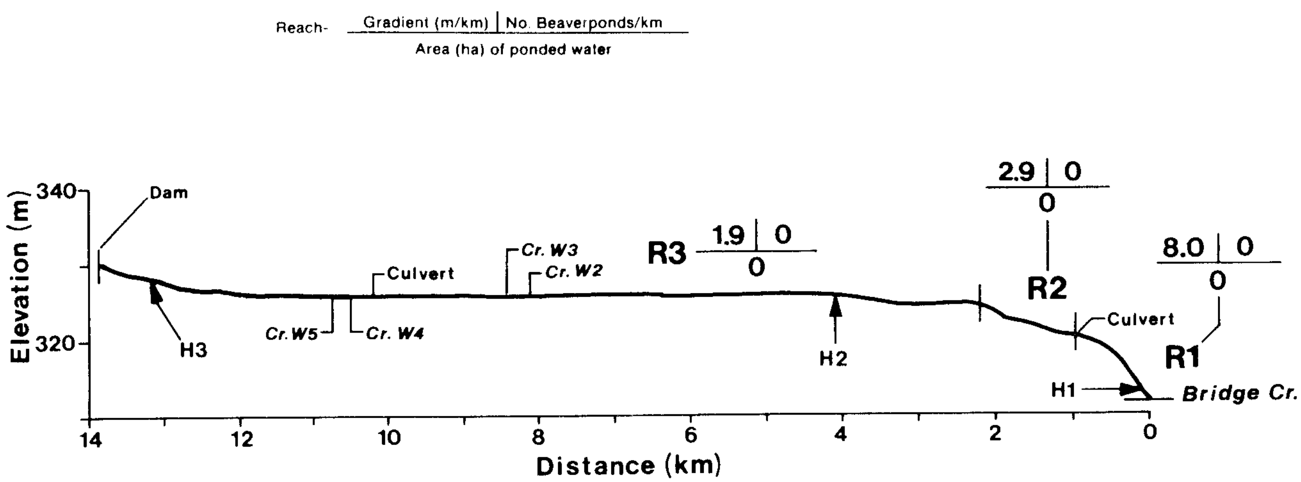


Figure 4.1 Longitudinal profile and habitat zonation, West Interception Ditch.

Table 4.1 Summary of physical habitat characteristics at sampling stations on the West Interception Ditch, July 1984.

			Channel Features at Transect						Cover Type Distribution (%)							
												Pool Type				
Station	Date	Water Temp(°C) (Time)(h)	Rooted Width (m)	Wetted Width (m)	Local Gradient (%)	Mean Depth (cm)	Mean Velocity ($cm \cdot s^{-1}$)	Discharge[a] ($m^3 \cdot s^{-1}$)	Riffle	Run	Flat	1	2	3	4	5
H1-T1	18 July	24 (1415)	4.2	4.2	2.0	8 (4-14)	27 (5-43)	0.02	48	43	-	9	-	-	-	-
-T2	18 July	25 (1600)	7.2	5.7	1.5	10 (9-12)	25 (15-31)	0.02	14	60	26		-	-	-	-
-T3	18 July	25 (1640)	10.5	5.5	1.5	12 (8-16)	29 (22-34)	0.02	-	79	-	21	-	-	-	-
-T4	19 July	17 (0920)	7.7	3.9	2.5	15 (14-16)	34 (11-46)	0.02	21	74	-	5	-	-	-	-
-T5	19 July	17 (1000)	18.3	11.2	0.8	17 (14-20)	18 (14-20)	0.02	-	12	84	4	-	-	-	-
H2-T1	19 July	23 (1625)	14.0	13.2	0.25	37 (27-43)	2.3 (2-3)	0.02	-	-	100	-	-	-	-	-
-T2	19 July	23 (1640)	12.8	12.8	0.25	22 (18-26)	2.3 (2-3)	0.02	-	-	100	-	-	-	-	-
-T3	19 July	-	10.7	9.7	0.25	15 (11-19)	7 (5-11)	0.02	-	-	100	-	-	-	-	-
H3-T1	20 July	16 (0945)	5.8	5.8	0.25	33 (29-37)	Negl.	0.02	-	-	100	-	-	-	-	-
-T2	20 July	16 (1000)	7.6	7.6	0.25	46 (33-60)	Negl.	0.02	-	-	100	-	-	-	-	-
-T3	20 July	16 (1020)	6.3	6.3	0.25	35 (14-48)	Negl.	0.02	-	-	100	-	-	-	-	-

	Bank Features (RUB/LUB)							Substrate Distribution (%)											Aquatic Veg.	
Station	Cond. (%)	Stab. (No.)	Under. (cm)	Slope (Deg.)	Cover (No.)	Depth (cm)	Over. (cm)	Sand	Silt	FG	MG	CG	VCG	SC	LC	SB	LB (BR)	EMB. (No.)	Macro. (No.)	Algae (No.)
H1-T1	10/70	4/2	8/10	136/136 (50)/(32)[b]	4/1	20/22	90/0	-	-	76	24	-	-	-	-	-	-	4	1	1
-T2	80/20	1/4	0/0	135/154	1/2	0/0	0/0	-	-	35	18	-	-	-	47	-	-	4	1	1
-T3	75/5	2/4	0/0	145/145	2/2	0/6	0/0	-	-	18	36	18	-	-	-	28	-	4	1	2
-T4	0/0	4/4	0/0	160/168	1/2	0/0	0/0	-	-	-	-	-	-	-	49	51	-	4	1	1
-T5	0/0	4/4	0/0	145/160	2/1	0/0	0/0	-	-	-	-	-	-	-	71	29	-	4	3	3
H2-T1	0/0	4/4	0/0	160/170	2/2	0/0	0/0	-	100	-	-	-	-	-	-	-	-	N/A[c]	4	1
-T2	0/0	4/4	0/0	166/174	4/4	0/0	0/0	-	100	-	-	-	-	-	-	-	-	N/A	4	1
-T3	0/0	4/4	0/0	165/165	2/4	0/0	0/0	-	100	-	-	-	-	-	-	-	-	N/A	5	1
H3-T1	0/0	4/4	0/0	155/164	2/2	0/0	0/0	-	100	-	-	-	-	-	-	-	-	N/A	2	1
-T2	0/0	4/4	0/0	175/167	2/2	0/0	0/0	-	100	-	-	-	-	-	-	-	-	N/A	2	1
-T3	0/0	4/4	0/0	175/175	2/2	0/0	0/0	-	100	-	-	-	-	-	-	-	-	N/A	4	1

[a]Recorded during water quality sampling on 25 July.
[b]Angle of undercut in parentheses.
[c]N/A - not applicable.
Note: Description of terms in Table 2.2.

Data from habitat station H1 (T1-T4) describe the habitat conditions in Reach 1. Data from the upper transect at this station (T5) likely are more representative of conditions in Reach 2; accordingly, data from T5 were not grouped with the T1-T4 data for analysis purposes. The mean wetted channel width at H1 was 4.8 m; mean depth was 11 cm. Mean current velocity at the station was 29 $cm \cdot s^{-1}$. The overall distribution of cover types at the four transects was as follows: Riffle (21%); Run (64%); Flat (6%); and Pool (9%). The substrate was dominated by coarse textured material; it ranged in size from fine gravel (0.4 to 0.8 cm) to small boulder (25.6 to 51.2 cm). Sedimentation of the coarse substrate material generally was low. Significant stream bank erosion was evident although on a localized basis. Macrophyte density was low, being restricted to sparse distribution of **Potamogeton pectinatus** along the channel margin.

Data from stations H2 and H3 provide a characterization of habitat conditions in Reach 3. Mean channel width in the lower section of the reach (H2) was 11.9 m; mean channel depth was 25 cm. The mean velocity at the three transects was 3.9 $cm \cdot s^{-1}$. Channel configuration in the upper portion of the reach (H3) differed noticeably. In this section the channel was narrower (mean width 6.6 m), deeper (mean depth 38 cm), and current velocity was markedly reduced (i.e., negligible). Despite differences in channel configuration, the cover type distribution was uniform at both stations (i.e., 100% Flat). The substrate consisted of 100% silt at all transects. Predominance of Flat type habitat and fine textured substrate characterize low gradient, low habitat diversity areas. Bank erosion was negligible in the entirety of Reach 3 owing to the presence of sloping, well-vegetated banks.

The density of macrophyte growths in the W.I.D. varied on a longitudinal basis. In Reach 1 (H1) channel coverage was less than 5%. In the upper sections, macrophyte channel coverage ranged from 50-75% (H2) to 15-75% (H3; Plate 4). The dominant species at all stations was **Typha latifolia**; also represented were **Potamogeton**, **Elodea** and **Megalodonta**. Conditions in 1984 are similar to those described in 1977 (Tsui et al. 1977), although overall channel coverage appears to have increased.

4.1.4 MINOR TRIBUTARIES OF W.I.D.

Inflow from several small tributaries enter the West Interception Ditch and contribute to the Bridge Creek - Lower Beaver Creek drainage system (Figure 2.2). Creeks W2 to W5 in the present study represent the mainstem and/or tributaries of Creek No. 1 to Creek No. 3 (Noton and Chymko 1978) which prior to the diversion entered directly into Beaver Creek. Creeks W2 and W3 correspond to former Creeks No. 1 and 2, respectively. Creeks W4 and W5 represent a tributary of Creek No. 3 and the main branch of Creek No. 3, respectively. Creek W1 was not investigated since the drainage pattern and point of entry into the W.I.D. were undefined.

Two of the four defined drainages, W2 and W4, are classed as first-order streams (Appendix B, Table B2). These systems are characterized by relatively short stream channel lengths (W2 - approx. 2.5 km; W4 -approx. 5.0 km) and small drainage areas (W2-1.8 km^2; W4-10.4 km^2). Creeks W3 and W5 feature greater stream channel lengths (W3 - approx. 16 km; W5 - approx. 8 km) and relatively larger drainage areas (W3-26 km^2; W5-18.3 km^2).

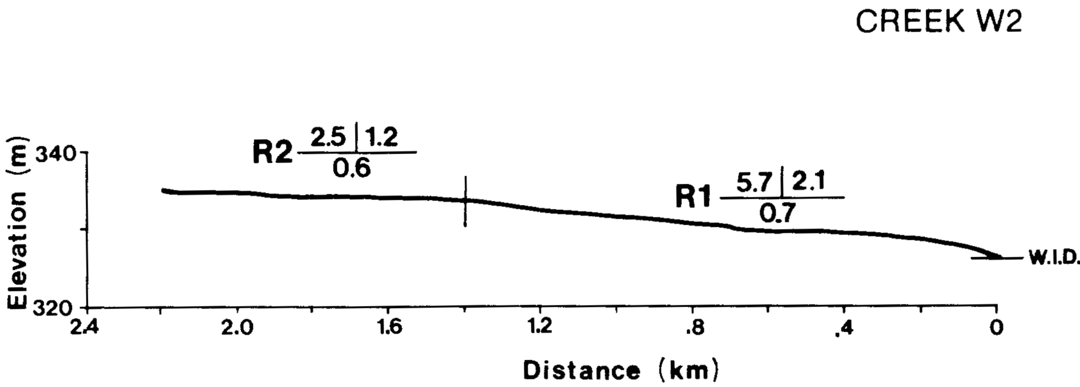
Streamflows were measured in W3, W4, and W5 on three occasions during the study period (June, July, September). Highest flows were recorded in the June survey (Appendix B; Table B3); values ranged from 0.07 $m^3 \cdot s^{-1}$ in Creek W3 to less than 0.01 $m^3 \cdot s^{-1}$ in Creek W5. Discharge in each of the streams was less than 0.01 $m^3 \cdot s^{-1}$ both during July and September.

Creeks W2 to W5 are characterized by high gradients in the lower reaches, ranging from 3.4 to 5.7 $m \cdot km^{-1}$ (Figures 4.2 and 4.3). Habitat features generally associated with high gradient reaches (predominance of Riffle/Run cover types, coarse substrate, etc.) are not evident. This likely is due to the extensive occurrence of channel control by beaver (Plate 5). The frequency of beaver dams and total pondage is highest in Creek W3 (Reach 1 - 2.8 beaverponds per km, 17.8 ha ponded water).

Habitat in the lower reaches of all streams is dominated by Flat type habitat resulting from beaver pondage; substrates primarily consist of silt. Overall, habitat diversity in these streams is low and they are suited only to use by small, non-game fish species (e.g., cyprinids).

4.1.5 BRIDGE CREEK

Habitat conditions in Bridge Creek have not previously been described. In the present study habitat stations were established at three locations (Figure 2.2). Station H1 was situated on lower Bridge Creek (km 0.2) immediately upstream of the Highway 63 road crossing. Stations



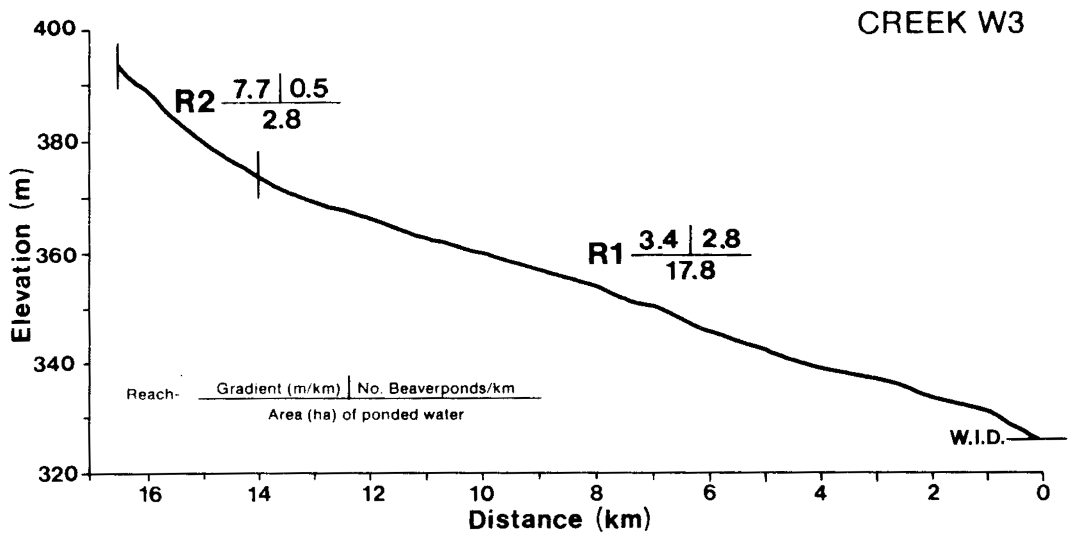


Figure 4.2 Longitudinal profile and habitat zonation, Creek W2 and Creek W3.

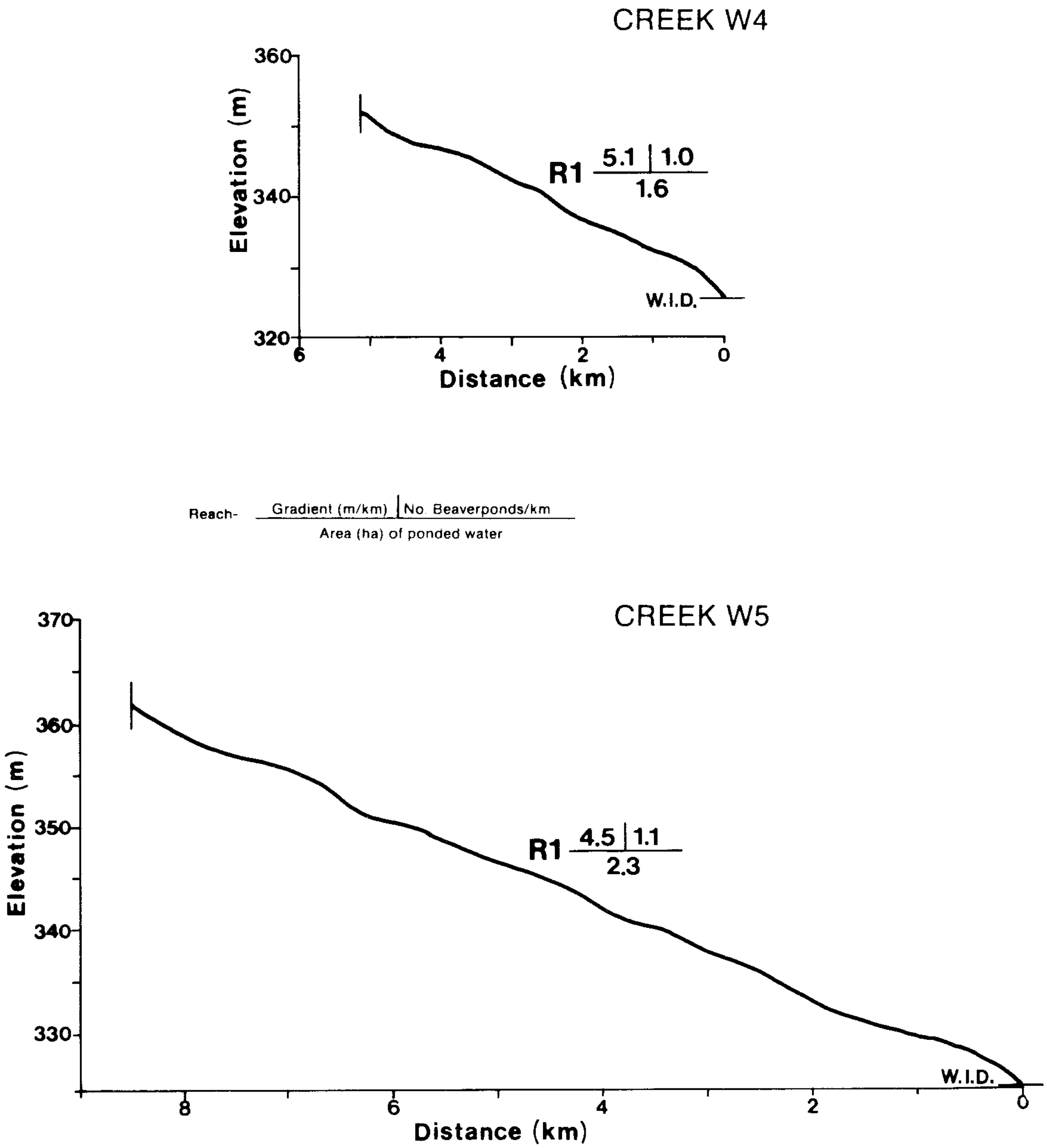


Figure 4.3 Longitudinal profile and habitat zonation, Creek W4 and Creek W5.

H2 and H3 were located immediately downstream and upstream of the Bridge Creek-W.I.D. confluence (km 3.6), respectively. The position of these stations in relation to the longitudinal profile and habitat zonation is illustrated in Figure 4.4. A summary of the data collected at the habitat stations is presented in Table 4.2.

Three major habitat reaches are identifiable on the basis of stream gradient (Figure 4.4). Reach 1 (km 0-0.5) exhibits a steep gradient (46 $m \cdot km^{-1}$). Data from station H1 which were collected on 21 July 1984 provide a description of existing habitat conditions. Major channel characteristics were as follows: mean wetted width was 2.6 m, mean depth was 21 cm, and mean velocity was 24 $cm \cdot s^{-1}$. Habitat diversity in the reach was high; Riffle (15%), Run (35%), and Pool (50%) cover types were well represented. Pools were all of low quality (Class 1). Substrates contained a substantial proportion of both sand (40%) and coarse (60%) substrate. The coarse substrate ranged in size from medium gravel (0.8 to 1.6 cm) to small boulders (25.6 to 51.2 cm); bedrock also was well represented. Much of the large cobble (12.8 to 25.6 cm) and bedrock was formed of bitumen. Existing bank erosion was moderate to high; stability against further erosion generally was low. Sedimentation of coarse substrates (embeddedness) ranged from low to moderate.

Reach 2 (km 0.5-4.5) is characterized by a high gradient (14.3 $m \cdot km^{-1}$). Two habitat sub-reaches are present in this section due to the inflow of the W.I.D. (i.e., resulting in altered channel configuration). Downstream from the W.I.D. confluence at station H2, the major channel

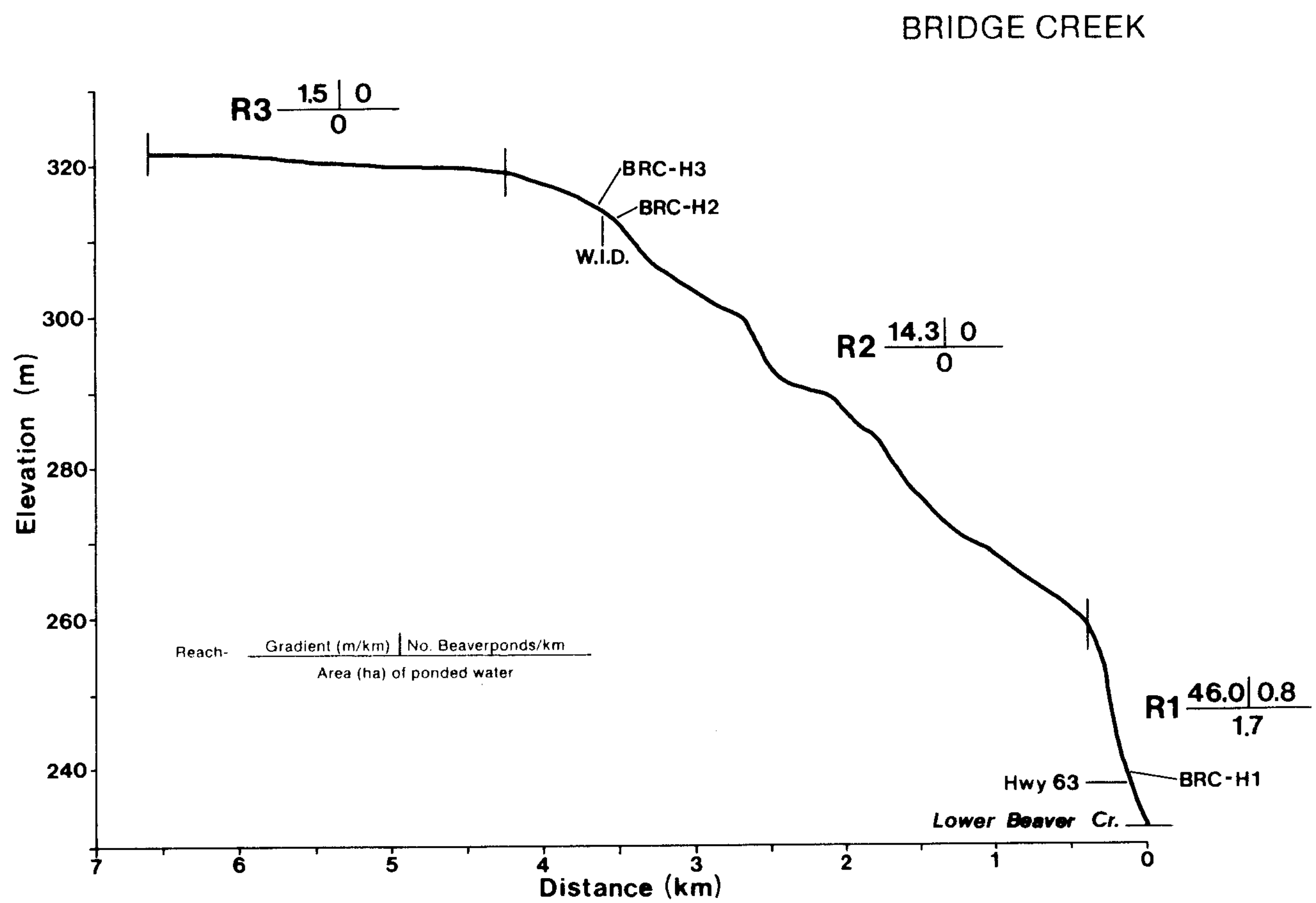


Figure 4.4 Longitudinal profile and habitat zonation, Bridge Creek.

Table 4.2 Summary of physical habitat characteristics at sampling stations on Bridge Creek, July 1984.

Station	Date	Water Temp(°C) (Time)(h)	Channel Features at Transect: Rooted Width (m)	Wetted Width (m)	Local Gradient (%)	Mean Depth (cm)	Mean Velocity (cm·s⁻¹)	Discharge (m³·s⁻¹)	Cover Type Distribution (%): Riffle	Run	Flat	Pool Type 1	2	3	4	5
H1-T1	21 July	15 (1420)	5.4	3.2	2.0	9 (5-12)	48 (45-54)	0.02	39	43	-	18	-	-	-	-
-T2	21 July	16 (1725)	18.2	2.3	1.5	30 (24-32)	12 (2-22)	-	-	74	-	26	-	-	-	-
-T3	21 July	15 (1550)	7.6	2.4	2.0	14 (8-17)	32 (0-78)	-	34	-	-	66	-	-	-	-
-T4	21 July	-	7.2	2.8	1.5	16 (14-18)	17 (3-42)	-	-	32	-	68	-	-	-	-
-T5	21 July	16 (1715)	3.3	2.2	1.5	34 (32-35)	10 (6-25)	-	-	32	-	68	-	-	-	-
H2-T1	19 July	23 (1520)	2.5	1.9	1.5	17 (14-20)	59 (41-68)	0.02	-	84	-	16	-	-	-	-
-T2	19 July	21 (1435)	2.1	2.1	0.5	38 (33-46)	13 (0-24)	-	-	48	-	52	-	-	-	-
-T3	19 July	22 (1415)	1.1	1.1	2.25	42 (36-48)	23 (13-32)	-	-	64		36	-	-	-	-
-T4	19 July	21 (1350)	2.2	2.2	1.0	46 (43-49)	17 (0-48)	-	30	-	-	-	70	-	-	-
-T5	19 July	21 (1325)	1.9	1.7	2.5	17 (15-19)	57 (45-63)	-	50	36	-	14	-	-	-	-
H3-T1	19 July	17 (1115)	1.25	1.25	2.5	43 (35-55)	16 (9-26)	-	36	64	-	-	-	-	-	-
-T2	19 July	17 (1135)	0.7	0.7	1.5	21 (18-25)	11 (5-21)	-	-	100	-	-	-	-	-	-
-T3	19 July	17 (1145)	2.8	1.9	-	20 (19-22)	Nil	-	-	-	-	100	-	-	-	-
-T4	19 July	17 (1210)	2.5	1.5	0.5	22 (15-26)	4 (3-5)	-	-	-	100	-	-	-	-	-
-T5	19 July	17 (1230)	1.6	0.9	0.5	13 (6-27)	13 (4-19)	-	-	22	-	78	-	-	-	-

Station	Bank Features (RUB/LUB): Cond. (%)	Stab. (No.)	Under. (cm)	Slope (Deg.)	Cover (No.)	Depth (cm)	Over. (cm)	Substrate Distribution (%): Sand	Silt	FG	MG	CG	VCG	SC	LC	SB	LB (BR)	EMB. (No.)	Aquatic Veg.: Macro. (No.)	Algae (No.)
H1-T1	90/80	1/1	0/0	145/150	1/1	0/0	15/0	-	-	-	-	16	-	32	36	16	-	4	1	1
-T2	90/95	2/1	0/0	145/145	1/1	0/0	0/0	78	-	-	22	-	-	-	-	-	-	5	1	1
-T3	20/100	3/1	0/0	105/135	0/0	0/5	0/0	36	-	-	21	-	-	-	-	-	(43)[a]	2	1	1
-T4	100/30	1/2	0/0	135/100	1/2	0/0	0/0	28	-	-	-	-	-	18[a]	36[a]	-	(18)	3	1	1
-T5	30/10	3/4	0/17	95/(45)[b]	4/4	0/0	0/55	54	-	-	-	-	-	-	-	-	(46)	-	1	1
H2-T1	25/25	3/3	0/0	130/140	1/1	8/0	0/0	21	-	53	-	-	-	-	-	26	-	5	1	1
-T2	0/5	4/4	0/20	157/90 (30)[b]	2/4	0/40	0/0	36	-	64	-	-	-	-	-	-	-	1	1	1
-T3	0/0	4/4	0/0	150/90	2/2	48/35	30/25	-	-	100	-	-	-	-	-	-	-	5	1	1
-T4	0/0	4/4	19/0	155/130	2/2	39/0	40/55	57	-	-	-	-	-	43	-	-	-	1-4	1	1
-T5	0/0	4/4	0/0	140/110	2/2	0/0	25/20	-	-	-	-	100	-	-	-	-	-	4	2	1
H3-T1	10/0	4/4	22/24	130/90 (25)/(22)[b]	2/4	3/0	13/95	80	-	-	-	-	-	-	20	-	-	1	1	1
-T2	10/10	3/3	0/0	90/100	2/2	7/11	30/0	100	-	-	-	-	-	-	-	-	-	1	1	1
-T3	95/20	1/3	11/0	170/125 (25)[b]	1/2	5/0	15/0	100	-	-	-	-	-	-	-	-	-	N/A[d]	1	1
-T4	65/45	1/2	0/0	160/140	1/1	0/0	0/0	100	-	-	-	-	-	-	-	-	-	N/A	1	1
-T5	20/75	3/1	26/0	145/150	2/1	24/0	0/0	56	-	44	-	-	-	-	-	-	-	1	1	1

[a]Bitumen dominated.
[b]Angle of undercut in parantheses.
[c]Flat shale.
[d]N/A - not applicable.
Note: Description of terms in Table 2.2.

characteristics were as follows: wetted width was 1.8 m, mean depth was 32 cm, and mean velocity was 34 $cm \cdot s^{-1}$. At the upper station (H3), the channel measurements were as follows: wetted width was 1.3 m, mean depth was 24 cm, and mean velocity was 9 $cm \cdot s^{-1}$. Habitat was moderately diverse both above and below the W.I.D. confluence, although Riffle and Run cover types were more prevalent in the downstream section due to a localized higher gradient. Cover types below the W.I.D. (H2) were distributed as follows: 16% Riffle, 46% Run, 38% Pool, and 0% Flat. The section above the W.I.D. (H3) exhibited the following cover type distribution pattern: 7% Riffle, 37% Run, 36% Pool, and 20% Flat. Pool habitat at both stations generally was of low quality. Slightly higher pool quality was recorded at H2 (i.e., minor input of Class 2 Pool). This was largely due to increased depth resulting from flow input from the W.I.D. Substrate in the section below the W.I.D. confluence was dominated by coarse material. The major groups were fine gravel (0.4 to 0.8 cm), small cobble (6.4 to 12.8), and small boulder (25.6 to 51.2 cm). Sand substrates also were common. Above the W.I.D. confluence, the substrate was dominated by sand although some fine gravel and large cobble were recorded. At the lower station (H2), streambanks displayed little previous erosion, and stability was high. At the upper station (H3), streambank erosion ranged from low to high at the various transects; stability against further erosion was rated as low to moderate.

The uppermost reach (R3), which is approximately 2 km in length, was not investigated in this study. On the basis of its low gradient (1.5 $m \cdot km^{-1}$), however, it is assumed that it would exhibit low diversity habitat comprised almost entirely of Flat cover type and silt/sand substrate.

4.1.6 LOWER BEAVER CREEK

Habitat conditions in Lower Beaver Creek during 1977, one year after completion of the diversion, were described by Tsui et al. (1977). Their sampling station was located downstream of the North Starter Dike. Habitat consisted of riffles (80% gravel, 20% cobble) and silted pools during low flow periods; at high water levels, the substrate consisted entirely of shifting sand. Average channel width and depth was 8 m and 18 cm, respectively. Banks were described as being low and stable with overhanging brush. Construction of the catchment basin just downstream of the North Starter Dike has since eliminated the shifting sand.

During the present study, a habitat station (H1) was established on Lower Beaver Creek at a site immediately upstream of Highway 63 (Figure 2.2). The station was 3.2 km upstream from the Athabasca River and approximately 800 m upstream from the entry of Bridge Creek.

Only one reach (R1) was identified on the basis of gradient, although it is certain that the quality of habitat below the entry of Bridge Creek would be considerably higher due to the presence of greater flows (Figure 4.5). Reach 1 is characterized by a moderate gradient (4.7 $m \cdot km^{-1}$). Habitat conditions within the reach are characterized by data from H1

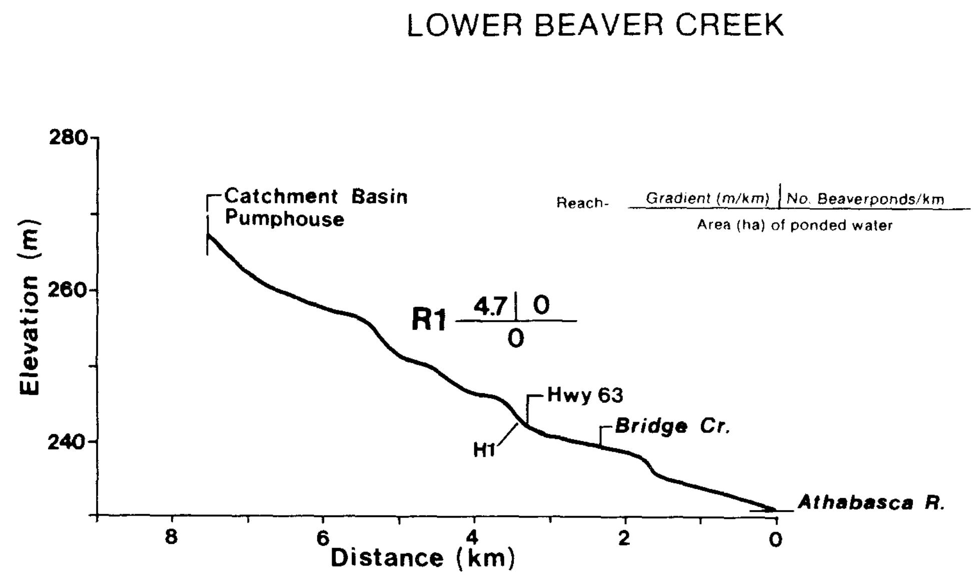


Figure 4.5 Longitudinal profile and habitat zonation, Lower Beaver Creek.

(Table 4.3). Major channel characteristics on the 22 July survey date were as follows: wetted width was 3.5 m, mean depth was 20 cm, and mean velocity was 2.8 $cm \cdot s^{-1}$. Habitat diversity was low as indicated by the overall cover type distribution: 0% Riffle, 3% Run, 82% Flat, and 15% Pool. All pools were low quality (i.e., Class 1). Habitat diversity generally is much higher in moderate gradient reaches. In this case, the high degree of uniformity is due to the extremely low discharge which results in masking of cover types. Overall, silt was the most prevalent substrate material (i.e., 64% distribution dominance). The coarse material ranged in size from very coarse gravel (3.2 to 6.4 cm) to large cobble (12.8 to 25.6 cm). Sedimentation of coarse substrates was moderate (i.e., 25-50% coverage of interstitial space). Macrophyte density generally was low (i.e., 5-25% channel coverage). In contrast, algal density was high (i.e., greater than 75% coverage of surface area). Banks generally exhibited little erosion and were fairly stable with respect to further erosion tendencies.

4.2 WATER QUALITY

4.2.1 PHYSICAL PARAMETERS

Within the West Interception Ditch/Lower Beaver Creek drainage system, water temperatures during the three periods sampled ranged from 3.0 to 24.0°C with both values recorded at station WID-W1 (Table 4.4). In 1977, July, and September temperatures in the West Interception Ditch (W.I.D.) were 5.0°C cooler and approximately 9.0°C warmer, respectively,

Table 4.3 Summary of physical habitat characteristics at sampling stations on Lower Beaver Creek, July 1984.

Station	Date	Water Temp(°C) (Time)(h)	Channel Features at Transect: Rooted Width (m)	Wetted Width (m)	Local Gradient (%)	Mean Depth (cm)	Mean Velocity (cm·s^{-1})	Discharge (m^3·s^{-1})	Cover Type Distribution (%): Riffle	Run	Flat	Pool Type: 1	2	3	4	5
H1-T1	22 July	14.5 (1455)	2.9	2.3	1.0	10 (8-14)	4 (2-6)	0.02[a]	-	-	100	-	-	-	-	-
-T2	22 July	-	3.4	3.2	1.0	21 (15-26)	1.5 (1-2)	-	-	-	100	-	-	-	-	-
-T3	22 July	-	-	4.0	1.0	18 (15-24)	5	-	-	17	8	75	-	-	-	-
-T4	22 July	-	6.0	2.8	0.5	12 (5-19)	2.3 (0-5)	-	-	-	100	-	-	-	-	-
-T5	22 July	-	5.4	5.4	0.25	39 (29-46)	1	-	-	-	100	-	-	-	-	-

Station	Bank Features (RUB/LUB): Cond. (%)	Stab. (No.)	Under. (cm)	Slope (Deg.)	Cover (No.)	Depth (cm)	Over. (cm)	Substrate Distribution (%): Sand	Silt	FG	MG	CG	VCG	SC	LC	SB	LB (BR)	EMB. (No.)	Aquatic Veg.: Macro. (No.)	Algae (No.)
H1-T1	100/0	1/4	0/0	155/165	1/4	0/0	0/0	-	-	-	-	-	33	67	-	-	-	3	2	5
-T2	0/0	4/4	0/0	165/160	4/4	0/0	0/0	-	80	-	-	-	-	-	20	-	-	2	2	5
-T3	0/30	4/2	0/0	160/150	4/1	0/0	0/0	-	74	-	-	-	13	-	13	-	-	3	2	5
-T4	15/0	3/4	0/0	120/160	3/4	0/0	0/0	-	82	-	-	-	-	18	-	-	-	3	1	5
-T5	0/15	4/3	0/47	165/90 (45)[b]	4/3	0/13.5	0/0	-	83	-	-	-	8	9	-	-	-	3	3	5

[a]Recorded during water quality sampling on 29 July.
[b]Angle of undercut in parentheses.
Note: Description of terms in Table 2.2.

Table 4.4. Summary of water quality data for the West Interception Ditch/Lower Beaver Creek System obtained in 1984.

Site/Date	W5-W		W4-W			W3-W			W1D-W2			WID-W1		
Parameter	17 June	25 July	17 June	25 July	25 Sept.	17 June	25 July	25 Sept.	17 June	25 July	25 Sept.	17 June	25 July	26 Sept.
Temperature °C	17.0	21.0	17.0	17.0	4.5	18.0	20.0	5.5	19.0	22.0	6.0	21.0	24.0	3.0
pH	7.6	6.8	7.2	6.5	7.7	6.8	6.8	8.2	6.8	6.9	8.5	6.9	8.0	8.5
Specific Conductance $\mu S{\cdot}cm^{-1}$	250	300	360	340	360	280	300	315	325	300	440	325	325	450
Dissolved Oxygen	3.0	1.0	5.7	3.2	7.5	3.0	4.5	4.2	4.4	6.2	9.2	9.0	7.8	11.0
Oxygen % Saturation	30	10	58	33	57	31	49	33	47	70	73	100	92	81
Turbidity N.T.U.	2.5	4.0	1.1	1.0	1.0	5.4	26.0	5.2		1.4	4.3	3.8	1.9	2.2
Calcium	20.70	29.40	31.0	36.00	39.30	21.90	25.60	32.40	23.40	30.40	49.00	27.60	28.50	47.80
Magnesium	7.20	9.40	10.80	11.80	14.10	8.50	9.50	13.70	9.20	10.80	17.90	9.90	12.00	16.80
Sodium	18.50	21.20	22.60	24.00	25.50	21.20	25.50	25.00	23.60	28.70	48.00	22.70	32.30	48.50
Potassium	2.5	1.03	1.75	0.75	1.38	2.37	2.05	3.15	2.48	1.66	3.45	2.10	2.04	3.10
Chloride	3.10	2.20	3.40	2.60	4.00	2.10	1.70	2.00	2.10	3.70	16.40	3.30	5.50	13.60
Sulphate	52.0	21.8	124.0	118.0	108.0	34.8	6.2	4.9	46.0	56.5	50.5	75.0	45.5	77.0
PP Alkalinity, as $CaCO_3$	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	4.0	L0.1	L0.1	4.0	L0.1	L0.1	6.0
Alkalinity, T. as $CaCO_3$	58.3	135.0	34.0	72.1	88.0	100.0	155.0	192.0	95.0	129.0	230.0	76.0	149.0	180.0
Bicarbonate	71.0	165.0	41.5	88.0	107.5	122.0	189.0	224.5	116.0	157.5	271.0	93.0	182.0	205.0
Carbonate	0	0	0	0	0	0	0	5.0	0	0	5.0	0	0	7.0
Hardness, T. as $CaCO_3$	81.5	112.0	122.0	138.5	156.0	90.0	103.0	137.5	96.5	120.5	196.0	110.0	121.0	189.0
Silica (Reactive)	2.20	5.40	3.64	2.40	3.92	1.55	2.71	4.14	2.30	1.45	3.73	3.76	1.61	0.17
Total Filterable Residue												200	225	324
Total Non-Filterable Residue												3.2	0.8	1.2
Chemical Oxygen Demand												96	98	90
Oil & Grease												0.3	0.3	0.2
Nitrogen, T. as N	1.43	2.10	1.53	1.62	1.27	3.31	2.21	1.59	1.06	1.41	1.05	1.23	1.28	1.05
Nitrate + Nitrate Nitrogen as N	0.011	0.006	0.008	0.019	0.005	0.011	0.008	0.005	0.003	0.008	0.005	0.008	0.004	0.005
Kjeldahl Nitrogen, T. as N	1.42	2.10	1.52	1.60	1.26	3.30	2.20	1.58	1.06	1.40	1.04	1.22	1.28	1.04
Ammonia Nitrogen, T. as N	0.02	0.13	0.02	0.11	0.01	0.05	0.09	0.02	0.05	0.07	0.02	0.02	0.03	0.02
Phosphorus, T. as P	0.077	0.385	0.041	0.085	0.032	0.160	0.260	0.200	0.077	0.037	0.032	0.027	0.030	0.017
Ortho-Phosphorus as P												0.024	0.025	L0.003
Total Organic Carbon	50.5	40.0	58.0	49.0	39.5	36.5	35.0	37.5	41.0	40.0	48.0	40.0	38.0	36.3
Total Inorganic Carbon	11.0	30.0	5.0	13.0	17.5	21.0	34.0	40.0	20.0	27.0	44.0	15.0	30.0	44.0
Phenol												0.010	0.007	0.011
Arsenic, T.												0.0005	0.0002	0.0004
Selenium, T.												L0.0002	L0.0002	L0.0002
Boron, T.												0.21	0.17	0.18
Cadmium, T.												L0.001	L0.001	L0.001
Copper, T.												0.001	L0.001	L0.001
Iron, T.												0.57	0.26	0.08
Chromium, T.												0.003	L0.001	L0.001
Manganese, T.												0.03	0.03	0.01
Zinc, T.												0.002	L0.001	0.007
Lead, T.												0.008	L0.002	L0.002
Vanadium, T.												L0.001	L0.001	L0.001
Nickel, T.												0.001	0.001	L0.001
Mercury, T.												L0.0001	L0.0001	L0.0001
Cyanide, T.												0.006	0.006	0.007
Tannin & Lignin												3.5	3.1	2.3
Ion Balance	1.07	0.99	1.03	0.96	1.04	1.00	0.98	0.94	1.03	0.96	0.97	1.02	0.95	1.02

Notes: All values are reported in $mg{\cdot}L^{-1}$ unless otherwise stated.
L - Less Than; T. - Total; N - Nitrogen; P - Phosphorus.

Continued ..

Table 4.4. Continued.

Site/Date	BRC-W2			BRC-W1			LBC-W2			LBC-W1		
Parameter	17 June	25 July	25 Sept.	18 June	29 July	21 Sept.	19 June	29 July	21 Sept.	19 June	29 July	22 Sept.
Temperature °C	18.0	19.0	5.0	19.0	14.5	6.0	11.0	14.0	7.5	16.0	16.0	6.0
pH	7.8	7.8	8.2	6.5	7.4	7.6	7.4	8.0	8.0	7.7	7.3	7.7
Specific Conductance $\mu S{\cdot}cm^{-1}$	160	190	200	365	515	625	730	650	640	300	625	625
Dissolved Oxygen	7.8	8.0	5.8	9.0	8.2	10.7	8.3	8.8	10.0	10.0	9.2	9.0
Oxygen % Saturation	81	90	46	96	81	85	74	84	82	100	92	72
Turbidity N.T.U.	ND	5.2	10.0	21.0	18.0	10.0	3.1	3.4	3.6	13.0	18.0	18.0
Calcium	8.70	20.50	22.00	31.30	56.00	66.00	61.00	64.00	64.00	32.20	60.00	74.00
Magnesium	3.20	5.00	7.90	10.50	17.10	22.20	23.40	21.50	22.40	10.90	18.50	23.30
Sodium	20.40	20.50	24.80	24.50	40.00	53.50	61.50	53.50	49.00	27.30	49.50	60.00
Potassium	0.44	0.44	1.03	2.10	2.19	2.93	1.74	1.67	1.48	2.04	2.28	2.47
Chloride	10.20	11.50	13.00	6.60	17.00	36.60	33.10	33.70	29.70	8.70	28.00	47.50
Sulphate	16.3	11.7	9.1	86.0	102.0	125.0	51.5	35.5	37.0	75.0	85.0	93.0
PP. Alkalinity as $CaCO_3$	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	22.4	L0.1	L0.1	L0.1	L0.1
Alkalinity, T. as $CaCO_3$	43.0	80.3	106.0	85.0	196.0	199.0	293.0	259.0	287.0	102.0	230.0	250.0
Bicarbonate	52.5	98.0	129.0	104.0	239.0	243.0	357.0	261.0	350.0	124.5	280.5	305.0
Carbonate	0	0	0	0	0	0	0	027.0	0	0	0	0
Hardness, T. as $CaCO_3$	35.0	72.0	87.5	121.5	210.0	256.0	249.0	248.5	252.0	125.5	226.0	281.0
Silica (Reactive)	2.11	5.10	8.50	4.00	5.60	6.20	6.60	7.60	7.30	3.92	6.65	7.24
Total Filterable Residue				225	351	440				230	400	465
Total Non-Filterable Residue				40.0	17.0	10.4				24.8	19.0	12.8
Chemical Oxygen Demand				126	89	74				107	79	65
Oil & Grease				1.0	1.2	L0.1				0.8	0.7	1.2
Nitrogen, T. as N	1.67	2.12	1.67	1.20	1.40	0.83	L0.30	0.69	0.33	1.20	1.22	0.68
Nitrate + Nitrite Nitrogen as N	0.006	0.016	0.007	0.010	0.043	0.010	L0.003	0.011	0.013	0.037	0.044	0.021
Kjeldahl Nitrogen, T. as N	1.66	2.10	1.66	1.20	1.36	0.82	0.30	0.68	0.32	1.16	1.18	0.66
Ammonia Nitrogen, T. as N	0.08	0.15	0.04	0.07	0.12	0.03	0.03	0.06	L0.01	0.05	0.20	0.04
Phosphorus, T. as P	0.050	0.125	0.062	0.057	0.058	0.041	0.021	0.022	0.022	0.038	0.057	0.046
Ortho-Phosphorus as P				0.035	0.040	0.023				0.030	0.040	0.018
Total Organic Carbon	69.0	71.0	65.0	39.0	36.0	25.5	13.5	12.3	10.5	35.5	30.5	20.8
Total Inorganic Carbon	6.0	15.0	19.5	17.0	36.0	45.0	68.0	59.0	66.0	20.0	46.0	57.0
Phenol				0.010	0.006	0.010				0.014	0.009	0.007
Arsenic, T.				0.0016	0.0013	0.0009				0.0010	0.0013	0.0009
Selenium, T.				L0.0002	L0.0002	0.0003				L0.0002	L0.0002	0.0002
Boron, T.				0.22	0.20	0.22				0.23	0.18	0.17
Cadmium, T.				L0.001	L0.001	L0.001				L0.001	L0.001	L0.001
Copper, T.				0.001	0.002	0.001				L0.001	0.002	L0.001
Iron, T.				1.90	7.52	9.05				0.13	6.27	5.30
Chromium, T.				L0.001	0.004	0.001				L0.001	0.003	0.001
Manganese, T.				0.09	0.23	0.28				L0.01	0.28	0.33
Zinc, T.				0.004	0.002	0.004				0.002	0.002	0.004
Lead, T.				L0.002	L0.002	L0.002				L0.002	L0.002	L0.002
Vanadium, T.				L0.001	0.001	0.001				0.002	L0.001	0.001
Nickel, T.				0.004	0.004	0.002				0.004	0.004	L0.001
Mercury, T.				L0.0001	L0.0001	L0.0001				L0.0001	L0.0001	L0.0001
Cyanide, T.				0.005	0.006	0.006				0.003	0.009	0.005
Tannin & Lignin				3.7	3.5	2.1				3.6	2.7	ND
Ion Balance	1.07	1.07	1.07	0.96	0.93	0.99	0.98	0.97	0.98	0.97	0.94	0.97

Notes: All values are reported in $mg{\cdot}L^{-1}$ unless otherwise stated.
L - Less Than; T. - Total; N - Nitrogen; P - Phosphorus; ND - no data.

than during the comparable sampling periods in the present study (Tsui et al. 1977). The water in the drainage system was brown in colour.

The pH within this system ranged from slightly acidic (pH 6.5) to alkaline (pH 8.5). The low pH values likely were the result of drainage from muskeg areas. Acidic conditions were not reported in the W.I.D. or Lower Beaver Creek during May to September 1977 (Tsui et al. 1977).

The non-filterable residue levels in the drainage system ranged from 0.8 $mg{\cdot}L^{-1}$ at station WID-W1 to 40.0 $mg{\cdot}L^{-1}$ at station BRC-W1. Notably lower levels were recorded at stations WID-W1 and LBC-W1. The concentrations showed a direct relationship to stream discharge. Similar conditions were reported in Tsui et al. (1977).

Dissolved oxygen concentrations at the stations associated with the tributaries were noticeably lower than those recorded at the remaining stations in the drainage. While the concentrations generally ranged from 4.4 to 11.0 $mg{\cdot}L^{-1}$, values at W5-W, W4-W and W3-W ranged from 1.0 to 7.5 $mg{\cdot}L^{-1}$, and were frequently less than 5.0 $mg{\cdot}L^{-1}$ minimum required by sport fish. The low levels probably were the result of drainage from stagnant ponds associated with beaver dams. Dissolved oxygen measurements at station W3-W were conducted within the beaver pond due to the proximity of the beaver dam to the W.I.D. (Plate 5). Dissolved oxygen levels at stations WID-W1 and LBC-W2 were very similar to those in July and September reported in Tsui et al. (1977).

4.2.2 MAJOR IONS

Although the water in the drainage system generally was of the calcium bicarbonate type, the ionic dominance varied considerably between stations and between sampling periods (Figure 4.6). The influence of sodium, commonly associated with groundwater, was notable at all stations. Sulphate concentrations, however, were erratic; sulphate frequently varied from being the dominant to the least abundant anion. The cause for such behaviour was not apparent. It appeared, however, the major source of the sulphate ion originates in the W.I.D. and its associated tributaries. This likely accounts for the higher sulphate concentrations in Bridge Creek below the W.I.D. confluence than was recorded in Bridge Creek (BRC-W2) above the confluence. At stations where the sulphate concentrations were high, there was a corresponding decrease in the buffering capacity of the water, probably because of acidification as suggested by the low total alkalinity values and in some cases low pH. It should be recognized, however, that muskeg waters commonly are low in total alkalinity and may have an acidic pH.

4.2.3 NUTRIENTS

4.2.3.1 Nitrogen

The total nitrogen concentrations in the drainage system ranged from less than 0.30 mg $N \cdot L^{-1}$ to 3.31 mg $N \cdot L^{-1}$. Notable trends among sampling stations were not apparent. The highest concentrations

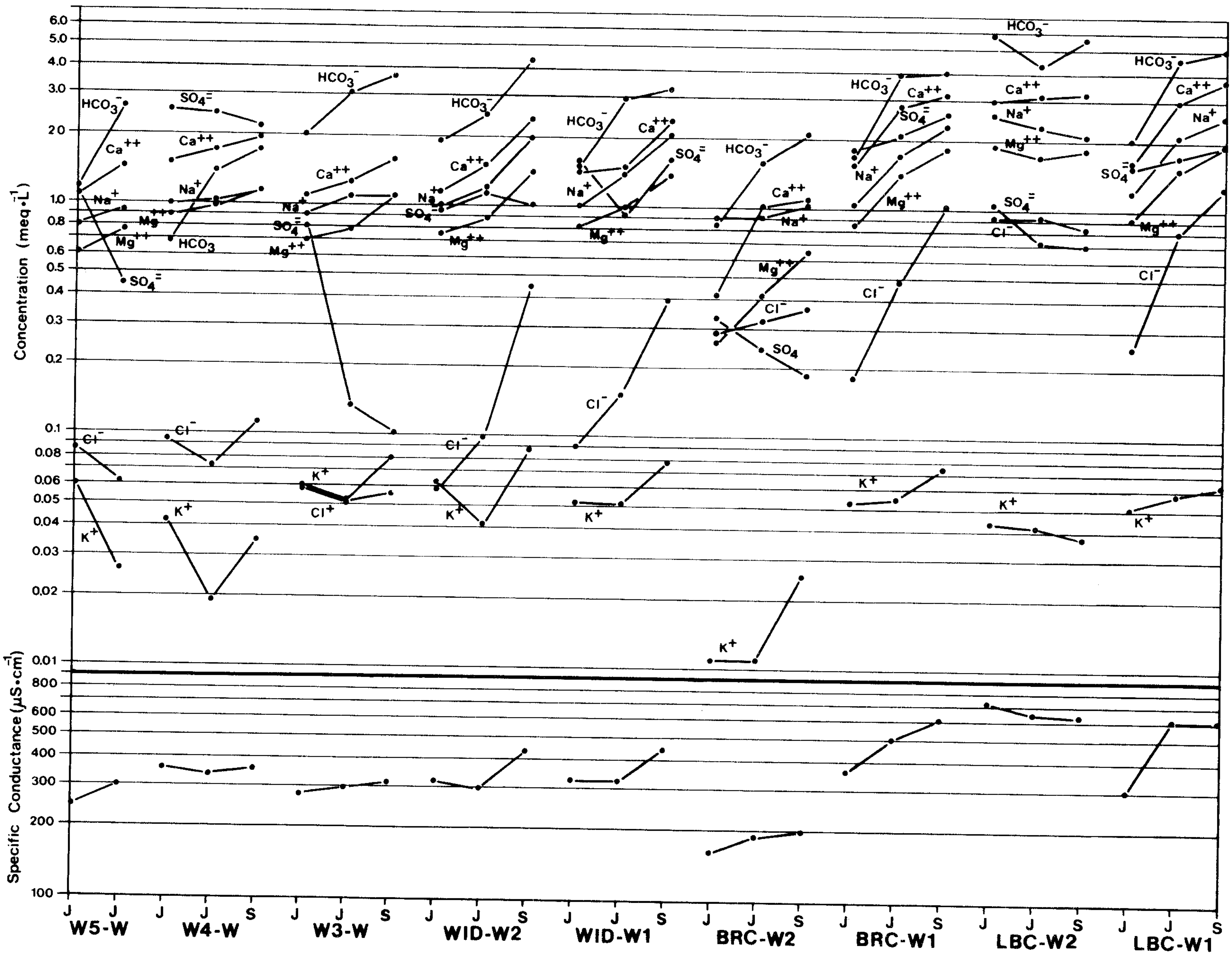


Figure 4.6 Ionic dominance of the major ions, and specific conductance profiles, for the West Interception Ditch system in June, July and September, 1984.

generally occurred in July and, for reasons stated in Section 3.2.3.1, important seasonal differences were not exhibited. The total nitrogen levels generally exceeded the ASWQO of 1.0 mg $N \cdot L^{-1}$. Concentrations in July and September reported in Tsui et al. (1977) generally were lower and within the ASWQO. Nitrate + nitrite concentrations were less in the drainage system with values ranging from less than 0.003 to 0.044 mg $N \cdot L^{-1}$.

Ammonia concentrations, which ranged from less than 0.01 to 0.20 mg $N \cdot L^{-1}$, generally were low except for the 0.20 mg $N \cdot L^{-1}$ value recorded at station LBC-W1.

4.2.3.2 Phosphorus

The concentrations of total phosphorus in the drainage system ranged from 0.017 mg $P \cdot L^{-1}$ at WID-W1 to 0.385 mg $P \cdot L^{-1}$ at W5-W. The concentrations varied considerably and showed no trend among the stations. The levels frequently exceeded the ASWQO of 0.05 mg $P \cdot L^{-1}$. Notably higher concentrations were recorded by Tsui et al. (1977) in the W.I.D., and in Lower Beaver Creek near station LBC-W2. Ortho-phosphorus concentrations, ranging from less than 0.003 to 0.040 mg $P \cdot L^{-1}$ were similar among stations WID-W1, BRC-W1, and LBC-W1. At each station the highest values occurred in July which was identical to the behaviour of total phosphorus at those stations.

4.2.3.3 Reactive Silica

Reactive silica concentrations ranged from 0.17 to 8.50 $mg \cdot L^{-1}$. Concentrations generally were higher in the Bridge Creek and Lower Beaver Creek stations than in the other stations within this system. The concentrations were lowest in June and highest in September except at WID-W1 where the reverse was shown. Concentrations of this nutrient are normally higher in the fall period due to reduced vegetation demands and increased groundwater influence.

4.2.3.4 Total Organic Carbon

Total organic carbon concentrations, ranging from 10.5 $mg \cdot L^{-1}$ (LBC-W2) to 71.0 $mg \cdot L^{-1}$ (BRC-W2), showed no trends among the stations except that during each sampling period the highest values occurred at BRC-W2 and the lowest at LBC-W2.

4.2.4 TRACE METALS AND OTHER SUBSTANCES

The concentrations of trace metals and elements in the drainage system generally were below their detection limits except for iron and manganese, which exceeded the ASWQO (Table 4.4). Total iron levels (ranging from 0.08 to 9.05 $mg \cdot L^{-1}$) frequently exceeded the ASWQO of 0.30 $mg \cdot L^{-1}$ with the highest values occurring at BRC-W1. The values increased from June to September at BRC-W1 and LBC-W1, while the reverse was shown at WID-W1. Speculatively, groundwater was the source of iron, particularly during the September survey; a dense layer of a rusty precipitate, probably ferric hydroxide, was observed on the substrate at stations BRC-W1 and LBC-W1. Hem (1970) indicated that groundwater commonly contains iron with concentrations of 1.0 to 10 $mg{\cdot}L^{-1}$. The water yields a ferric hydroxide precipitate when it discharges to the surface.

Total manganese concentrations ranged from less than 0.01 to 0.33 $mg{\cdot}L^{-1}$ and frequently exceeded the ASWQO of 0.05 $mg{\cdot}L^{-1}$ at BRC-W1 and LBC-W1. A groundwater source is suspected since the behaviour of manganese is closely related to iron.

Phenol concentrations recorded at WID-W1, BRC-W1, and LBC-W1 all exceeded the ASWQO of 0.005 $mg{\cdot}L^{-1}$. The source of phenol was likely natural. Oil and grease present in the drainage probably originated from natural sources.

4.3 ZOOBENTHOS

4.3.1 WEST INTERCEPTION DITCH

Three benthic stations were evaluated on the W.I.D. (Figure 2.7). Station WID-B1 was situated 12.2 km downstream from the source. Substrate at this station consisted of coarse cobble and boulder, with little sand or silt present. The macrophyte **Potamogeton pectinatus** occurred sparsely along margins and amongst the cobbles. During the spring sampling period, the channel was shallow (less than 25 cm deep) and current was moderate (30-50 $cm \cdot s^{-1}$). Rheophilic, lithophilic taxa (i.e., Simuliidae[a], baetid and heptageniid mayflies, net-spinning caddisflies) occurred at this station but were more abundant on submerged vegetation than on rocky substrates; consequently, they were underrepresented in quantitative samples (Appendix D, Table D8). In samples from the rocky substrate, the community was dominated by Oligochaeta and Chironomidae (Figure 4.7), the latter increasing in importance through the year. Very high densities, biomass and richness were recorded in fall; however, because Chironomidae were so prevalent, diversity fell to 25 % of its summer value (Table 4.5).

Station W3-B (Figure 2.7) was almost lentic in character due to a beaver dam at the mouth. In spring, water depth was 1.5 m, and the substrate consisted of fine gravel overlain by a silt/sand/organic mixture. Dense beds of **Carex** bordered the creek, and flow was minimal. This station corresponded to Station 7 of Tsui et al. (1977). The benthos of this station was dominated by Oligochaeta and Chironomidae (Figure 4.7), although a more diverse fauna was collected in qualitative samples from the **Carex** beds (Appendix D, Table D9).

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[a]Dr. P.H. Adler (**ex** University of Alberta) kindly identified an auxilliary sample collected in June. This contained five **Simulium verecundum** complex (cytotype ACD) and one **S. aureum** (cytotype B).

WEST INTERCEPTION DITCH

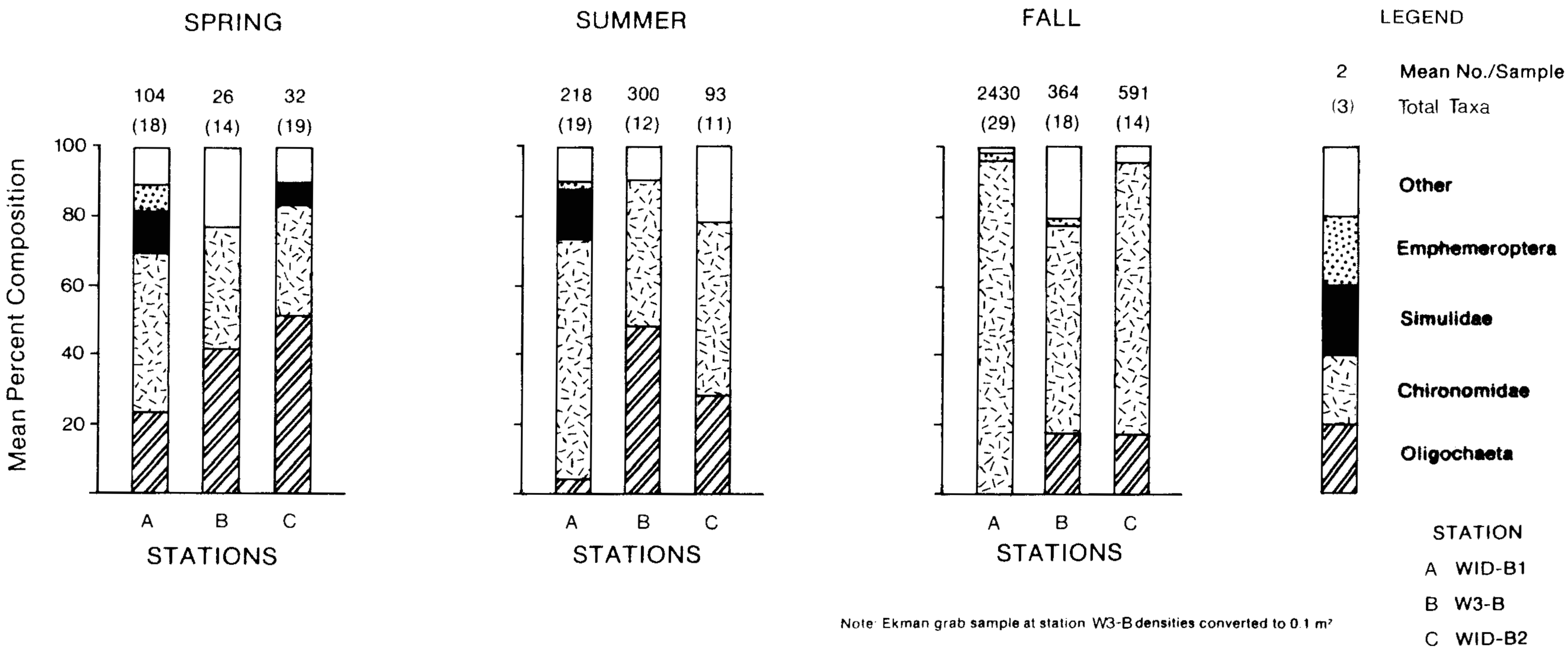

Figure 4.7 Relative abundance of major taxonomic groups of benthic invertebrates in the West Interception Ditch, and Creek W3, 1984.

Table 4.5 Mean density (no. per 0.1 m^2), mean biomass (mg per 0.1 m^2), diversity, and taxonomic richness of zoobenthos at stations associated with the West Interception Ditch/Lower Beaver Creek System, 1984.

Station		Spring	Summer	Fall
WID-B1	Density	31.9	92.9	591.2
	Biomass	4.3	20.9	80.3
	Diversity	2.309	1.664	1.091
	Richness	19	11	14
WID-B2	Density	104.2	218.3	2430.5
	Biomass	14.1	22.0	178.0
	Diversity	1.888	1.621	0.382
	Richness	18	19	29
W3-B	Density[a]	24.7	301.3	364.3
	Biomass	5.4	16.8	11.2
	Diversity	1.885	1.546	1.854
	Richness	14	12	18
BRC-B	Density	15.4	31.3	8.3
	Biomass	1.6	2.6	0.7
	Diversity	2.782	2.417	1.070
	Richness	13	10	7
LBC-B1	Density	35.3	147.7	231.6
	Biomass	5.5	23.3	17.6
	Diversity	1.123	1.585	2.043
	Richness	10	15	18
LBC-B2	Density	218.7	984.6	353.5
	Biomass	42.3	163.0	38.2
	Diversity	2.150	4.151	1.635
	Richness	19	31	23

[a] Ekman grab samples (area: 0.023 m^2) were taken at station W3-B. Densities and biomass have been converted to 0.1 m^2 area.

At station WID-B2, which corresponded with Station 5 of Tsui et al. (1977), the stream channel was densely vegetated with aquatic macrophytes (**Typha**, **Potamogeton**, **Elodea**, **Megalodonta**); streamflows were slow but detectable in all three sample periods. Substrate consisted of a dense root mat over clay/silt. Water depth exceeded 60 cm in the spring.

Oligochaeta and Chironomidae were dominant in the quantitative samples during each sampling period (Figure 4.7); a moderately rich fauna, comparable to W3-B, was collected at this station (Appendix D, Table D10). Biomass and density both increased from June to September (Table 4.5), but diversity declined. Seasonal progression was marked by an increase in proportion of Chironomidae; Oligochaeta also increased in abundance, but to a lesser extent.

Tsui et al. (1977) surveyed the W.I.D. system one year after completion. Their level of taxonomic resolution and method of biomass determination differed from those of the present study. To permit a more direct evaluation of changes in community structure between 1977 and the present, the data of Tsui et al. (1977) were reanalysed to express measurements in units similar to the present study (Table 4.6).

The most important change between study years was noted for dominant species. At WID-B1, Simuliidae made up 40-45% of the fauna in 1977, whereas in 1984, its abundance had declined to 10-15%. **Baetis** similarly declined in abundance, whereas Oligochaeta and Chironomidae

Table 4.6 Mean density (no. per 0.1 m^2), mean biomass[a] (mg per 0.1 m^2), diversity[b], and taxonomic richness[c] of zoobenthos at West Interception Ditch and tributary stations, 1977 as estimated from data of Tsui et al. (1977).

Station		Spring	Summer	Fall
W.I.D. 13.7 km	Density	159.9	108.4	230.5
N. of Beaver Creek	Biomass	3.3	1.5	4.6
Reservoir Rd.	Diversity	2.526	2.159	2.035
(Station 2)	Richness	15	17	8
Creek W-3	Density	119.2	ND[d]	ND
Upstream of	Biomass	1.8	ND	ND
Confluence with	Diversity	1.619	ND	ND
W.I.D. (Stn. 7)	Richness	13	ND	ND
W.I.D. 4.0 km	Density	798.3	780.1	205.0
N. of Beaver Creek	Biomass	8.2	5.4	3.9
Reservoir	Diversity	0.296	0.548	2.032
(Station 5)	Richness	6	7	11
Lower Beaver Creek	Density	165.1	46.7	66.7
	Biomass	< 0.1	25.0	100.0
	Diversity	0.360	0.226	0.171
	Richness	4	2	2

[a]Biomass estimates of Tsui et al. (1978) were volumetric ($cm^3 \cdot m^{-2}$). They were converted to mg AFDW by assuming a specific gravity of 1.05, and an AFDW:wet weight ratio of 0.1428 (Reger et al. 1977).

[b]Recalculated from Tsui et al. (1977) using a family level of taxonomic resolution.

[c]Genera of Chironomidae pooled as one taxonomic unit.

[d]Data not available.

increased. This may reflect an increase in the accumulation of organic material exported from upstream areas in the W.I.D., where macrophytes dominate. Simuliidae feed upon suspended organic material, which may now largely be retained by growing macrophytes during spring and summer. Oligochaeta and Chironomidae are typically detrital deposit feeders that overwinter as immatures. The decomposition of submergent macrophytes in the fall likely results in the downstream transport of organic materials. These materials may accumulate in the porous cobble interstices during low summer and fall flows. Benthic densities were markedly higher in summer and fall of 1984 than in 1977, reflecting the increased productivity at WID-B1. Biomass estimates were more than tenfold greater in these seasons in 1984; however, this may indicate incompatibility of the two biomass determination methods, since densities in 1984 did not increase to this extent and the modal size of animals was relatively small (Appendix D, Table D32).

Composition of the benthic community at W3-B also showed significant change. In 1977, the station was characterized by slow flows and organic substrate (Tsui et al. 1977), similar to conditions recorded in 1984. However, in 1977 macrophytes were abundant and presumably provided attachment sites for the Simuliidae, which constituted over 79 percent of the benthos in spring, 1977. A beaver dam, situated at the mouth of Creek W3, had increased water depth at station W3-B, apparently past the level of tolerance for submergent and floating-leaf plants. Although densities were much lower in spring 1984 in comparison with 1977 estimates, diversity was slightly greater, and richness was equivalent if shoreline sweep taxa were included in the former samples.

WID-B2 also exhibited reduced densities compared to 1977 samples. In 1977, the fauna consisted almost entirely of Chironomidae in spring and summer, with **Caenis** sp. (Ephemeroptera) becoming dominant in fall. In 1984, Oligochaeta and Chironomidae were codominant in spring and summer; **Caenis** was absent at this station. Almost twice the number of taxa were recorded in 1984, and because abundance was more equitably distributed among species, diversity increased substantially in spring and summer from levels noted in 1977.

4.3.2 LOWER BEAVER CREEK SYSTEM

Three stations were sampled within the Lower Beaver Creek drainage area (Figure 2.7). Station BRC-B was situated on Bridge Creek, approximately 200 m upstream of Hwy 63. At this location, the creek flows through a steep narrow valley, densely shaded by conifers. During the spring of 1984, stream depth was shallow (10-30 cm) and flows moderate (30-50 $cm \cdot s^{-1}$). Substrate consisted of cobbles embedded in sand; bitumen inclusions were common.

Few animals were collected in any season at BRC-B (Table 4.5). In spring and summer, the fauna were equitably distributed among Oligochaeta, Simuliidae, Chironomidae, and baetid mayflies (Figure 4.8) resulting in relatively high diversity estimates. Oligochaeta dominated in fall. Productivity in Bridge Creek is probably limited by nutrient input. The high degree of channel shading reduced light penetration to the stream bed, limiting autochthonous production. Conifer needles, having a low nutrient value, provide the primary riparian input.

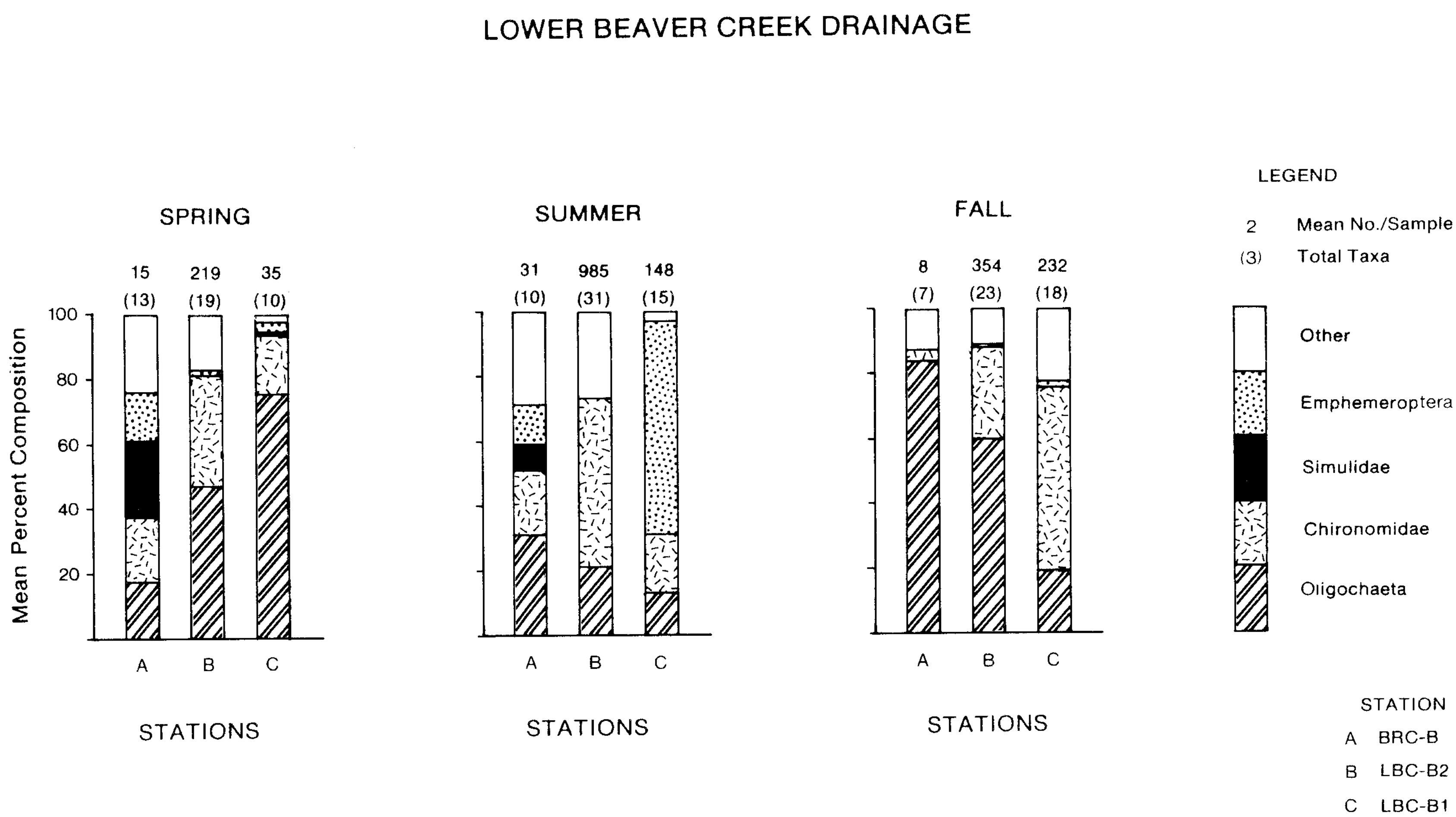

Figure 4.8 Relative abundance of major taxonomic groups of benthic invertebrates in the Lower Beaver Creek drainage area, 1984.

Station LBC-B2 on Lower Beaver Creek (200 m upstream of Hwy 63) was located in a flat, open valley (Figure 2.7). Streambanks were densely vegetated by willow and alder. During the spring, the creek at this station was 1.5 m wide and shallow (7 cm), with moderate flow (20 $cm \cdot s^{-1}$). Substrate consisted of medium sized gravel, covered with dense periphytic growth. Moss occurred on dry areas of the stream bed.

This station showed the highest density estimates of the three stations in the Lower Beaver Creek drainage. Numerous taxa were collected, especially in summer and fall (Table 4.5), and summer diversity was greater than at any other station in the Syncrude Development Area. Oligochaeta and Chironomidae were more abundant than any other taxa.

Tsui et al. (1977) sampled this creek at a point several kilometres upstream from the present station. They recorded higher spring densities but lower biomass (Table 4.6). In summer and fall, the reverse was true; they found only two and four taxa, respectively. Diversity was correspondingly low; Oligochaeta and Chironomidae dominated this sample. The low diversity was attributed to the homogeneous nature of the mud/sand substrate at the 1977 station. The high abundance and diversity recorded at the 1984 station likely can be attributed to the presence of a clean gravel substrate which provides greater habitat heterogeneity, and the abundant energy source provided by both autochthonous production and riparian inputs.

Lower Beaver Creek was sampled 80 m downstream of its confluence with Bridge Creek (station LBC-B1). The two creeks form an extensive sandy delta, densely overgrown with willows. At this station, the creek flows between low sandy banks over a substrate of cobble embedded in sand. Some bitumen was present. In the spring, the creek was approximately 4 m wide, with depths of 20-30 cm and flows of 70-80 $cm \cdot s^{-1}$.

Values of density, biomass and taxonomic richness recorded at LBC-B1 were intermediate between those at LBC-B2 and BRC-B (Table 4.5). All biotic measures increased from spring to fall except biomass, which was maximal in summer. Oligochaetes were prevalent in spring, but were replaced by **Baetis** (Ephemeroptera) in summer and by Chironomidae in fall.

Although this station is exposed and likely receives abundant riparian input of organic matter from upstream, diversity and abundance of fauna were less than at the upstream Lower Beaver Creek station (LBC-B2). It is possible that continual input of sand and silt from the delta region, and from eroding upstream banks, inhibits periphytic growth and reduces the interstitial volume within the cobble substrate.

Detailed tables of taxonomic compositon, abundance and biomass for stations LBC-B1, LBC-B2 and BRC-B, are presented in Appendix D, Tables D11 to 13 and Table D32.

4.4 FISH

Five species of fish were recorded in the West Interception Ditch/Lower Beaver Creek System in 1984: longnose sucker, white sucker, fathead minnow, lake chub and brook stickleback (Table 4.7). Brook stickleback and lake chub were the only species present in the upper part of the drainage system (i.e., W.I.D., Upper Beaver Creek). Brook stickleback was the most abundant species, contributing 73.9% to the combined catch from all sample stations.

4.4.1 WEST INTERCEPTION DITCH

The West Interception Ditch (W.I.D.) exhibited a very low utilization by fish in 1984. Of the three species recorded, only brook stickleback was present at all sampling stations (Table 4.7). This species was the most abundant in the catch, contributing 55.6% (n=10) to the total catch from all stations combined. Fathead minnow (38.8% of the catch) was present only at EF1, the lowermost W.I.D. sampling station (Figure 2.2). One lake chub was recorded in the W.I.D.; this individual was captured at the uppermost sample station (EF3).

The low numbers of fish utilizing the W.I.D. likely is a reflection of the inability of this system to overwinter fish (i.e., flow limitations). In most areas, the W.I.D. likely freezes to the bottom. In areas not freezing to the bottom anoxic conditions likely would result due to the abundance of decaying submergent and emergent aquatic vegetation. The absence of

Table 4.7. Percentage composition of fish species recorded at electrofishing stations on the West Interception Ditch (WID), Bridge Creek (BRC), and Lower Beaver Creek (LBC), 1984.

	Fish Species				
Station	Longnose sucker	White sucker	Fathead minnow	Lake chub	Brook stickleback
WID-EF1	0	0	58.3	0	41.7
WID-EF2	0	0	0	0	100.0
WID-EF3	0	0	0	25.0	75.0
Combined	0	0	38.8	5.6	55.6
(n)[a]	(0)	(0)	(7)	(1)	(10)
BRC-EF1	40.0	30.0	0	10.0	20.0
BRC-EF2	0	0	0	0	0
BRC-EF3	0	0	4.8	16.7	78.5
BRC-EF4	0	0	73.3	0	26.7
Combined	2.6	2.0	49.7	5.2	40.5
(n)	(4)	(3)	(76)	(8)	(62)
LBC-EF1	0	1.3	0	6.3	92.4
LBC-EF2	0	0	0	0	100.0
Combined	0	0.4	0	2.2	97.4
(n)	(0)	(1)	(0)	(5)	(225)
All Sites Combined	1.0	1.0	20.6	3.5	73.9
(n)	(4)	(4)	(83)	(14)	(297)

[a]Number of fish captured and observed.

fish from all sampled stations in the spring survey supports this assumption (Appendix E, Table E4). Fish captured in the W.I.D. during the summer and fall surveys may have moved into the W.I.D. from downstream habitats (i.e., Bridge Creek) or from tributaries (i.e., Creeks W2, W3, W4 and W5). In addition, fish may have been flushed into the W.I.D. from Creek B1. Erosional scars on the dam separating the two drainages (Figure 2.2) indicated that during freshet periods, water from Creek B1 flowed over the dam into the W.I.D.

Similarities exist between the results of 1977 (Tsui et al. 1977) and 1984 studies. In both cases, brook stickleback and fathead minnow were the dominant species recorded. In both study years, these species were absent in the catch in the spring, yet were present (in low numbers) in the fall sampling periods. Tsui et al. (1977) also concluded that these species had invaded the W.I.D. from Bridge Creek or from the W.I.D. tributaries. It is evident that habitat conditions in the W.I.D. are unsuitable for the establishment of resident fish populations.

4.4.2 W.I.D. TRIBUTARIES

Of the four main W.I.D. tributaries, only Creek W2 was sampled in the present study. A backpack electrofishing survey was conducted in this system on 30 May 1984 (Appendix E, Table E4). Brook stickleback and fathead minnow were the only species recorded. All fish were captured in a large beaver pond situated approximately 150 m upstream from the creek mouth. A small concentration of fathead minnow spawners (i.e., seven ripe males and one ripe female) were captured in a shallow (50-75 cm), nearshore area, an area with an abundance of submerged woody vegetation for cover. One brook stickleback adult also was recorded in the beaver pond.

Brook stickleback and fathead minnow likely were more abundant in Creek W2 than indicated by the limited sampling results. The presence of numerous large, stable beaver dams (that may restrict fish movement) and numerous deep beaver ponds suitable for overwintering suggests that fathead minnow and brook stickleback are year-round residents in Creek W2.

The other W.I.D. tributaries (i.e., Creeks W3, W4, and W5) exhibited similar habitat characteristics to those present in Creek W2. Tsui et al. (1977) recorded brook stickleback and fathead minnow in Creek W5 and Creek W3. These species likely were common cohabitants of all the W.I.D. tributaries.

4.4.3 BRIDGE CREEK

A total of five fish species was recorded in Bridge Creek. Of these, fathead minnow (49.7%) and brook stickleback (40.5%) made the largest contribution to the electrofishing catch (Table 4.7). Lake chub, white sucker and longnose sucker (in decreasing order of abundance) also were recorded. The highest species diversity (i.e., four species) was present at EF1, the farthest downstream station. Fish were not collected at EF2. This section, located immediately above the Highway 63 road crossing, exhibited predominantly shallow depths and a low occurrence of instream cover, factors that may account for the apparent lack of fish use. In addition, a 33 cm high cascade at the culvert outlet (Highway 63 road crossing) formed a barrier to upstream fish passage at all flow stages observed.

Fathead minnow were recorded only in EF3 and EF4, the two upstream electrofishing stations (Table 4.7). This species was most abundant in spring at EF4 when a CUE of 8.1 fish·min^{-1} was recorded (Appendix E, Table E4). Fathead minnow adults and juveniles were present in EF4 during all sampled periods; these individuals may be resident in the upper portion of Bridge Creek. Distribution of this species was restricted to deeper pool areas with abundant instream and bankside cover.

Brook stickleback were collected at the two upstream sample stations during all sampled periods (Table 4.7). This species exhibited the highest CUE (3.1 fish·min^{-1}) in EF4 during the summer survey (Appendix E, Table E4). In the fall, this species was most abundant (CUE of 2.8 fish·min^{-1}) in section EF3. This section is located immediately downstream from EF2, below the confluence of Bridge Creek and the W.I.D. This apparent shift in abundance between adjoining sections may be related to seasonal feeding and overwintering movements. Adult and juvenile brook stickleback were present in the upper sample reaches of Bridge Creek during all periods. Brook stickleback were present in low numbers (n = 2) at EF1 (below Highway 63) during the spring sample period but were absent during summer and fall.

Lake chub were present in low numbers and exhibited a sporadic distribution both spatially and seasonally within Bridge Creek (Table 4.7). This species was recorded during spring sampling in EF1 and during the summer surveys at EF3 (Appendix E, Table E4). The presence of adult and juveniles in the catch suggests that there may be a resident population within the system.

Longnose and white suckers (juveniles) were the other species present in Bridge Creek; both these species were recorded at EF1 during the summer survey (Appendix E, Table E4). These individuals likely moved upstream from the Athabasca River. The outfall barrier at the culvert outlet likely limits the extent of upstream penetration into the system.

4.4.4 LOWER BEAVER CREEK

Brook stickleback was the most abundant species recorded during electrofishing surveys on Lower Beaver Creek, contributing 92.4% and 100.0% to the total catches from stations EF1 and EF2, respectively (Table 4.7). Adult lake chub and juvenile white suckers were present only during the July survey in EF1. These individuals were captured in a large pool immediately downstream of the Highway 63 culvert outlet.

Brook stickleback were abundant in Lower Beaver Creek and exhibited a relatively stable seasonal abundance within sample stations. CUE ranged from 2.4 to 2.8 fish·min^{-1} at EF1 and from 4.8 to 6.3 fish·min^{-1} at EF2 for all sampled periods (Appendix E, Table E4). The higher CUE's recorded in EF2 may reflect the greater abundance of cover (in the form of submergent aquatic vegetation) in this section. The presence of all life history stages (i.e., adult, juvenile, young-of-the-year) of brook stickleback indicates this species is resident within the sample area. Beaver ponds situated at the lower end of EF1 provide suitable overwintering habitat in the area.

In May of 1977, longnose sucker were observed spawning in Lower Beaver Creek below the North Starter Dike (Tsui et al. 1977). Additional sampling in this area in September 1977 recorded numerous longnose and white sucker young-of-the-year (y-o-y). These individuals likely were members of established sucker spawning runs in Beaver Creek (R.R.C.S. 1973). Although sampling was not conducted in this immediate area in 1984, the absence of sucker y-o-y at collection stations situated approximately 4 km downstream from the 1977 sample station suggests that longnose suckers and white suckers did not spawn in the area in 1984. This may have been due to one or all of the following: low quality substrate; restricted flows during migration and spawning period; possibility of movement blockage at the Highway 63 culvert; or sucker spawning populations in the original Beaver Creek have been eliminated.

SECTION 5.0

BEAVER CREEK DIVERSION SYSTEM

The Beaver Creek Diversion System consists of a series of reservoirs and diversion canals designed to divert streamflow from the southern boundary of the Syncrude Canada Ltd. mine site (Figure 2.3). The system originates at Beaver Creek Reservoir, which was formed by the impoundment of Upper Beaver Creek. The reservoir receives input from three major sources (i.e., Upper Beaver Creek, Creek B2, and Creek B1). Upper Beaver Creek drains an area to the south and enters at the south end of the reservoir. Creek B2 enters at the southwestern portion of the reservoir. Creek B1 drains an area to the west and empties into the northwest portion of the reservoir. The lower reach of Creek B1, which is channelized, drains a small impoundment created by the West Perimeter Road and the dam separating Creek B1 and the W.I.D drainage basins.

Water from Beaver Creek Reservoir is diverted through a diversion canal into Ruth Lake and then via another diversion canal into Poplar Creek Reservoir. A spillway at the southern end of Poplar Creek Reservoir directs water into Poplar Creek which in turn flows into the Athabasca River. To accommodate the additional inflow from Poplar Creek Reservoir, a section of Poplar Creek downstream of the spillway confluence has been channelized and the banks armoured with rip-rap and gabion structures. Eleven drop structures are located within the channelized section to reduce water velocities and thereby minimize bed and bank scour.

5.1 UPPER BEAVER CREEK

5.1.1 AQUATIC HABITAT

5.1.1.1 Description of Drainage Area

Upper Beaver Creek drains an area of 165 km^2 which is predominantly highland terrain. The stream extends a distance of approximately 32 km southward from its point of entry into Beaver Creek Reservoir. The major tributary to Upper Beaver Creek is Cache Creek which enters at km 5.5.

5.1.1.2 Streamflows During Study Period

A Water Survey of Canada gauging station (Station No. 07DA018) is located on Upper Beaver Creek approximately 2.5 km upstream of Beaver Creek Reservoir (Figure 2.3). The hydrograph for the period 1 May to 21 September is illustrated in Figure 5.1. The peak discharge (13.8 $m^3{\cdot}s^{-1}$) during the recording period occurred on 2 June; prior to this event, flows were in the order of 0.3 $m^3{\cdot}s^{-1}$ to 0.9 $m^3{\cdot}s^{-1}$. Apart from a minor peak (1.0 $m^3{\cdot}s^{-1}$) in early July, the flow was relatively stable over the summer and early fall (i.e., ranging from 0.1 $m^3{\cdot}s^{-1}$ to 0.5 $m^3{\cdot}s^{-1}$).

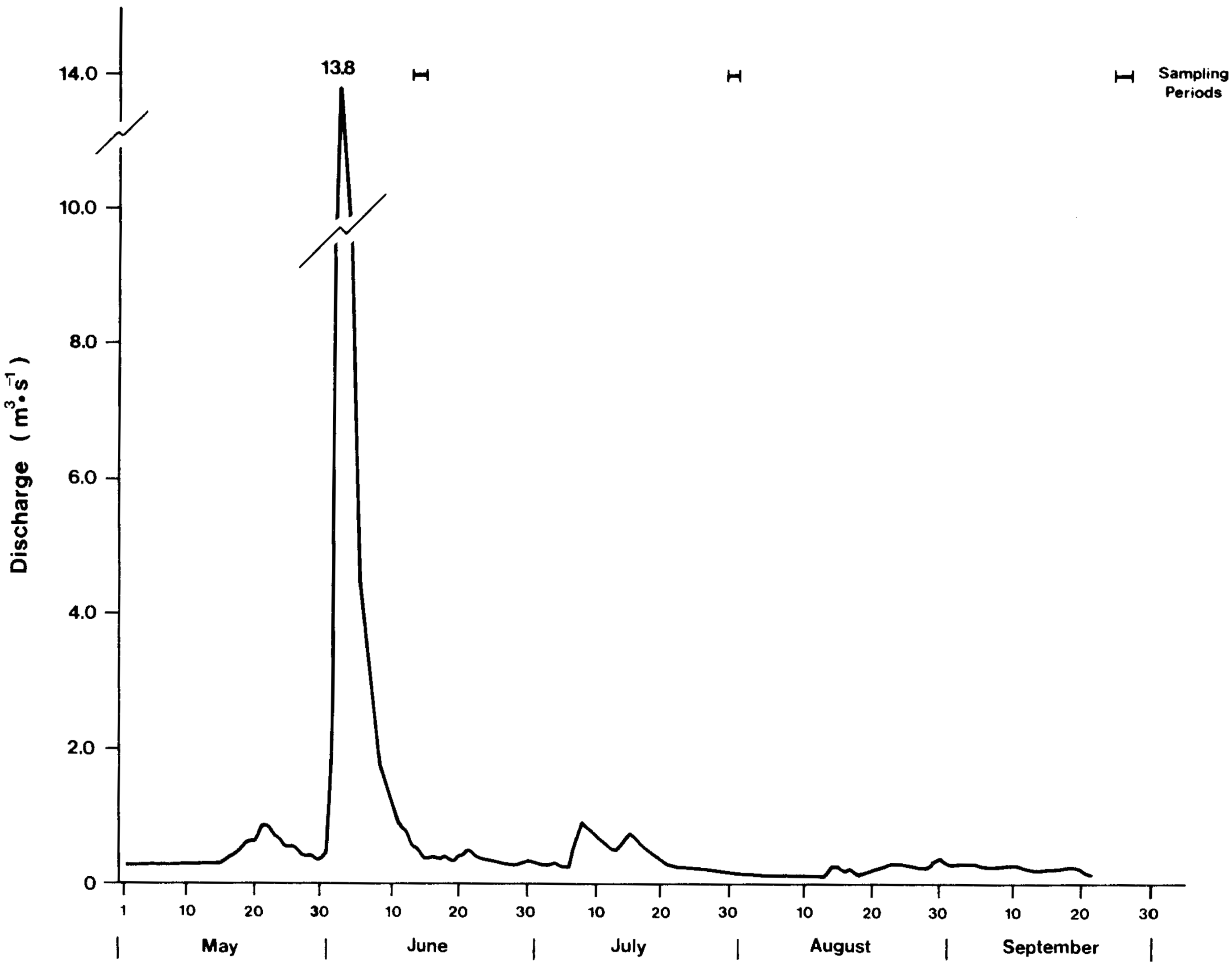

Figure 5.1 Beaver Creek hydrograph, 1 May to 21 September 1984 (based on preliminary Water Survey of Canada data for Station No. 07DA018).

5.1.1.3 Mainstem Upper Beaver Creek

Fishery surveys have been conducted on Upper Beaver Creek on several occasions (Noton and Chymko 1978; O'Neil 1979, 1982). Detailed and systematic habitat sampling was not carried out during these prior surveys. Previous investigators described Upper Beaver Creek as a low gradient, meandering, brown-water stream characterized by low current velocity, sand-silt substrate, and predominantly Flat type habitat.

The longitudinal profile (Figure 5.2) indicates the presence of three discrete habitat reaches: a low gradient reach (R1), a moderate gradient reach (R2), and a high gradient reach (R3). During the present study, only Reach 1 received an on-site investigation (H1, Table 5.1). Station H1 was located approximately 4.0 km upstream from the reservoir. The major channel characteristics at the transect were as follows: wetted width was 8.4 m, mean depth was 75 cm, and mean velocity was 3 $cm \cdot s^{-1}$. The habitat was dominated (100%) by Flat cover type. Substrate consisted entirely of sand-silt material. Streambanks exhibited a high degree of erosion (i.e., 60-80% of intersected bank disturbed). The presence of macrophytes and attached algae was negligible. Overall, the habitat in Reach 1 was extremely homogeneous, with low fishery suitability. Conditions in the upper sections, and in particular Reach 2 (with a moderate gradient), may be more suitable for fish.

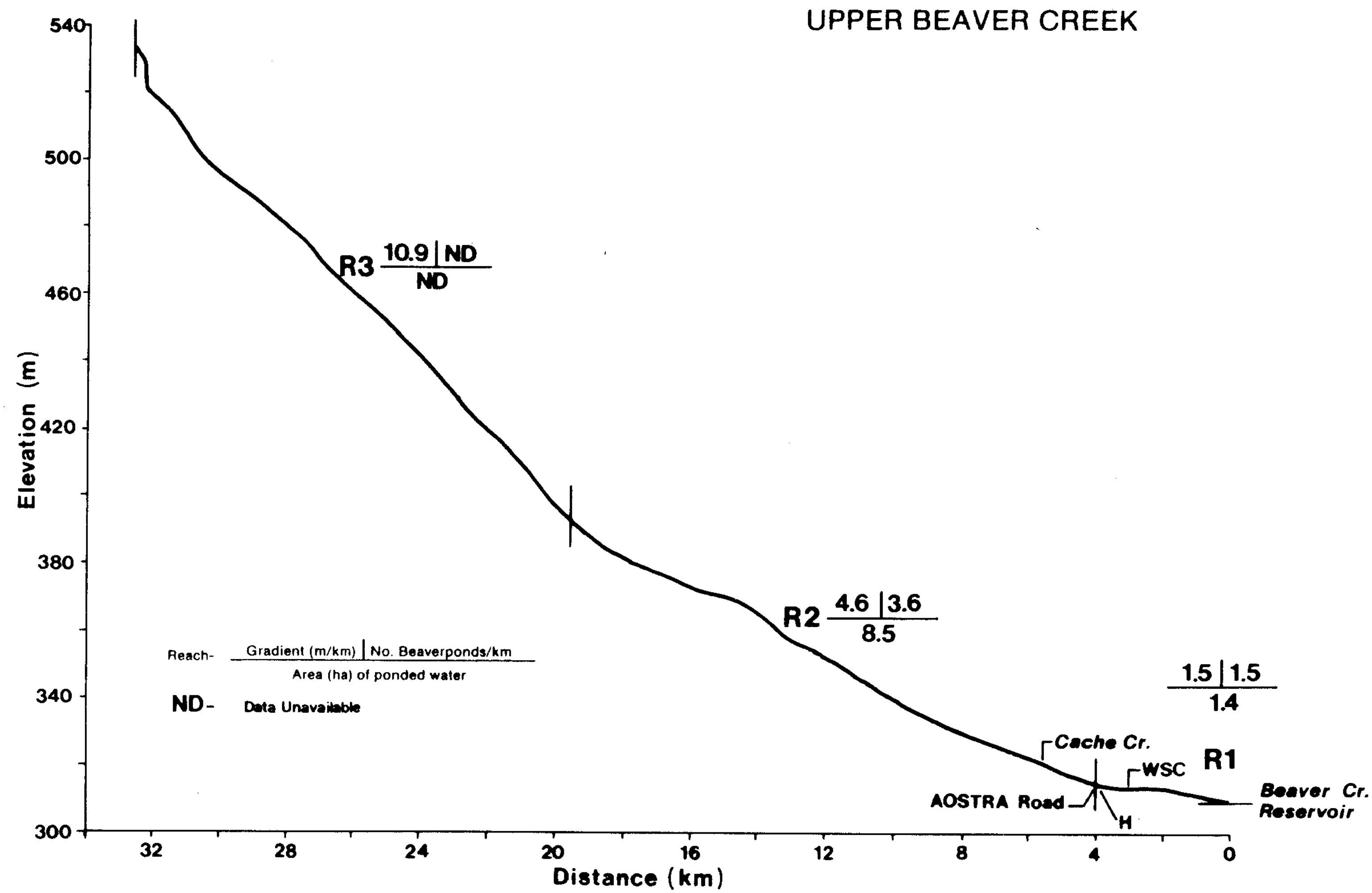

Figure 5.2 Longitudinal profile and habitat zonation, Upper Beaver Creek.

Table 5.1 Summary of physical habitat characteristics at sampling stations on Upper Beaver Creek, September 1984 and Creek B1, July 1984.

Station	Date	Water Temp(°C) (Time)(h)	Channel Features at Transect: Rooted Width (m)	Wetted Width (m)	Local Gradient (%)	Mean Depth (cm)	Mean Velocity ($cm \cdot s^{-1}$)	Discharge ($m^3 \cdot s^{-1}$)	Cover Type Distribution (%): Riffle	Run	Flat	Pool Type 1	2	3	4	5
Upper Beaver Creek																
H	26 Sept.	5 (1707)	8.4	8.4	0.25	75 (60-90)	3 (1-4)	- 0.18[a]	-	-	100	-	-	-	-	-
Creek B1																
H1-T1	20 July	20 (1215)	4.6	3.0	1.0	29 (22-33)	24 (8-36)	0.06[b]	-	100	-	-	-	-	-	-
-T2	20 July	20 (1240)	3.5	2.8	1.0	24 (22-27)	26 (2-55)	-	-	58	-	42	-	-	-	-
-T3	20 July	20 (1305)	4.3	2.8	1.0	28 (23-32)	20 (8-38)	-	-	55	-	45	-	-	-	-
H2-T1	20 July	21 (1425)	4.6	4.2	3.5	16 (15-17)	63 (32-85)	-	64	18	-	18	-	-	-	-
-T2	20 July	21 (1445)	4.3	4.2	3.0	15 (14-17)	40 (25-48)	-	55	45	-	-	-	-	-	-
-T3	20 July	21 (1510)	4.5	3.5	3.0	14 (12-18)	46 (27-68)	-	9	73	-	18	-	-	-	-

Station	Bank Features (RUB/LUB): Cond. (%)	Stab. (No.)	Under. (cm)	Slope (Deg.)	Cover (No.)	Depth (cm)	Over. (cm)	Substrate Distribution (%): Sand	Silt	FG	MG	CG	VCG	SC	LC	SB	LB (BR)	EMB. (No.)	Aquatic Veg.: Macro. (No.)	Algae (No.)
Upper Beaver Creek																				
H	60/80	4/3	0/0	125/120	3/2	5/41	140/55	- 100 -		-	-	-	-	-	-	-	-	N/A[c]	1	1
Creek B1																				
H1-T1	0/25	4/4	0/0	177/160	2/2	0/0	0/35	-	50	33	-	-	-	-	17	-	-	5	4	2
-T2	10/5	4/4	0/0	145/165	2/2	0/0	0/0	-	-	100	-	-	-	-	-	-	-	4	2	2
-T3	5/40	4/3	0/0	152/130	2/2	0/18	0/0	-	-	-	55	45	-	-	-	-	-	4	2	2
H2-T1	10/25	4/4	0/0	166/126	2/2	0/0	0/0	-	-	-	-	-	-	28	72	-	-	5	1	1
-T2	2/2	4/4	0/0	150/140	2/2	0/0	0/0	-	-	-	-	-	-	-	100	-	-	4-5	1	1
-T3	0/0	4/4	0/0	152/155	2/2	0/0	0/0	-	-	-	-	100	-	-	-	-	-	4	1	1

[a]WSC Station No. 07DA018 (preliminary data for 21 September).
[b]Recorded during water quality sampling on 25 July.
[c]N/A - not applicable.
Note: Description of terms in Table 2.2.

5.1.1.4 Tributaries

Cache Creek

Cache Creek is a second-order stream which enters Beaver Creek approximately 5.5 km upstream of the reservoir (Figure 2.3). It drains an extensive area of predominantly muskeg terrain. Cache Creek did not receive any on-site investigation during this or previous studies. A review of the longitudinal profile (Figure 5.3), however, suggests the presence of three discrete habitat reaches (R1-moderate, R2-steep, R3-high). The initial reach (R1) features a high frequency of beaver dams ($4.0 \cdot km^{-1}$) and beaver ponded area; therefore, it can be assumed that the habitat is uniform and dominated by the Flat cover type.

Creek B2

Creek B2 is a second-order stream, draining predominantly highland terrain ($63.6\ km^2$). This stream was not investigated during the study. Three relatively discrete habitat reaches were identified on the basis of gradient differences (Figure 5.3). A previous site inspection of the lower reach conducted by R.L. & L. Environmental Services Ltd. personnel indicated that the creek is a small, brown-water stream dominated by Flat habitat and sand-silt substrate; beaver activity was extensive. Calculated frequency of major beaver ponds was $4.9 \cdot km^{-1}$, and pondage was 4.9 ha in Reach 1 (Figure 5.3).

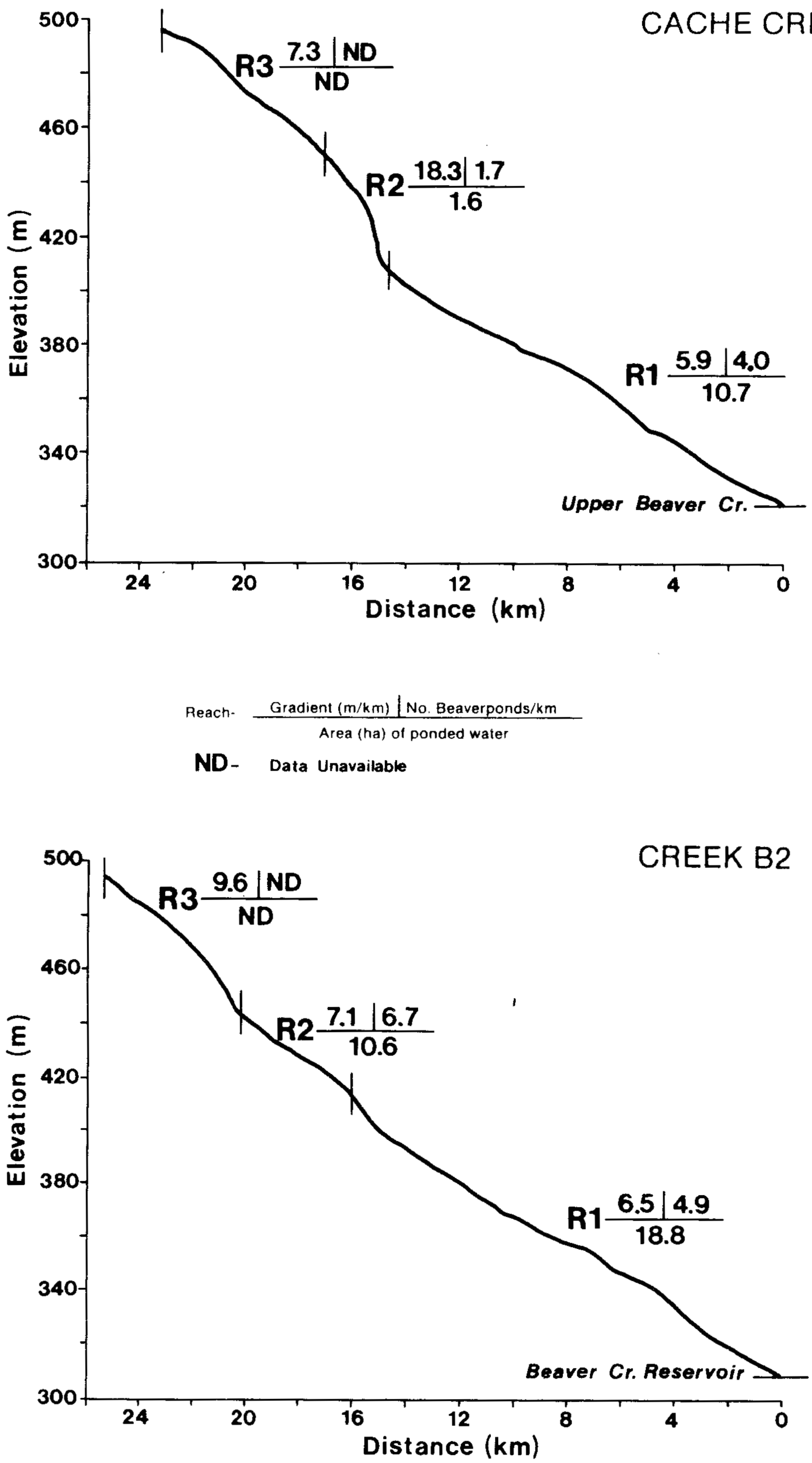

Figure 5.3 Longitudinal profile and habitat zonation, Cache Creek and Creek B2.

5.1.2 WATER QUALITY

5.1.2.1 Physical Parameters

In Upper Beaver Creek, the water temperature at stations UBC-W ranged from 7.0 to 23.0°C, with the highest value occurring in July (Table 5.2). The pH was neutral (ranging from 7.1 to 8.4), and was similar to that reported in 1977 by Noton and Chymko (1978). The total non-filterable residue values were low, with the highest value of 14.4 $mg \cdot L^{-1}$ recorded in June. The dissolved oxygen levels ranged from 8.2 to 10.2 $mg \cdot L^{-1}$ which were above the minimum ASWQO of 5.0 $mg \cdot L^{-1}$. The oxygen saturation levels ranged from 82 to 117%; they were similar to those reported in Noton and Chymko (1978) except these authors did not encounter a supersaturated condition in Upper Beaver Creek.

5.1.2.2 Major Ions

The ionic dominance generally was from HCO_3^- > Ca^{++} > Na^+ > Mg^{++} > $SO_4^=$ > Cl^- > K^+ (Figure 5.4). The waters varied seasonally from calcium bicarbonate to a sodium bicarbonate type because calcium and sodium were of near equal dominance. The levels of total filterable residue (150 to 250 $mg \cdot L^{-1}$) increased from June to September. Compared to other ions, sulphate concentrations exhibited the largest fluctuations among sampling stations and among sampling periods, with notable decreases in July and September.

Table 5.2. Summary of water quality data for the Beaver Creek Diversion System obtained in 1984.

Site/Date	UBC-W			B1-W2			B1-W1		
Parameter	**15 June**	**30 July**	**22 Sept.**	**17 June**	**25 July**	**25 Sept.**	**17 June**	**25 July**	**25 Sept.**
Temperature °C	18.0	23.0	7.0	17.0	18.0	5.0	19.0	20.0	7.0
pH	7.1	8.4	8.2	6.9	6.9	8.4	8.1	7.5	8.5
Specific Conductance $\mu S{\cdot}cm^{-1}$	225	350	325	250	250	280	250	320	320
Dissolved Oxygen	8.2	10.2	10.0	6.5	8.0	8.6	7.3	7.0	8.8
Oxygen % Saturation	85	117	82	65	82	67	78	77	72
Turbidity N.T.U.	1.5	6.0	9.3	1.4	1.2	1.6	1.8	1.5	4.3
Calcium	20.70	34.00	33.10	18.70	29.30	28.70	19.00	24.20	30.20
Magnesium	7.20	9.70	12.00	7.40	9.50	12.00	7.00	9.10	12.10
Sodium	23.30	40.00	49.50	24.50	27.50	29.60	24.80	27.00	29.30
Potassium	1.51	1.26	1.42	1.48	1.07	1.38	1.55	1.12	1.53
Chloride	1.80	1.70	2.00	1.50	1.10	1.20	1.60	0.90	1.20
Sulphate	23.5	16.0	15.6	15.5	5.6	5.5	23.4	13.0	8.8
PP Alkalinity as $CaCO_3$	L0.1	L0.1	L0.1	L0.1	L0.1	6.0	L0.1	L0.1	2.0
Alkalinity, T. as $CaCO_3$	103.0	183.0	213.0	110.0	165.0	186.0	104.0	146.0	169.0
Bicarbonate	126.0	223.0	260.0	134.0	201.0	212.0	127.0	178.0	201.0
Carbonate	0	0	0	0	1.01	7.0	0	0	2.5
Hardness, T. as $CaCO_3$	81.5	125.0	132.0	77.0	112.5	121.0	76.5	98.0	125.0
Silica (Reactive)	4.70	5.70	6.84	1.54	2.70	3.10	1.40	1.29	4.64
Total Filterable Residue	150	214	250				155	175	189
Total Non-Filterable Residue	14.4	8.0	4.0				0.8	4.0	4.4
Chemical Oxygen Demand	72	69	65				135	59	75
Oil & Grease	1.7	1.0	L0.1				0.4	6.6	1.5
Nitrogen, T. as N	0.97	1.01	0.69	0.91	1.17	0.82	0.79	1.17	1.10
Nitrate + Nitrite Nitrogen as N	0.015	0.017	0.007	0.011	0.007	0.004	0.014	0.007	L0.003
Kjeldahl Nitrogen, T. as N	0.96	1.00	0.68	0.90	1.16	0.82	0.78	1.16	1.10
Ammonia Nitrogen, T. as N	0.02	0.01	L0.01	0.01	0.14	L0.01	L0.01	0.05	0.02
Phosphorus, T. as P	0.100	0.147	0.119	0.066	0.130	0.040	0.049	0.047	0.053
Ortho-Phosphorus as P	0.060	0.079	0.089				0.027	0.034	0.013
Total Organic Carbon	27.2	26.5	22.4	33.0	33.5	26.3	30.0	30.5	29.2
Total Inorganic Carbon	21.0	38.0	48.0	23.0	35.0	37.5	21.0	31.0	37.0
Phenol	0.006	0.010	0.009				0.012	0.004	0.007
Arsenic, T.	0.0002	0.0013	0.0015				0.0006	0.0002	0.0005
Selenium, T.	L0.0002	L0.0002	0.0002				L0.0002	0.0004	0.0002
Boron, T.	0.28	0.33	0.34				0.20	0.16	0.12
Cadmium, T.	0.001	0.001	L0.001				L0.001	L0.001	L0.001
Copper, T.	L0.001	L0.001	L0.001				L0.001	L0.001	L0.001
Iron, T.	1.46	2.43	2.13				0.57	0.41	0.57
Chromium, T.	0.001	0.001	L0.001				0.001	L0.001	0.001
Manganese, T.	0.070	0.130	0.040				0.060	0.070	0.100
Zinc, T.	0.002	0.011	0.001				0.002	0.001	0.003
Lead, T.	L0.002	L0.002	L0.002				L0.002	L0.002	L0.002
Vanadium, T.	0.001	L0.001	L0.001				L0.001	L0.001	0.001
Nickel, T.	0.002	L0.001	L0.001				0.001	L0.001	L0.001
Mercury, T.	L0.0001	0.0002	L0.0001				L0.0001	L0.0001	L0.0001
Cyanide, T.	0.005	0.005	0.007				0.005	0.006	0.007
Tannin & Lignin	2.2	2.9	2.1				2.6	2.5	1.9
Ion Balance	1.03	1.06	1.04	1.03	1.01	0.91	1.01	0.98	1.04

Notes: All values are reported as $mg{\cdot}L^{-1}$ unless otherwise stated.
L - Less Than; T. - Total; N - Nitrogen; P - Phosphorus.

Continued ...

Table 5.2. Continued.

Site/Date	BCR-W						RL-W		
Parameter	15 June		24 July		23 Sept.		16 June	27 July	24 Sept.
	comp.	5 m	comp.	5 m	comp.	5 m		comp.	
Temperature °C	+	13.0	+	20.0	+	8.0	21.0s;19.0b	25.0s;22.0b	6.0s;6.0b
pH	+	7.2	+	7.5	+	7.3	7.9s;7.8b	9.0s;8.6b	9.0s;9.0b
Specific Conductance $\mu S \cdot cm^{-1}$	+	360	+	350	+	380	400s;420b	355s;355b	340s;370b
Dissolved Oxygen	+	3.0	+	7.2	+	8.8	8.3s;3.4b	9.0s;7.5b	10.6s;10.0b
Oxygen % Saturation	+	27	+	77	+	73	93s;36b	106s;85b	84s;79b
Turbidity N.T.U.	5.1	4.8	5.5	4.8	5.1	5.1	4.1	2.5	1.0
Calcium	21.40	21.00	28.10	25.00	29.60	30.10	22.80	21.50	25.60
Magnesium	7.40	7.60	11.00	9.00	11.00	11.00	8.50	8.50	10.20
Sodium	43.00	51.00	34.70	41.00	47.00	47.50	47.00	41.00	45.00
Potassium	2.12	2.15	1.53	1.60	1.72	1.72	2.25	1.55	1.74
Chloride	21.80	28.50	12.60	13.50	16.70	16.60	24.90	15.00	15.80
Sulphate	29.5	30.5	22.0	21.5	17.1	17.0	26.8	21.8	14.1
PP Alkalinity as $CaCO_3$	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	9.0	4.0
Alkalinity, T. as $CaCO_3$	118.0	125.0	138.0	142.0	174.0	173.0	214.0	214.0	154.0
Bicarbonate	144.0	152.5	168.0	173.0	212.0	211.0	163.5	156.0	178.0
Carbonate	0	0	0	0	0	0	0	11.0	5.0
Hardness, T. as $CaCO_3$	84.0	84.0	107.0	97.5	119.0	120.5	92.0	95.0	106.0
Silica (Reactive)	4.55	4.42	1.48	1.90	3.06	3.20	4.70	1.05	1.32
Total Filterable Residue	210		200		240		225	210	212
Total Non-Filterable Residue	3.2		6.4		4.8		1.6	2.8	9.2
Chemical Oxygen Demand	68		83		74		63	63	64
Oil & Grease	0.4		1.9		1.4		0.3	0.4	1.7
Nitrogen, T. as N	1.05	0.81	1.11	1.18	1.04	0.96	0.97	1.16	0.96
Nitrate + Nitrite Nitrogen as N	0.007	0.011	0.012	0.016	0.037	0.040	0.009	L0.003	0.003
Kjeldahl Nitrogen, T. as N	1.04	0.80	1.10	1.16	1.00	0.92	0.96	1.16	0.96
Ammonia Nitrogen, T. as N	0.04	0.01	0.06	0.15	L0.01	L0.01	0.02	0.10	L0.01
Phosphorus, T. as P	0.051	0.053	0.071	0.115	0.062	0.057	0.054	0.039	0.027
Ortho-Phosphorus as P	0.022		0.032		0.017		0.022	0.028	0.006
Total Organic Carbon	23.5	24.2	29.2	28.2	25.5	26.7	23.5	27.0	27.0
Total Inorganic Carbon	26.0	27.0	29.0	30.0	37.0	38.0	29.0	30.0	28.5
Phenol	0.008		0.006		0.009		0.010	0.014	0.006
Arsenic, T.	0.0005		0.0006		0.0007		0.0005	0.0002	0.0006
Selenium, T.	L0.0002		L0.0002		0.0005		L0.0002	L0.0002	0.0004
Boron, T.	0.27		0.24		0.25		0.26	0.19	0.19
Cadmium, T.	L0.001		L0.001		L0.001		L0.001	L0.001	L0.001
Copper, T.	L0.001		L0.001		L0.001		L0.001	L0.001	L0.001
Iron, T.	0.93		0.93		0.49		0.34	0.35	0.11
Chromium, T.	0.001		0.002		0.001		0.001	0.002	L0.001
Manganese, T.	0.120		0.120		0.090		0.010	0.050	0.030
Zinc, T.	L0.001		L0.002		L0.010		0.003	0.003	0.003
Lead, T.	L0.002		L0.002		L0.002		L0.002	L0 002	L0.002
Vanadium, T.	L0.001		L0.001		L0.001		L0.001	L0.001	0.001
Nickel, T.	0.001		0.001		L0.001		0.001	0.001	L0.001
Mercury, T.	L0.0001		L0.0001		L0.0001		L0.0001	L0.0001	L0 0001
Cyanide, T.	0.005		0.005		0.010		0.003	0.004	0.006
Tannin & Lignin	1.9		2.2		2.0		1.7	1.9	1.4
Ion Balance	1.00	1.0	1.03	1.03	1.04	1.05	1.00	0.98	1.03

Continued ...

Notes: All values are reported as $mg \cdot L^{-1}$ unless otherwise stated.
L - Less Than; T. - Total; N - Nitrogen; P - Phosphorus; s - Surface; b - Bottom; comp. - Composite; + - Parameters shown in Table 5.6.

Table 5.2. Continued.

Site/Date Parameter	PCR-W								
	16 June		26 July				24 Sept.		
	comp.	15 m	comp.	2 m	11 m	15 m	comp.	5 m	15 m
Temperature °C	+	4.5	+	21.0	10.0	9.0	+	9.0	6.0
pH	+	7.6	+	7.6	7.7	ND	+	7.8	7.5
Specific Conductance $\mu S \cdot cm^{-1}$	+	780	+	430	650	650	+	460	750
Dissolved Oxygen	+	0.0	+	7.4	0.4	0.2	+	7.7	1.8
Oxygen % Saturation	+	0	+	83	3	1	+	66	14
Turbidity N.T.U.	2.9	4.9	3.8	7.0	6.5	7.2	9.0	6.5	10.5
Calcium	30.20	34.00	29.10	24.50	37.00	37.50	34.40	30.50	40.30
Magnesium	13.40	15.00	11.90	10.50	15.50	14.60	12.70	10.80	16.00
Sodium	85.00	98.00	82.00	50.00	100.00	82.50	74.50	61.00	98.50
Potassium	2.80	2.98	2.64	2.10	3.06	3.02	2.50	2.18	3.07
Chloride	60.00	75.00	57.50	26.10	88.00	74.50	43.00	33.50	75.00
Sulphate	19.7	14.7	15.4	20.5	12.0	10.3	11.7	15.0	5.3
PP Alkalinity as $CaCO_3$	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	3.0	6.0	L0.1
Alkalinity, T. as $CaCO_3$	214.0	258.0	214.0	159.0	254.0	264.0	220.0	190.0	270.0
Bicarbonate	261.0	315.0	261.0	194.0	310.0	322.0	261.0	217.0	329.0
Carbonate	0	0	0	0	0	0	4.0	7.0	0
Hardness, T. as $CaCO_3$	131.0	147.0	122.0	104.5	156.0	154.0	138.0	121.0	167.0
Silica (Reactive)	5.09	6.30	4.16	1.50	6.34	6.50	5.35	4.00	7.80
Total Filterable Residue	360		340		240	410	316	276	403
Total Non-Filterable Residue	8.0		16.0	1.6	14.8		12.4	4.8	24.8
Chemical Oxygen Demand	63		59				64	64	64
Oil & Grease	0.2		0.4				1.8	3.6	0.3
Nitrogen, T. as N	1.05	1.21	1.30	1.12	1.03	1.37	1.59	1.24	2.45
Nitrate + Nitrite Nitrogen as N	0.007	0.011	0.004	0.020	0.008	0.010	0.046	0.062	0.004
Kjeldahl Nitrogen, T. as N.	1.04	1.20	1.30	1.10	1.02	1.36	1.54	1.18	2.44
Ammonia Nitrogen, T. as N	0.14	0.32	0.29	0.02	0.02	0.49	0.50	0.10	1.07
Phosphorus, T. as P.	0.240	0.190	0.230	0.027	0.295	0.285	0.360	0.041	0.550
Ortho-Phosphorus as P	0.049		0.058				0.088	0.005	0.071
Total Organic Carbon	20.2	23.0	24.2	24.0	21.3	23.5	25.0	24.7	24.0
Total Inorganic Carbon	48.0	60.0	49.0	32.0	56.0	61.0	48.0	37.0	60.0
Phenol	0.008		0.016	0.017	0.013		0.006	0.007	0.006
Arsenic	0.0009		0.0006	0.0004	0.0004		0.0011	0.0005	0.0010
Selenium, T.	L0.0002		L0.0002	L0.0002	L0.0002		0.0003	0.0003	0.0003
Boron, T.	L0.29		0.27	0.23	0.30		0.22	0.22	0.27
Cadmium, T.	L0.001		L0.001	L0.001	L0.001		L0.001	L0.001	L0.001
Copper, T.	L0.001		L0.001	0.003	L0.001		L0.001	L0.001	L0.001
Iron, T.	2.30		2.95	0.25	4.50		L0.01	0.39	0.44
Chromium, T.	0.001		0.003	0.002	L0.001		L0.001	L0.001	L0.001
Manganese, T.	0.096		1.040	0.030	1.660		1.100	0.280	0.210
Zinc, T.	L0.001		L0.001	0.008	0.006		0.003	0.006	0.001
Lead, T.	L0.002		L0.002	L0.002	L0.002		L0.002	L0.002	L0.002
Vanadium, T.	L0.001		L0.001	L0.001	0.004		0.001	0.001	0.002
Nickel, T.	L0.001		L0.001	0.002	0.002		L0.001	L0.001	L0.001
Mercury, T.	0.0002		L0.0001	0.0016	0.0010		L0.0001	0.0001	L0.0001
Cyanide, T.	0.003		0.005	0.042	0.005		0.006	0.008	2.200
Tannin & Lignin	1.0		1.3				1.5	1.5	1.7
Ion Balance	1.00	0.96	0.98	0.99	0.97	1.00	1.02	0.97	1.02

Continued ...

Notes: All values are reported as $mg \cdot L^{-1}$ unless otherwise stated; ND - No data; + - Parameters shown in Table 5.17.
L - Less Than; T. - Total; N - Nitrogen; P - Phosphorus; s - Surface; b - Bottom; comp. - Composite.

Table 5.2. Continued.

Site/Date Parameter	PC-W3 18 June	PC-W3 26 July	PC-W3 23 Sept.	PC-W2 18 June	PC-W2 26 July	PC-W2 23 Sept.	PC-W1 18 June	PC-W1 28 July	PC-W1 26 Sept.
Temperature °C	14.0	19.0	5.0	20.0	22.0	7.0	21.0	24.0	5.0
pH	7.74	7.5	8.1	7.9	8.0	7.7	7.8	8.6	8.5
Specific Conductance $\mu S \cdot cm^{-1}$	275	425	560	425	400	480	475	460	410
Dissolved Oxygen	10.4	9.1	11.4	9.0	8.2	11.0	8.9	8.4	9.2
Oxygen % Saturation	100	97	89	97	93	90	97	98	72
Turbidity N.T.U.	15.0	5.6	3.0	6.0	6.5	5.5	8.0	10.1	4.2
Calcium	20.00	31.00	37.20	23.50	27.30	32.60	25.70	27.10	33.10
Magnesium	9.30	11.50	16.60	10.60	9.40	13.10	10.60	10.00	13.00
Sodium	28.20	61.00	75.00	58.00	53.50	64.50	58.00	55.00	66.00
Potassium	1.05	0.87	1.30	2.21	2.05	1.90	2.15	2.08	1.98
Chloride	14.20	59.00	72.50	30.50	33.50	43.20	33.90	29.50	42.20
Sulphate	17.4	11.1	10.0	22.6	19.0	13.6	24.7	19.6	14.1
PP. Alkalinity as $CaCO_3$	L0.1	L0.1	L0.1	L0.1	7.3	L0.1	L0.1	L0.1	L0.1
Alkalinity, T. as $CaCO_3$	107.0	155.0	187.0	147.0	160.0	184.0	149.0	159.0	206.0
Bicarbonate	130.5	189.0	228.0	179.0	177.0	224.5	182.0	194.0	251.0
Carbonate	0	0	0	0	9.0	0	0	0	0
Hardness, T. as $CaCO_3$	88.0	125.0	161.0	102.5	107.0	135.5	108.0	109.0	136.0
Silica (Reactive)	3.90	5.26	8.40	4.10	1.30	5.00	4.15	1.92	4.40
Total Filterable Residue							260	260	296
Total Non-Filterable Residue							22.4	28.0	2.8
Chemical Oxygen Demand							87	69	70
Oil & Grease							1.0	1.2	1.7
Nitrogen, T. as N	0.92	1.11	0.83	L0.92	1.15	0.94	0.88	1.29	1.06
Nitrate + Nitrite Nitrogen as N	0.003	0.013	0.010	L0.003	0.012	0.078	0.015	0.027	0.122
Kjeldahl Nitrogen, T. as N	0.92	1.10	0.82	0.92	1.14	0.86	0.86	1.26	0.94
Ammonia Nitrogen, T. as N	0.07	0.05	L0.01	0.05	0.02	0.01	0.04	0.32	0.02
Phosphorus, T. as P	0.046	0.035	0.021	0.051	0.060	0.037	0.040	0.052	0.033
Ortho-Phosphorus as P							0.038	0.026	0.005
Total Organic Carbon	34.8	36.7	29.5	25.8	27.0	25.8	25.1	26.0	25.7
Total Inorganic Carbon	22.0	31.0	42.0	33.0	34.0	40.0	32.0	39.0	39.5
Phenol							0.006	0.026	0.006
Arsenic, T.							0.0004	0.0005	0.0008
Selenium, T.							L0.0002	L0.0002	0.0004
Boron, T.							0.27	0.19	0.19
Cadmium, T.							L0.001	L0.001	L0.001
Copper, T.							L0.001	L0.001	L0.001
Iron, T.							0.69	0.78	0.62
Chromium, T.							L0.001	0.004	0.002
Manganese, T.							0.080	0.080	0.040
Zinc, T.							0.002	0.002	L0.002
Lead, T.							L0.002	L0.002	L0.002
Vanadium, T.							0.003	L0.001	L0.001
Nickel, T.							L0.001	L0.001	L0.001
Mercury, T.							L0.0001	L0.0001	L0.0001
Cyanide, T.							0.003	0.005	0.010
Tannin & Lignin							1.9	1.8	1.7
Ion Balance	1.04	1.03	1.09	1.08	1.00	1.07	1.06	1.05	1.01

Notes: All values are reported as $mg \cdot L^{-1}$ unless otherwise stated.
L - Less Than; T. - Total; N - Nitrogen; P - Phosphorus.

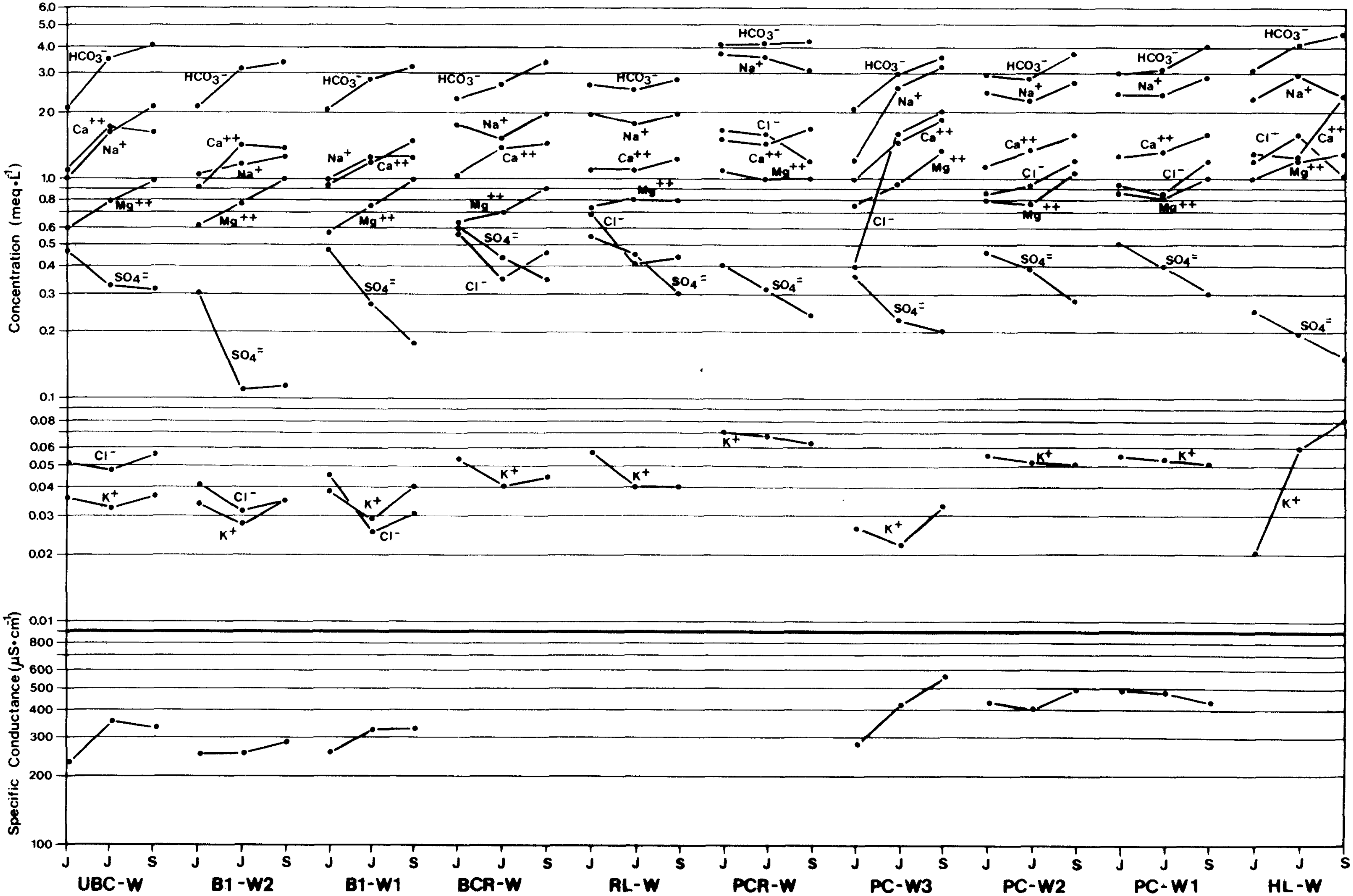

Figure 5.4 Ionic dominance of the major ions, and specific conductance profiles, for the Beaver Creek Diversion system in June, July and September, 1984.

5.1.2.3 Nutrients

The total nitrogen concentrations ranged from 0.97 to 1.01 mg $N \cdot L^{-1}$. The values which were near the ASWQO of 1.0 mg $N \cdot L^{-1}$ were highest in July. A considerably lower value (0.23 mg $N \cdot L^{-1}$) was reported in Upper Beaver Creek in June and July 1977 (Noton and Chymko 1978). The nitrate + nitrite values (ranging from 0.015 to 0.017 mg $N \cdot L^{-1}$) were highest in July, and showed a seasonal relationship identical to that of total nitrogen. Ammonia levels were low, ranging from less than 0.01 to 0.02 mg $N \cdot L^{-1}$.

Total phosphorus concentrations ranged from 0.100 to 0.147 mg $P \cdot L^{-1}$ with the highest level in July, and all exceeded the ASWQO of 0.05 mg $P \cdot L^{-1}$. Concentrations reported in Noton and Chymko (1978) were only slightly lower during the same periods in 1977. Orthophosphorous concentrations (ranging from 0.060 to 0.089 mg $P \cdot L^{-1}$) increased from June to September.

Reactive silica concentrations ranged from 4.70 to 6.84 $mg \cdot L^{-1}$; the highest levels occurred in September. Similar values in Upper Beaver Creek were reported in Noton and Chymko (1978). Total organic carbon levels ranged from 22.4 to 27.2 $mg \cdot L^{-1}$ with the highest level occurring in June. Higher concentrations (36.0 to 41.0 $mg \cdot L^{-1}$) were reported in Upper Beaver Creek by Noton and Chymko (1978).

5.1.2.4 Trace Metals and Other Substances

The concentrations of trace metals and elements were generally below their detection limits, except for iron and manganese levels which exceeded the ASWQO. Total iron values (1.46 to 2.43 $mg \cdot L^{-1}$) and total manganese (0.040 to 0.130 $mg \cdot L^{-1}$) exceeded the objectives of 0.30 and 0.05 $mg \cdot L^{-1}$, respectively. With respect to other parameters, phenol concentrations (ranging from 0.006 to 0.010 $mg \cdot L^{-1}$) exceeded the ASWQO of 0.005 $mg \cdot L^{-1}$. Oil and grease (<0.1 to 1.7 $mg \cdot L^{-1}$) were present in low levels.

5.1.3 ZOOBENTHOS

In the spring of 1984, Upper Beaver Creek (station UBC-B) was approximately 7 m wide, flowing in a deeply incised channel (Figure 2.8). Substrate was a mixture of sand, silt and organic material. Depth was approximately 1.5 m, and water velocities were low but detectable. Qualitative sweep samples included an area of rapid flow over a beaver dam located 35 m downstream of the quantitative sample station; this provided much of the taxonomic richness of the station.

The three replicate benthic samples collected in the spring at this station were exceedingly variable. One Ekman grab sample contained 94 organisms; the others contained two, and zero animals (Appendix D, Table D14). Consequently, the spring estimates of density and biomass must be interpreted with caution. Spring samples contained primarily the mayfly

Caenis and Chironomidae. **Caenis** densities remained fairly constant in summer and fall, but Oligochaeta and especially Chironomidae became increasingly abundant and proportionately assumed greater importance (Figure 5.5). Although density progressively increased from June to September, biomass, diversity, and taxonomic richness were greatest in summer (Table 5.3).

Noton and Chymko (1978) sampled the same site in 1977, and also found high variability in density among replicates. Their estimates of abundance were lower in spring and summer (78 and 56 organisms per 0.1 m^2, respectively) than was found in the present study (Table 5.3). Their sampling protocol consisted of washing samples through a 0.650 mm mesh sieve bucket prior to sorting, whereas a 0.250 mm mesh sieve was used in the present study. Since 40 to 85 percent of the animals collected in the present study were retained in sieves with apertures less than 1.0 mm (Appendix D, Table D33), this discrepancy may largely account for the differences. Noton and Chymko (1978) reported densities in their October samples (1049 per 0.1 m^2) roughly equivalent to the densities in the September samples of the present study. Since the 1984 September samples again contained many small organisms (similar sized organisms would have passed through the larger sieve used in 1977), the data suggest either a reduction in fall densities between 1977 and 1984, or that further hatching and growth of larvae occurred late in the fall. **Caenis** and Chironomidae are both known to grow in fall and overwinter as immatures; both were abundant in fall samples collected by Noton and Chymko (1978). These authors attributed the increase to greater habitat

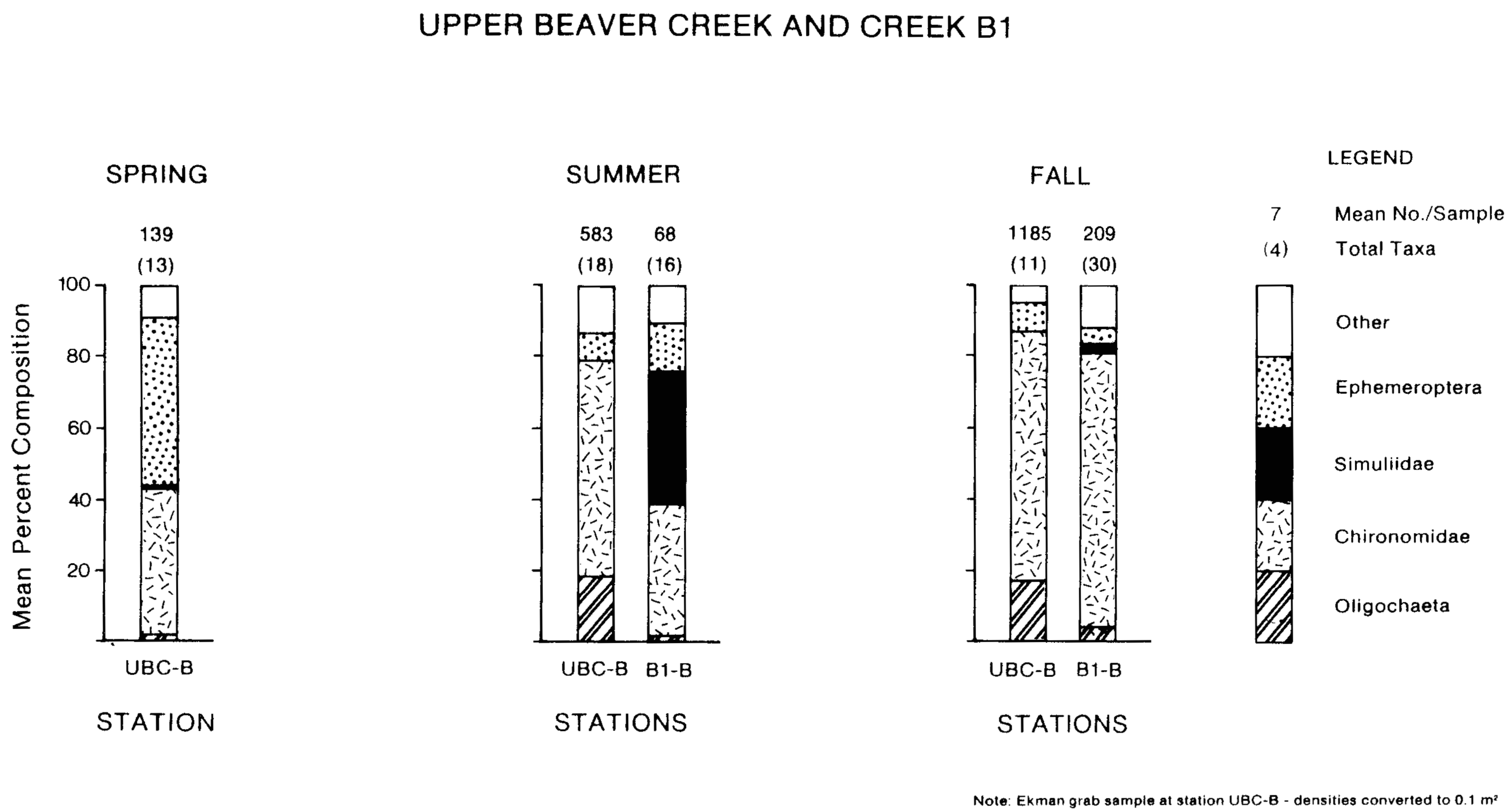

Figure 5.5 Relative abundance of major taxonomic groups of benthic invertebrates in Upper Beaver Creek and Creek B1, 1984.

Table 5.3 Mean density (no. per 0.1 m^2), mean biomass (mg per 0.1 m^2), diversity, and taxonomic richness of zoobenthos at stations associated with the Beaver Creek Diversion System, 1984.

Station		Spring	Summer	Fall
PC-B1	Density	150.3	460.0	148.2
	Biomass	24.1	76.9	12.1
	Diversity	1.673	2.041	2.891
	Richness	19	21	32
PC-B2	Density	168.4	444.0	1087.6
	Biomass	31.3	84.9	44.8
	Diversity	0.877	1.909	1.198
	Richness	14	21	31
PC-B3	Density	19.0	15.9	89.9
	Biomass	2.4	5.0	7.5
	Diversity	2.948	2.465	1.407
	Richness	14	10	13
PC-B4	Density	11.3	79.7	613.3
	Biomass	4.3	12.7	62.0
	Diversity	3.176	3.048	1.485
	Richness	13	24	23
UBC-B	Density[a]	139.3	582.7	1131.7
	Biomass	34.4	85.0	53.2
	Diversity	1.602	1.945	1.351
	Richness	13	18	11
B1-B	Density	ND[b]	67.9	209.0
	Biomass	ND	8.9	12.2
	Diversity	ND	2.254	1.634
	Richness	ND	16	30

[a] Ekman grab samples (area: 0.023 m^2) were taken at this station. Densities and biomass have been converted to 0.1 m^2 area.

[b] Data not available; station not sampled in spring.

stability and organic content that resulted from reduced flow levels in fall.

Noton and Chymko (1978) also reported high absolute or relative abundance of several taxa that were rare or absent in the present study. Elmidae contributed over 30 percent to their summer samples; one individual was found in the present study. They also found **Sialis** (Megaloptera:Sialidae) and **Limnephilus** (Trichoptera:Limnephilidae) to be common in fall, whereas these were not found in 1984. It is possible that the fauna were heterogeneously distributed at this station and the reduced quantitative sampling regime of the present study did not encounter the appropriate microhabitats. Since these taxa were not collected in qualitative sweep samples, however, the taxa may have been absent, suggesting a relatively high rate of species turnover in this system. **Sialis** had not been collected in the Syncrude lease area prior to the study of Noton and Chymko (1978).

5.1.4 FISH

Four species of fish were captured in Upper Beaver Creek in 1984 (Appendix E, Table E5). Three of these (i.e., white sucker, fathead minnow, and lake chub) were present at both the upper (EF) and lower (ES) sample stations (Figure 2.3). Brook stickleback were found only at the upper station; however, sampling of the lower station by boat electroshocking (a sampling method more selective of larger fish) may have underestimated the abundance of this species at the ES station.

Lake chub was the most abundant species in May captures from station UBC-ES, with a recorded CUE of 9.9 fish·min^{-1} (Appendix E, Table E5). Fathead minnows also were a common contributor to the catch (CUE = 3.2 fish·min^{-1}). One white sucker (an adult) also was captured. The greater stream depths (i.e., up to 3.0 m) present at station UBC-ES resulted in a reduced sampling efficiency of the electroshocking unit; therefore, the abundance of those species present was likely underestimated.

Backpack electrofishing (conducted from an inflatable boat) was employed during the September survey at station UBC-EF. Brook stickleback was the most abundant species captured (CUE = 0.9 fish·min^{-1}). White sucker (CUE = 0.5 fish·min^{-1}), fathead minnow (CUE = 0.6 fish·min^{-1}), and lake chub (CUE = 0.6 fish·min^{-1}) exhibited a similar abundance (Appendix E, Table E5).

White suckers captured during the September survey in Upper Beaver Creek were all y-o-y individuals. Previous studies in 1978 and 1981 (O'Neil 1979) also reported the presence of y-o-y white suckers in this area during summer and fall surveys. In addition, adult white suckers in spawning condition were recorded in the lower reaches of Upper Beaver Creek in the spring of 1978. The apparent lack of suitable spawning habitat for this species within the lower reaches of Upper Beaver Creek (Sec. 5.1.1) may indicate that spawning occurs farther upstream. However, successful recruitment may occur also within the sample areas.

All life stages of brook stickleback were present in 1984 indicating a resident population within the Upper Beaver Creek system. The lake chub and fathead minnows captured in 1984 were predominantly adults. These fish may have migrated into the system from Beaver Creek Reservoir during the spring and summer; however, resident populations may also occur within the Upper Beaver Creek system.

5.2 CREEK B1

5.2.1 AQUATIC HABITAT

5.2.1.1 Description of Drainage Area

Creek B1, a second-order stream, originates in the Thickwood Hills situated to the southwest of the study area. It then flows in a northeasterly direction for approximately 27 km before discharging into the northwest corner of Beaver Creek Reservoir (Figure 2.3). Creek B1 adjoins the W.I.D. approximately 3.0 km upstream from Beaver Creek Reservoir; an earthen dam separates the two drainages and creates a small impoundment on Creek B1. Water from this impoundment is subsequently diverted to Beaver Creek Reservoir through a channelized waterway.

5.2.1.2 Streamflows During Study Period

Discharge measurements were taken in Creek B1 on three occasions during the present study (Appendix B; Table B3). The discharges recorded were as follows: 0.21 $m^3 \cdot s^{-1}$ (June), 0.06 $m^3 \cdot s^{-1}$ (July), and 0.02 $m^3 \cdot s^{-1}$ (September).

5.2.1.3 Habitat Zonation

Systematic habitat evaluation of Creek B1 had not been conducted prior to this study. On 20 July 1984 a detailed habitat survey was undertaken on the lower 3.0 km of Creek B1 (from impoundment downstream to reservoir). It had been determined earlier in this study that areas within this reach were utilized extensively for spawning by white suckers and lake chub. Two major reaches were identified on the basis of the gradient differences as determined from a 1:20 000 airphoto mosaic (Figure 5.6). Field surveys revealed the presence of five discrete sub-reaches in the lower reach (R1). Detailed measurements were taken at two stations (H1, H2) situated within Sub-reaches 4 and 2, respectively. Synoptic data were obtained in the remaining sub-reaches.

Sub-reach 1 (km 0-0.40)

Sub-reach 1 is approximately 400 m in length and is characterized by a steep local gradient (3.0 to 3.5%). Specific habitat characteristics in this section (Station H2) are described in Table 5.1 and illustrated in Plate 7. Physical channel features were as follows: wetted width was 4.0 m, mean depth was 15 cm, and mean velocity was 50 $cm \cdot s^{-1}$. As expected due to the steep gradient, the dominant cover types were Riffle (43%) and

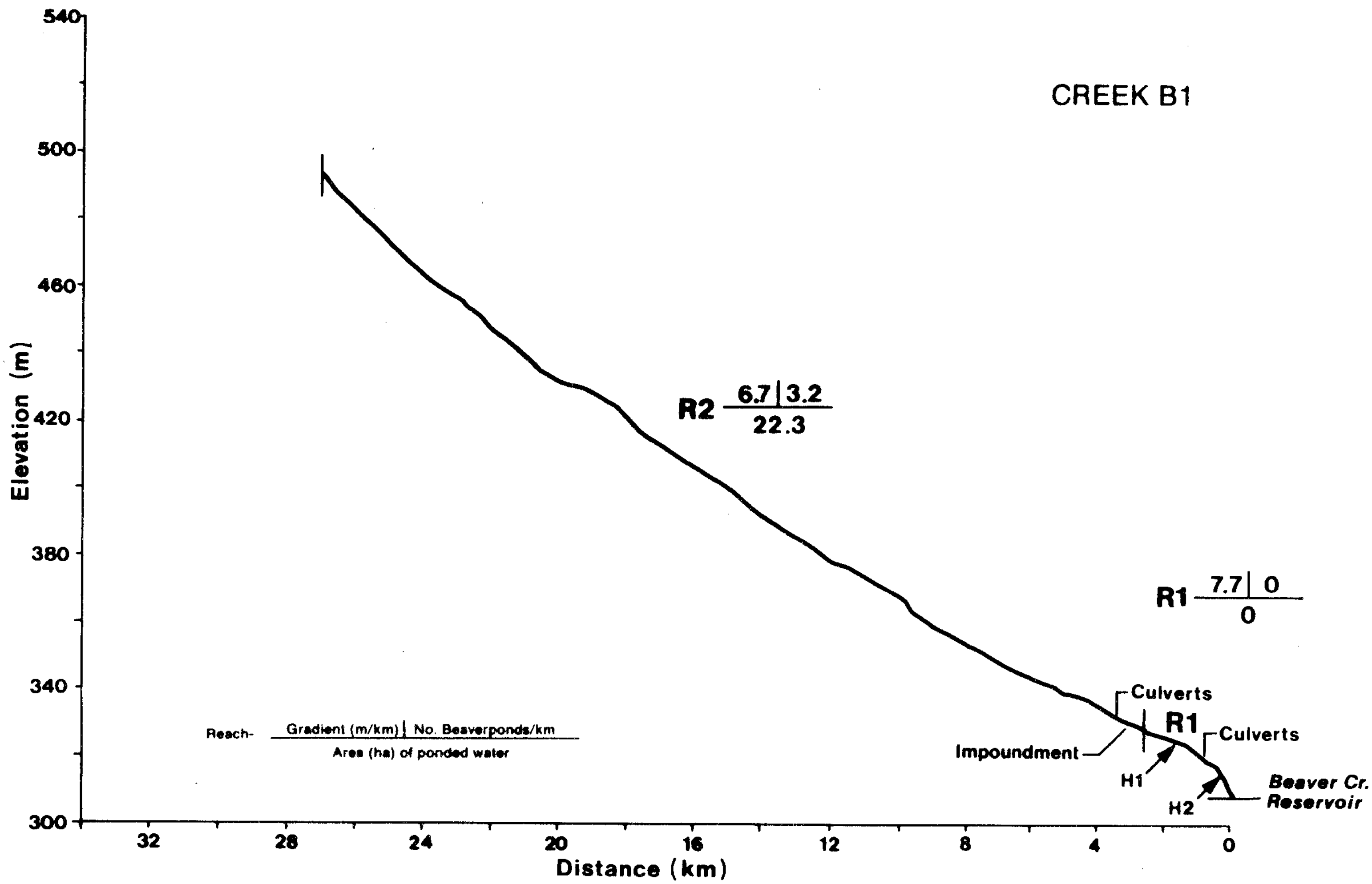

Figure 5.6 Longitudinal profile and habitat zonation, Creek B1.

Run (45%). The remaining habitat consisted of low quality (Class 1) Pool (12%). The substrate consisted largely of granular material ranging in size from coarse gravel (1.6 to 3.2 cm) to large cobble (12.8 to 25.6 cm). Sediment deposition on coarse substrates was low (i.e., less than 25% coverage of interstitial area). Growth of macrophytes and attached algae was negligible. Previous erosion of the banks was very limited; resistance to further erosion was high due to the predominantly cobble-boulder texture of the banks and the extensive vegetation cover (grasses, forbs).

Sub-reach 2 (km 0.4-1.04)

Sub-reach 2 is approximately 640 m in length and features a low gradient (0.5%). The section was characterized by a low diversity of cover types (i.e., mainly Run). The substrate contained more fines in comparison to the downstream reach. Growth of **Typha latifolia** was extensive in the channel in response to the lower gradient.

Sub-reach 3 (km 1.04-1.73)

Sub-reach 3 has a length of approximately 690 m. The local gradient in this section is moderate (0.8%). The dominant cover type was Run, but Flat also was represented. The substrate consisted of coarse material ranging from cobble (6.4 to 25.6 cm) to large boulder (25.6 to 51.2 cm).

Sub-reach 4 (km 1.73-2.73)

Sub-reach 4, a high gradient section (1.0%), is approximately 1.0 km in length. Data collected at station H1 provide a description of the reach (Table 5.1). Physical channel characteristics were as follows: wetted width was 1.9 m, mean depth was 27 cm, and mean velocity was 23 $cm \cdot s^{-1}$. The dominant cover types were Run (71%) and Pool (29%). All pools were of low quality (i.e., severe depth limitation). The substrate was dominated by coarse material ranging from medium gravel (0.8 to 1.6 cm) to large cobble (12.8 to 25.6 cm). Silt accumulation was evident in Pool areas. Overall, sediment deposition was low in Run areas. Previous erosion of stream banks generally was low; resistance to further erosion was rated as high. Growth of macrophytes or attached algae on the substrate was negligible.

Sub-reach 5 (km 2.73-3.05)

Sub-reach 5 is a short (approximately 305 m) section of stream situated between the upper road crossing (culverts) and the impoundment. The section was characterized by low local gradient (less than 0.1%), 100% Flat cover type, and silt substrate.

5.2.2 WATER QUALITY

5.2.2.1 Physical Parameters

In Creek B1, the water temperature at stations B1-W2 and B1-W1 ranged from 5.0 to 20.0°C, with the highest value occurring at B1-W1 in

July (Table 5.2). The pH ranged from near neutral (6.9) to alkaline (8.5); highest values occurred in September. At B1-W1, the total non-filterable residue levels were low, with the highest value of 4.4 $mg{\cdot}L^{-1}$ recorded in September. At B1-W2 and B1-W1, dissolved oxygen levels ranged from 6.5 to 8.8 $mg{\cdot}L^{-1}$ which met the ASWQO of 5.0 $mg{\cdot}L^{-1}$. The oxygen saturation levels ranged from 65 to 82%, and showed no seasonal trends.

5.1.2.2 Major Ions

The ionic character of the waters at B1-W2 and B1-W1 were similar (Figure 5.4). The ionic dominance generally was from $HCO_3^- > Ca^{++} > Na^+ > Mg^{++} > SO_4^= > Cl^- > K^+$. The waters varied from calcium bicarbonate to a sodium bicarbonate type because calcium and sodium were of near equal dominance. At B1-W1, levels of total filterable residue (155 to 189 $mg{\cdot}L^{-1}$) increased from June to September. At B1-W2 and B1-W1 the increased salinity in July and September also was indicated by the specific conductance values. Compared to other ions, sulphate concentrations exhibited the largest fluctuations among sampling stations and among sampling periods, with notable decreases in July and September.

5.2.2.3 Nutrients

The total nitrogen concentrations at the two stations were very similar, ranging from 0.79 to 1.17 mg $N{\cdot}L^{-1}$, and were highest in July.

The nitrate + nitrite values (<0.003 to 0.014 mg $N \cdot L^{-1}$) showed higher levels in June, identical to that of total nitrogen. Ammonia levels were low ranging from <0.01 to 0.14 mg $N \cdot L^{-1}$.

At the two stations, total phosphorus concentrations were similar ranging from 0.040 to 0.130 mg $P \cdot L^{-1}$ and showed no trends. Orthophosphorous concentrations at B1-W1 (0.013 to 0.034 mg $P \cdot L^{-1}$) were highest in July.

Reactive silica concentrations ranged from 1.29 to 4.64 $mg \cdot L^{-1}$ and at both stations the highest levels occurred in September. Total organic carbon levels (ranging from 26.3 to 33.5 $mg \cdot L^{-1}$) were similar at both stations.

5.2.2.4 Trace Metals and Other Substances

At B1-W1, the concentrations of trace metals and elements were generally below their detection limits, except for iron and manganese levels which exceeded the ASWQO. Total iron values (0.41 to 0.57 $mg \cdot L^{-1}$) and total manganese (0.060 to 0.100 $mg \cdot L^{-1}$) exceeded the objectives of 0.30 and 0.05 $mg \cdot L^{-1}$, respectively. With respect to other parameters, phenol concentrations (ranging from 0.004 to 0.012 $mg \cdot L^{-1}$) exceeded the ASWQO of 0.005 $mg \cdot L^{-1}$. Oil and grease (<0.4 to 6.6 $mg \cdot L^{-1}$) were present in low levels.

5.2.3 ZOOBENTHOS

Creek B1 was quantitatively sampled only in summer and fall. At B1-B, the creek was shallow and approximately 2 m wide, with moderate flow over coarse cobbles and small boulders (Figure 2.8). Inspection in spring indicated that Simuliidae and **Baetis** (mayflies) were abundant. These taxa also were abundant in summer, together with Chironomidae (Figure 5.5). Density, biomass and taxonomic richness increased in fall (Table 5.3). Decreased diversity in fall was attributed to increased relative abundance of Chironomidae.

Detailed tables of taxonomic composition, abundance and biomass are presented in Appendix D, Tables D15 and D33.

5.2.4 FISH

Fisheries sampling was conducted at two stations on Creek B1 in 1984 (Figure 2.3). The lowermost station (EF1) was situated immediately downstream of the temporary road crossing at km 0.4. The uppermost station (EF2) was located approximately 1.9 km upstream from the reservoir. Station EF1 was sampled during the spring and fall periods; station EF2 was sampled during the summer and fall periods.

Four species of fish were recorded in Creek B1 during 1984 (Table 5.4; Appendix E, Table E5). Lake chub were numerically dominant in catches from both sample stations, with a combined contribution of 49.5%

to the total catch (Table 5.4). White sucker, fathead minnow and brook stickleback (in decreasing order of abundance) made up the remainder of the catch.

Table 5.4. Percentage composition of fish species recorded at backpack electrofishing stations on Creek B1, 1984.

Station	Fish Captured and Observed	Fish Species			
		White sucker	Fathead minnow	Lake chub	Brook stickleback
B1-EF1	299	30.4	8.7	55.9	5.0
B1-EF2	451	16.8	18.6	45.1	19.5
Combined	750	22.3	14.6	49.5	13.6

In the fall survey (when both stations were sampled), highest capture rates (for all species) occurred at station EF2 (Appendix E, Table E5). The greater use of this area may be a response to the abundance of suitable feeding and rearing habitat for forage species and white sucker y-o-y. Station EF2 was situated in a moderate gradient reach which was characterized by a high habitat diversity and an abundance of instream and streambank cover (Sec. 5.2.1). In contrast, station EF1 was located in a high gradient reach and instream cover was restricted (Sec. 5.2.1).

The high capture rate (CUE = 256.7 fish$\cdot$min^{-1}) recorded for white suckers in EF1 on 31 May 1984 was a result of the presence of a large concentration of spawners (Appendix E, Table E5). These individuals were from a resident population in Beaver Creek Reservoir (and possibly Ruth

Lake and Poplar Creek Reservoir). Both ripe and spent adults were captured indicating spawning was in progress at the time of sampling. Water temperature on the sampling date was 12.5^{o}C (at 2030 hours). A visual survey of the system on 31 May estimated the presence of 300 to 500 spawners. Most of these were concentrated in a 140 m channel section located immediately downstream from the temporary road crossing (Plate 7). This area contained an abundance of suitable spawning substrate (Section 5.2.1). Lesser numbers of spawners were observed in the 300 m of stream channel situated immediately upstream from the road crossing. Suitable spawning habitat in this area was limited, and exhibited a more localized distribution. The abundance of white suckers (mainly y-o-y) in catches from both sample stations in the fall provided evidence of successful recruitment in 1984. These fish likely overwinter in Beaver Creek Reservoir.

The channelized section of Creek B1 also was utilized for spawning by lake chub. A capture rate of 110.0 fish·min^{-1} was recorded for lake chub in EF1 on 31 May (Appendix E, Table E5). All individuals captured were adults in spawning condition. The presence of lake chub eggs in substrate kick samples confirmed the occurrence of spawning in the area. Both lake chub and white sucker eggs were collected in the same kick sample indicating that these species utilized the same spawning areas and habitat types. Lake chub y-o-y were abundant in Creek B1 in the fall, confirming successful spawning.

Direct evidence of spawning use (i.e., the presence of eggs or spawning individuals) by brook stickleback and fathead minnow in Creek B1 was not obtained in the present study. The occurrence of y-o-y of these species in September catches, however, indicates some recruitment occurred in the system. These fish may have spawned within the channelized section or drifted downstream from spawning areas in Creek B1 situated upstream from the channelized sections. The shallow water depths in the channelized section of Creek B1 likely presents marginal conditions for overwintering (Sec. 5.2.1). Suitable overwintering areas were available both upstream (i.e., the impoundment) and downstream (i.e., Beaver Creek Reservoir) of the channelized reach.

5.3 BEAVER CREEK RESERVOIR

5.3.1 AQUATIC HABITAT

5.3.1.1 Description of Drainage Area

Beaver Creek Reservoir, located immediately south of the mine site, was formed by the impoundment of Upper Beaver Creek (Figure 2.3). Reservoir filling commenced in the fall of 1975 and the reservoir reached the level of the outlet channel by the spring of 1976 (Syncrude Canada Ltd. 1984).

Four major sources provide inflow to the reservoir, these being Upper Beaver Creek (Plate 8), Creek B2 (previously Creek No. 5), Creek

B1 (previously Creek No. 4), and the South Mine Sump (located behind the northern face of the dam). An outlet diversion channel drains from the northeastern sector of the reservoir into Ruth Lake.

5.3.1.2 Physical Characteristics

The physical characteristics of Beaver Creek Reservoir have been described by Noton and Chymko (1978), and Carmack and Killworth (1979). The reservoir is a moderately shallow waterbody featuring gently sloping and low-lying shorelines; the shoreline is irregular (Figure 5.7). Specific morphometric data are as follows:

Morphometry of Beaver Creek Reservoir

Surface Elevation	309.7 m
Length	3.4 km
Area	220 ha
Volume	4.9 X 10^6 m^3
Mean Depth	2.2 m
Maximum Depth	approx. 10 m
Flushing time	approx. 2 months

source: adapted from Carmack and Killworth (1979); Noton and Chymko 1978).

The substrate composition in the reservoir is extremely diverse because the flooded area included stream beds and bank (i.e., Beaver Creek), sand and gravel knolls, muskeg, and forest floor. In shoreline areas, the substrate is predominantly muskeg, sand, or gravel based. Sand and gravel materials are restricted to the area near the dam face. Sand

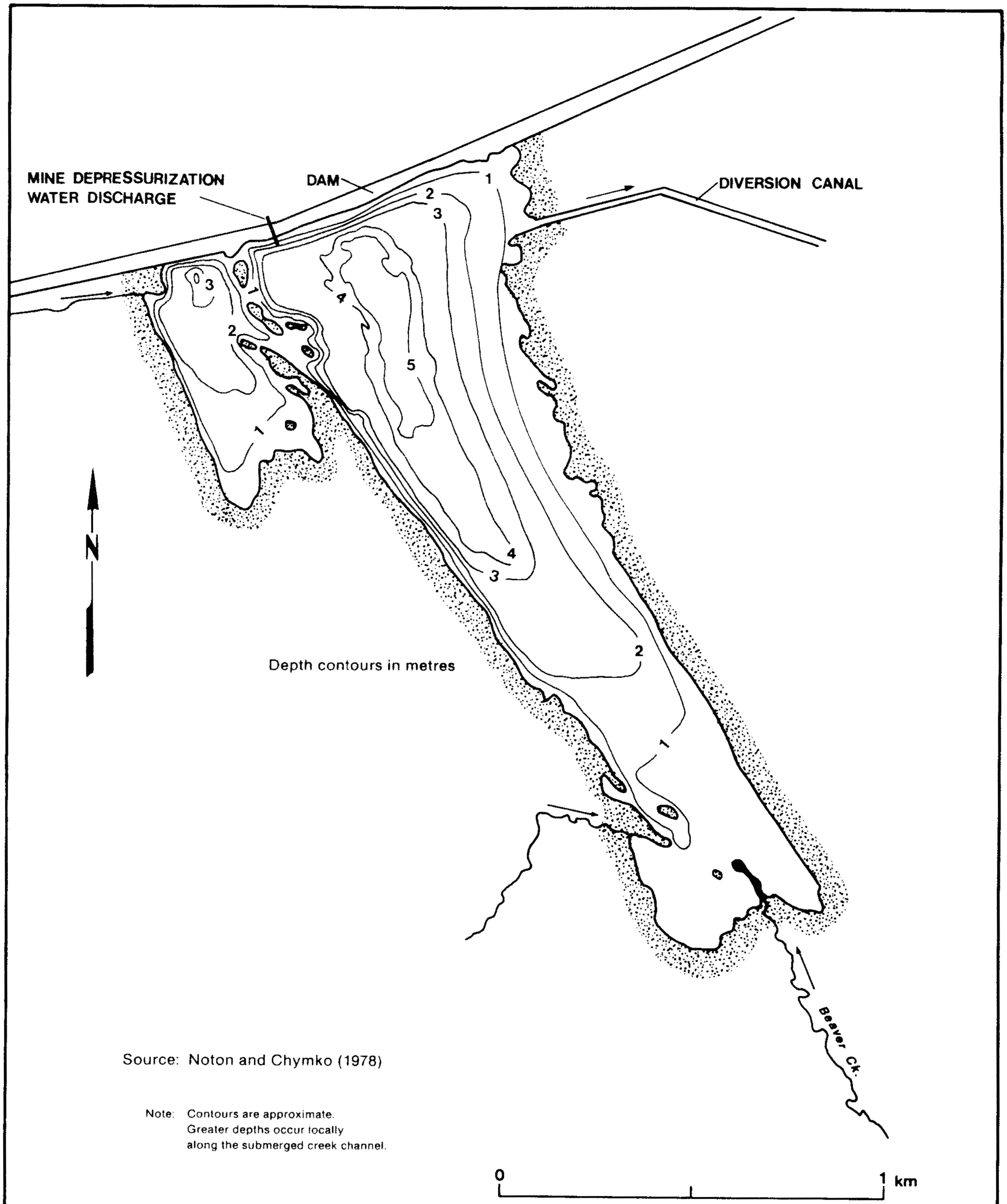

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Figure 5.7

BEAVER CREEK RESERVOIR BATHYMETRY

substrates are found along the western shoreline which exhibit slightly higher banks. Mud and organic substrates occur along the southern end of the reservoir. Substrate in the majority of the main basin consists of organic debris.

5.3.1.3 Macrophytes

The distribution of macrophyte species in Beaver Creek Reservoir during July 1984 is shown on Figure 5.8. The relative abundance of the various forms is given in Table 5.5. Submersed vegetation was widely distributed in the reservoir to a depth of 2.0 to 2.2 m. The smallest beds occurred along the dam face and in the southwest sector between sites 9 and 10. Floating-leafed species were not abundant. The most common species association was **Myriophyllum-Potamogeton zosteriformis** which covered fairly large areas. A number of changes have occurred since the 1977 survey. **Potamogeton pusillus (berchtoldii)** is no longer as abundant as in 1977, but is widely distributed; **P. zosteriformis** has become very common. **Typha** is now the dominant shoreline species. **Utricularia** was not observed in 1984. While the abundance of some species has decreased or the species has disappeared since 1977, others have increased in abundance and a few new species were found. Detailed descriptions of the macrophyte assemblages at specific sites are provided in Appendix F, Table F1.

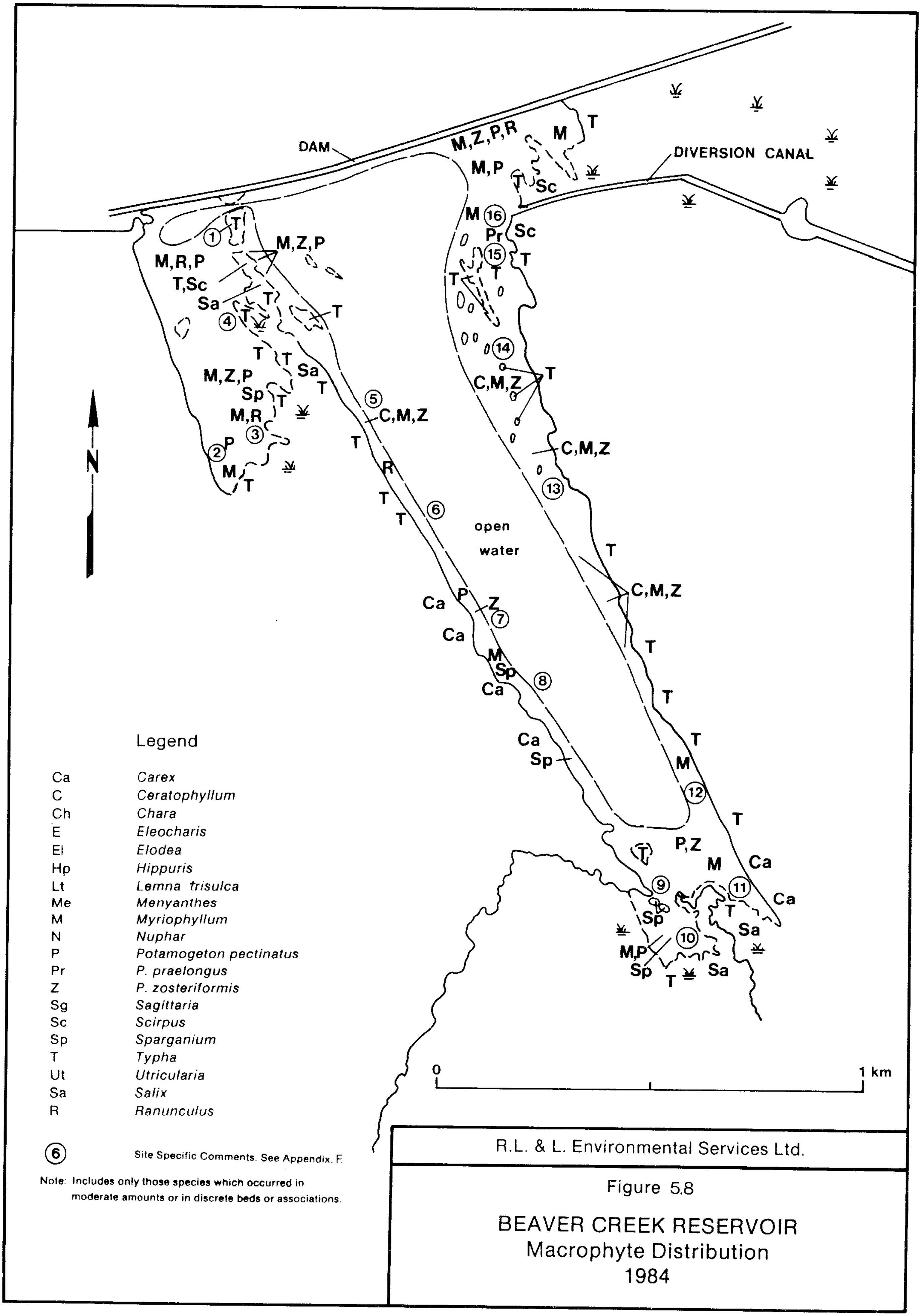


Figure 5.8

BEAVER CREEK RESERVOIR
Macrophyte Distribution
1984

Table 5.5 Distribution pattern and relative abundance of macrophytes found in Beaver Creek Reservoir, July 1984.

Species	Distribution Pattern
	Submersed
Callitriche spp.	Rare
Ceratophyllum demersum	Abundant
Drepanocladus spp.	Present
Lemna minor	Present[a]
Lemna trisulca	Present
Myriophyllum exalbescens	Abundant
Nuphar variegatum	Present
Potamogeton pectinatus	Abundant
Potamogeton pusillus	Common
Potamogeton richardsonii	Common
Potamogeton zosteriformis	Abundant
	Floating-Leafed
Polygonum amphibium	Present
Potamogeton natans	Rare
Sparganium spp.	Present
	Emergents
Carex spp.	Common
Equisetum spp.	Present
Hippuris vulgaris	Present[b]
Ranunculus spp.	Present
Sagittaria spp.	Present[b]
Scirpus spp.	Abundant
Typha latifolia	Abundant

[a]Small amounts of **Typha** beds

[b]Found in NW corner of reservoir

5.3.2 WATER QUALITY

5.3.2.1 Physical Parameters

The minimum and maximum temperatures in Beaver Creek Reservoir at station BCR-W were 7.5 and 22.0^{o}C, respectively, with the highest value recorded in July (Table 5.6 and Figure 5.9). Thermal stratification was not well developed. A marked temperature difference of 2.0^{o}C was observed between depths of 2 and 3 m in June. The stratification was weaker in July and in September the reservoir was isothermal. The temperature condition is similar to that observed in 1977 (Noton and Chymko 1978). A similar description of the temperature stratification was reported in Carmack and Killworth (1979).

The pH ranged from 7.2 to 7.7 and showed an inverse relationship with increased depth in July and September. In 1977, a similar relationship was reported by Noton and Chymko (1978). Furthermore, they recorded pH values of 8.3 to 8.5 on 28 July 1977 which were associated with a blue-green algal bloom.

Dissolved oxygen levels in the reservoir ranged from 2.2 to 9.8 mg·L^{-1}, with the lowest values reported at the bottom in June and the highest near the surface in July. In June and July, the oxygen saturation showed stratification similar to that recorded for temperature (Figure 5.9). In June, oxygen saturation levels of 82 to 90% were reported in the epilimnion (0 to 2 m) while during the same period in the hypolimnion (2 to

Table 5.6 Summary of temperature, dissolved oxygen, specific conductance and pH levels in Beaver Creek Reservoir (Station BCR-W) during June, July and September, 1984.

Parameter	Temperature (°C)			Dissolved Oxygen						Specific Conductance ($\mu S \cdot cm^{-1}$)			pH		
Depth (m)	June	July	Sept.	June		July		Sept.		June	July	Sept.	June	July	Sept.
				$mg \cdot L^{-1}$	% Sat.	$mg \cdot L^{-1}$	% Sat.	$mg \cdot L^{-1}$	% Sat.						
0	21.0	22.0	7.5	8.2	90	9.6	107	9.0	74	325	320	380	7.3	7.7	7.7
1	19.5	22.0	7.5	8.0	76	9.8	110	9.4	77	320	345	380	7.4	7.7	7.5
2	19.0	21.0	8.0	7.6	82	9.8	107	9.0	75	330	350	380	7.5	7.7	7.4
3	17.0	20.5	8.0	4.3	44	8.5	94	8.9	74	330	350	380	7.3	7.6	7.4
4	15.0	20.0	8.0	3.8	37	8.3	90	8.8	73	330	350	380	7.6	7.5	7.3
5	13.0	20.0	8.0	3.0	27	7.2	77	8.8	73	360	350	380	7.2	7.5	7.3
6	11.5		8.0	2.2	20			8.8	73	340	350	380	7.5	7.5	7.3

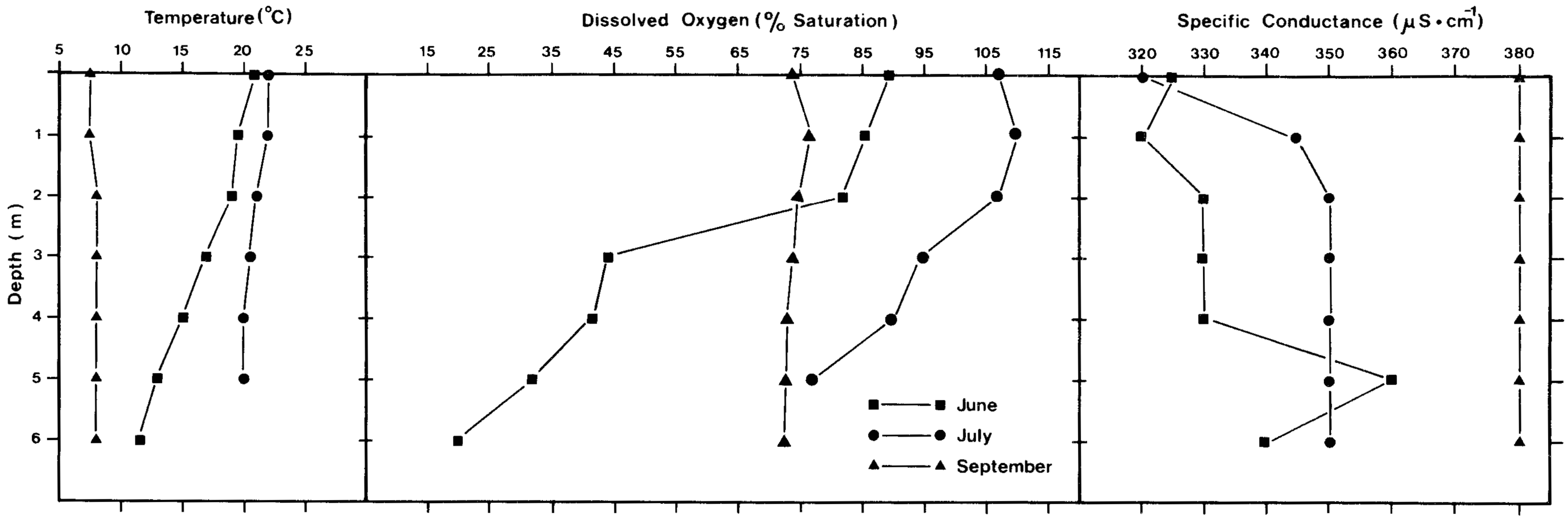


Figure 5.9 Depth profiles of temperature, dissoved oxygen, and specific conductance in Beaver Creek Reservoir during June, July, and September, 1984.

6 m) the values decreased to 20%. During this period the dissolved oxygen levels were below the ASWQO of 5.0 mg·L^{-1}. In July the stratification weakened; oxygen saturation ranged from 77 to 110%. The supersaturated levels near the surface were indicative of a high rate of primary productivity. Supersaturated conditions in July also were described by Noton and Chymko (1978). In September the reservoir was isothermal with an oxygen saturation level of approximately 75% throughout the water column. The chemical oxygen demand levels in the reservoir were similar during each sampling period.

The total non-filterable residue levels were similar during the sampling periods with values of 3.2 to 6.4 mg·L^{-1}. These values are similar to those associated with the creeks described in Sections 5.1.2.1 and 5.2.2.1. The Secchi disc visibilities in June and September were 1.0 and 0.90 m, respectively.

5.3.2.2 Major Ions

The Beaver Creek Reservoir water was of the sodium bicarbonate type with a dominance of $HCO_3^- > Na^+ > Ca^{++} > Mg^{++} > SO_4^= > CI^+ > K^+$ based on the composite samples (Table 5.2, Figure 5.4). The ionic character of the water differs from that of the creeks because of higher concentrations of sodium and, particularly, chloride in the reservoir. The data indicate slightly higher concentrations of sodium and chloride were present in the bottom (5 m) samples as compared to the composite samples. The specific conductance profiles shown in Figure 5.9 further indicated the presence of increased salinity near the bottom of the reservoir. In June the specific conductance showed a minor increase to 360 $\mu S \cdot cm^{-1}$ at 5 m which suggests that perhaps the saline mine water had contributed to the difference. In July, the specific conductance gradient showed a similar pattern to that of oxygen saturation. In September, a period of mixing, the ionic composition of the water was homogeneous. In general, salinity increased from June to September, similar to the condition exhibited by the creeks. The ionic character of the reservoir in July was similar to that reported for the same period in 1977 (Noton and Chymko 1978). These researchers, however, did not encounter any notable ionic differences between the surface and bottom waters in June.

5.3.2.3 Nutrients

The total nitrogen concentrations measured in the reservoir throughout the study were similar, ranging from 0.81 to 1.18 mg $N \cdot L^{-1}$. Trends between the composite samples and the 5 m samples, and between sampling periods, were not distinct. Total nitrogen values from the composite samples slightly exceeded the ASWQO of 1.0 mg $N \cdot L^{-1}$. In June, July, and September 1977, total nitrogen concentrations (approximately 0.40 mg $N \cdot L^{-1}$; Noton and Chymko 1978) were considerably lower than in the present study. The nitrate + nitrite concentrations ranged from 0.007 to 0.040 mg $N \cdot L^{-1}$ with the highest values occurring at 5 m depth. In addition, the values increased from June to September, probably the result of lower demand by the primary producers. In 1977 the surface values in June, July, and September were 0.248, less than 0.030, and 0.023 mg $N \cdot L^{-1}$, respectively, while at the bottom the levels were 0.340 mg $N \cdot L^{-1}$ in June, and 0.035 mg $N \cdot L^{-1}$ in July (Noton and Chymko 1978).

The total phosphorus concentrations ranged from 0.051 to 0.115 mg $P \cdot L^{-1}$, with July samples exhibiting the highest values. Only a slight difference in concentrations existed between the composite samples and those from the 5 m depth, with no distinct trend noted. Total phosphorus concentrations consistently exceeded the ASWQO of 0.05 mg $P \cdot L^{-1}$. The values farther exceeded the Environment Canada guideline of 0.025 mg $P \cdot L^{-1}$ which was established more specifically for lakes and reservoirs (McNeely et al. 1979). Ortho-phosphorus concentrations (range: 0.017 to 0.032 mg $P \cdot L^{-1}$) paralleled the total phosphorus values with the highest value recorded in July. In June 1977, Noton and Chymko (1978) found total phosphorus values of 0.016 and 0.202 mg $P \cdot L^{-1}$ at the surface and bottom, respectively. In July 1977, the top and bottom values were 0.100 and 0.030 mg $P \cdot L^{-1}$, respectively. In 1977, at the surface, ortho-phosphorus concentrations of 0.077, 0.031, and less than 0.016 mg $P \cdot L^{-1}$ were recorded in June, July, and September, respectively, while at the bottom, concentrations of 0.149 and 0.026 mg $P \cdot L^{-1}$ were found in June and July, respectively.

Reactive silica concentrations ranged from 1.48 to 4.55 $mg \cdot L^{-1}$; they were highest in June and showed little difference between the composite sample and the 5 m sample. Noton and Chymko (1978) reported a similar relationship between the surface and bottom samples and slightly higher concentrations in July as compared to June and September 1977. Total organic carbon levels ranged from 23.5 to 29.2 $mg \cdot L^{-1}$ and showed very little difference between sampling periods or between the composite and the 5 m samples. The values were similar to those found in the inflowing creeks.

5.3.2.4 Trace Metals and Other Substances

The concentrations of trace metals and elements in Beaver Creek Reservoir were generally below the detection limits. Total iron (0.49 to 0.93 $mg \cdot L^{-1}$) and total manganese (0.090 to 0.120 $mg \cdot L^{-1}$) concentrations exceeded the ASWQO of 0.30 and 0.050 $mg \cdot L^{-1}$, respectively. The highest values for both parameters were recorded in June and July. Iron values exceeding ASWQO of 0.30 $mg \cdot L^{-1}$ also were reported at the surface and bottom by Noton and Chymko (1978). Phenol concentrations (0.006 to 0.008 $mg \cdot L^{-1}$) slightly exceeded the ASWQO of 0.005 $mg \cdot L^{-1}$. Oil and grease levels were low ranging from 0.4 to 1.9 $mg \cdot L^{-1}$. In comparison, July 1977 phenol concentrations were lower (0.001 $mg \cdot L^{-1}$) at the surface and bottom, and oil and grease levels were considerably higher with the maximum values of 12.0 $mg \cdot L^{-1}$ at the surface (Noton and Chymko 1978).

5.3.3 PHYTOPLANKTON

Phytoplankton cell count and cell volume data for Beaver Creek Reservoir are presented in Appendix G, Table G1. During the three seasons sampled in 1984, numerical abundance of phytoplankton was highest during the summer (Figure 5.10); however, the standing crop expressed as bio-volume (i.e., on a cell volume basis) was lowest during the summer, reflecting the large number but small size of the phytoplankton present at that time. Bio-volume of phytoplankton was similar during late spring and fall (Figure 5.10).

In mid June, Beaver Creek Reservoir phytoplankton was dominated by Cryptophyta which contributed approximately 46% to the total cell volume in the sample (Figure 5.10). The dominant species in this group was **Cryptomonas erosa**, which alone accounted for 33% of the total. The second most abundant taxonomic division in June was Euglenophyta, comprised primarily of **Phacus pyrum** and **Trachelomonas planctonica.** This division contributed about 27% of the total cell volume in the sample. On a numerical basis, the Chlorophyta (34% of total cell numbers) and Cryptophyta (22%) were the predominant divisions.

In the summer sample, the phytoplankton was dominated by Cyanophyta (primarily **Aphanizomenon flos-aquae** and **Anabaena** sp.) followed closely by Bacillariophyta (primarily **Melosira granulata**). These divisions contributed approximately 40% and 37% to the total bio-volume of the sample, respectively. Although Cryptophyta was the dominant division in the spring sample, this group, along with the Crysophyta and Pyrrophyta, was not present in the routine counts of the summer samples. On a numerical basis (i.e., cell$\cdot$mL^{-1}), Cyanophyta contributed about 67% of the total cell numbers. Chlorophyta, composed primarily of **Oocystis** sp.,

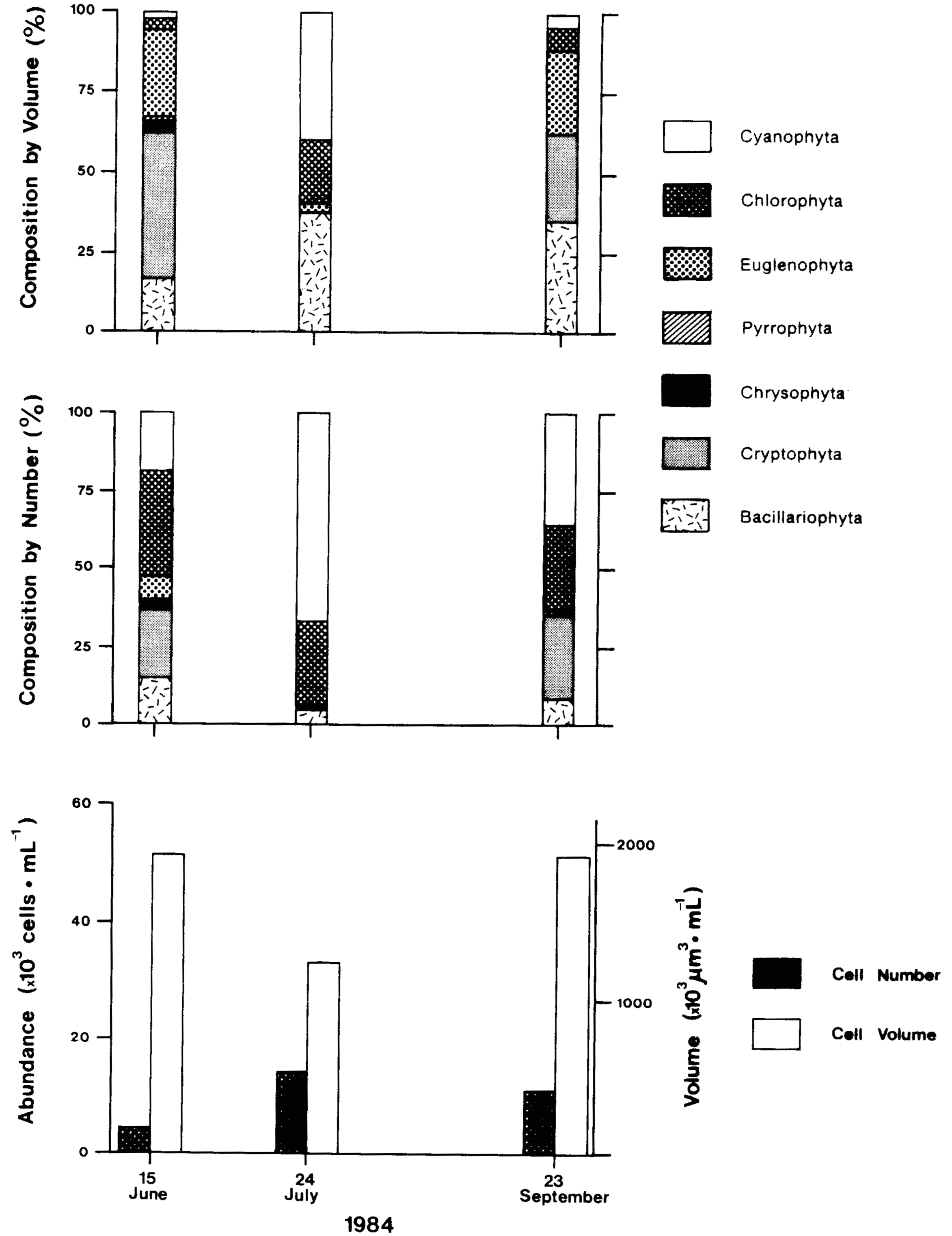


Figure 5.10 Abundance and percent composition of phytoplankton in Beaver Creek Reservoir, 1984.

Sphaerocystis schroeteri, and **Scenedesmus bijuga**, was second in abundance, contributing about 28% of the total cell numbers.

In the fall, the phytoplankton was dominated by Bacillariophyta (35% of the bio-volume) followed closely by Cryptophyta (27%) and Euglenophyta (26%). The Bacillariophyta was comprised of primarily **Synedra ulna**, **Melosira granulata**, and an unidentified centric. On a numerical basis, cyanophytes were most abundant (36% of total numbers) followed closely by chlorophytes (27%) and cryptophytes (27%).

Seasonal variation for the major phytoplankton species in Beaver Creek Reservoir is presented in Figure 5.11. **Cryptomonas erosa** was the dominant species by volume during the June sample period, but was absent from the counts in the summer sample. This species increased in abundance again in the fall. **Trachelomonas planctonica** was second in abundance in the late spring sample. This species also declined in abundance in summer, then increased to become the dominant species in the fall. **Melosira granulata**, a large diatom, contributed a major portion of the total bio-volume in each of the three samples, and was the dominant species in the July sample. **Synedra ulna**, another diatom, was absent from the spring and summer samples, but was the second most abundant species in the fall.

Previous phytoplankton data collected in 1977 (Noton and Chymko 1978) indicated that Cyanophyta was numerically dominant in late June and July but contributed only minor amounts to the totals in early June,

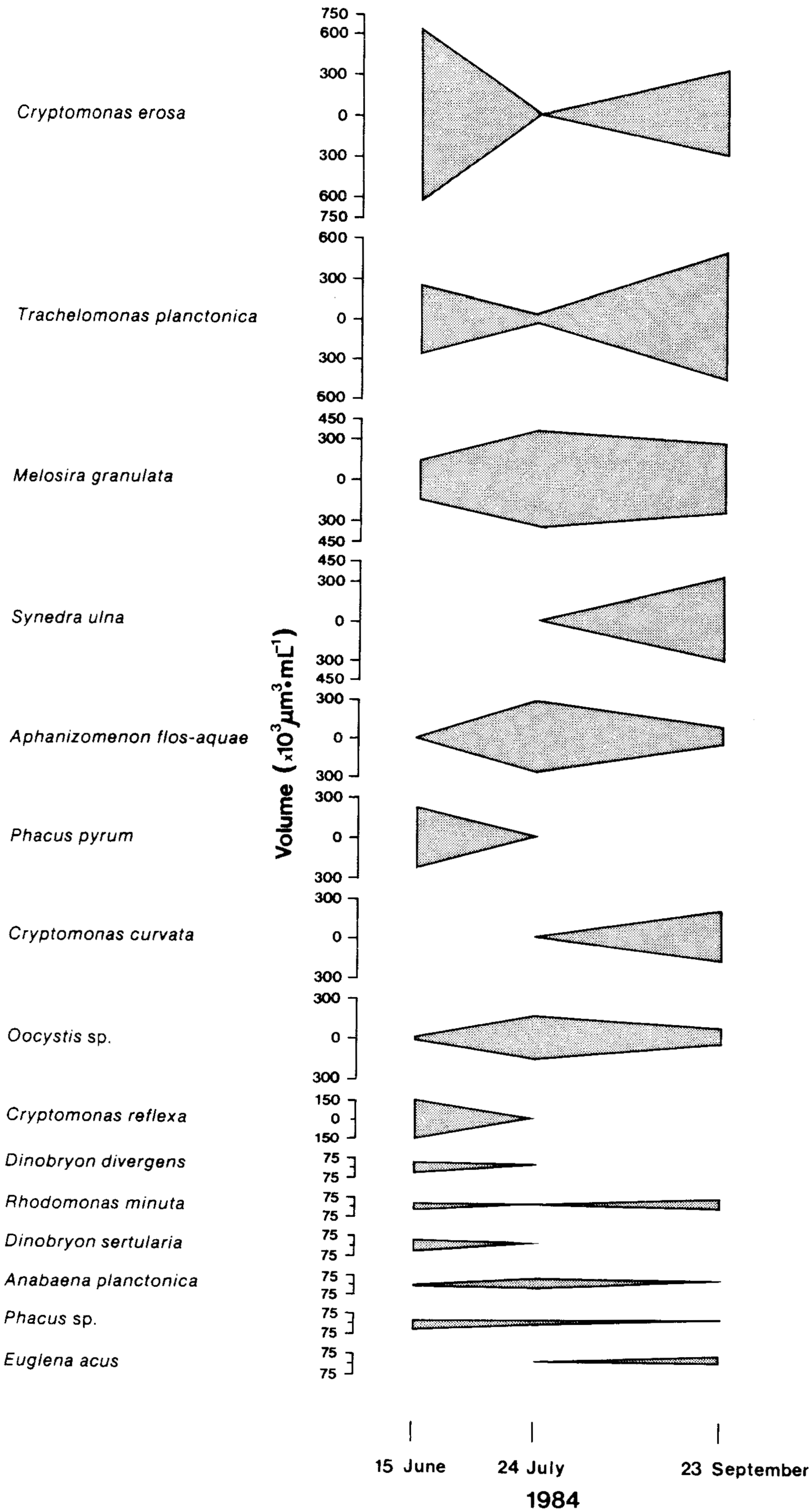


Figure 5.11 Seasonal variation (by volume) of dominant phytoplankton in Beaver Creek Reservoir, 1984.

and was absent from the samples by late September. It appears that the Cyanophyta followed a similar pattern in the spring and summer of 1984 (i.e., moderate numbers in mid-June, then becoming numerically dominant by late July); however, Cyanophyta continued to remain numerically dominant in late September.

Based on a comparison with the data collected by Noton and Chymko (1978), phytoplankton densities and taxonomic composition were not substantially different between the two studies although a more dense bloom of Cyanophyta was present in late July in 1977. The similarities in species composition and abundance between the present study and the 1977 study supports the conclusion of previous investigators (Jantzie et al. 1980) that mine depressurization water was not toxic to the algae in the reservoir.

5.3.4 ZOOPLANKTON

The species composition, numerical abundance, and calculated biomass (excepting nauplii) of crustacean plankton collected at the regular sampling station BCR-Z in Beaver Creek Reservoir are summarized in Table 5.7. Aliquot counts and calculated totals for each sample are included in Appendix C, Table C1. The species composition and numerical abundance of rotifers in the zooplankton samples are summarized in Table 5.8. The total numbers of species identified on all

Table 5.7 Species composition, numerical abundance, and calculated biomass of crustacean plankton from Beaver Creek Reservoir (Station BCR-Z), 1984. Unbracketed values are number·m^{-3}. Bracketed values are biomass expressed as mg wet weight·m^{-3}.

Species[a]	**15 June**	**24 July**	**23 Sept.**
COPEPODA			
CALANOIDA			
Diaptomus oregonensis LILLJEBORG 1889 A+C	1 007 (34.6)	4 927 (276.2)	6 887 (609.0)
diaptomid nauplii	9 859	13 311	509
CYCLOPOIDA			
Acanthocyclops vernalis FISCHER 1853 A+ adv.C	486 (15.9)	436 (10.9)	679 (14.5)
Diacyclops thomasi (FORBES) 1882 A+ adv.C	0	436 (11.7)	764 (22.8)
Mesocyclops edax (FORBES) 1891	69 (1.7)	218 (5.1)	297 (7.4)
cyclopoid copepodids, immature C	2 604 (15.3)	7 637 (50.1)	8 656 (76.6)
cyclopoid nauplii	9 165	8 292	22 912
CLADOCERA			
Bosmina longirostris (O.F. MÜLLER) 1785	1 864 (23.7)	17 675 (175.2)	4 497 (47.7)
Ceriodaphnia lacustris BIRGE 1893	0	109 (2.1)	0
Macrothrix hirsuticornis NORMAN & BRADY 1867	35 (0.6)	0	0
Daphnia parvula FORDYCE 1901	312 (4.7)	5 019 (37.5)	212 (4.5)
Diaphanosoma leuchtenbergianum FISCHER 1850	24 (1.2)	13 147 (391.6)	156 (6.8)
Alona guttata SARS 1862	11 (0.0)	55 (0.2)	13 (0.0)
Chydorus sphaericus (O.F. MÜLLER) 1785	24 (0.1)	126 (0.6)	170 (0.9)
Total[b]	**6 436** **(97.8)**	**49 785** **(961.2)**	**22 331** **(790.2)**

[a] A=adult; C=copepodid, usually I to III; adv.C=advanced copepodids, usually IV & V.
[b] excluding nauplii and non-crustaceans.

Table 5.8 Species composition and numerical abundance of rotifers in the zooplankton of Beaver Creek Reservoir (Station BCR-Z), 1984.

Species	**15 June ($No.\cdot m^{-3}$)**	**24 July ($No.\cdot m^{-3}$)**	**23 Sept. ($No.\cdot m^{-3}$)**
Keratella cochlearis (GOSSE 1851)	10 692	2 291	171 880
Keratella earlinae AHLSTROM 1943	74 498	41 241	23 760
Keratella quadrata (O.F. MÜLLER 1786)	21 384	0	806
Keratella hiemalis CARLIN 1943	972	0	0
Notholca acuminata (EHRENBERG 1832)	278	0	0
Euchlanis dilatata EHRENBERG 1832	0	3 055	0
Brachionus calycifloris PALLAS 1766	13 226	0	0
Brachionus quadridentatus (HERMANNS 1783)	17	218	170
Asplanchna priodonta GOSSE 1850	69	0	339
Synchaeta pectinata (?) EHRENBERG 1832	0	0	28 512
Synchaeta oblonga (?) EHRENBERG 1831	0	0	11 074
Synchaeta sp.	694	0	0
Gastropus (?) sp.	625	0	0
Filinia longiseta (EHRENBERG 1834)	1 597	436	1 570
Polyarthra dolichoptera IDELSON 1925	76 789	0	0
Polyarthra vulgaris CARLIN 1943	0	436	0
Rotaria neptunia EHRENBERG 1832	17	0	0
unidentified rotifers	0	0	3 946
Total	**200 858**	**47 677**	**242 057**

three sampling dates are:

Rotifera	-	17
Cladocera	-	7
Cyclopoida	-	3
Calanoida	-	1
Chaoboridae	-	0

There were fewer commonly occurring crustacean species and more rotiferan species in Beaver Creek Reservoir in 1984 than in 1977 (Noton and Chymko 1978).

5.3.4.1 Rotifera

The species composition of rotifers in Beaver Creek Reservoir was dominated by **Keratella** spp. on all three sampling dates, but was followed closely by **Polyarthra dolichoptera** in June and by **Synchaeta** spp. in September. **Keratella** was dominated by **K. earlinae** in the June and July samples. This species, considered to be a variant of **K. cochlearis** by Koste (1978) but not so by others (e.g., Baker 1979), is difficult to distinguish from the latter unless loricas are carefully cleaned and examined individually. Here an allotment to each species was made primarily on overall size and caudal spine length. In general, **K. earlinae** became less abundant and **K. cochlearis** more abundant towards fall. A small number of **K. hiemalis** occurred in the June sample. This species resembles a small **K. quadrata** and could have been overlooked in the presence of large numbers of **K. quadrata** in previous years.

Although much smaller in September, the rotiferan numbers in 1984 cannot be considered vastly different from those in 1977 (Figure 5.12).

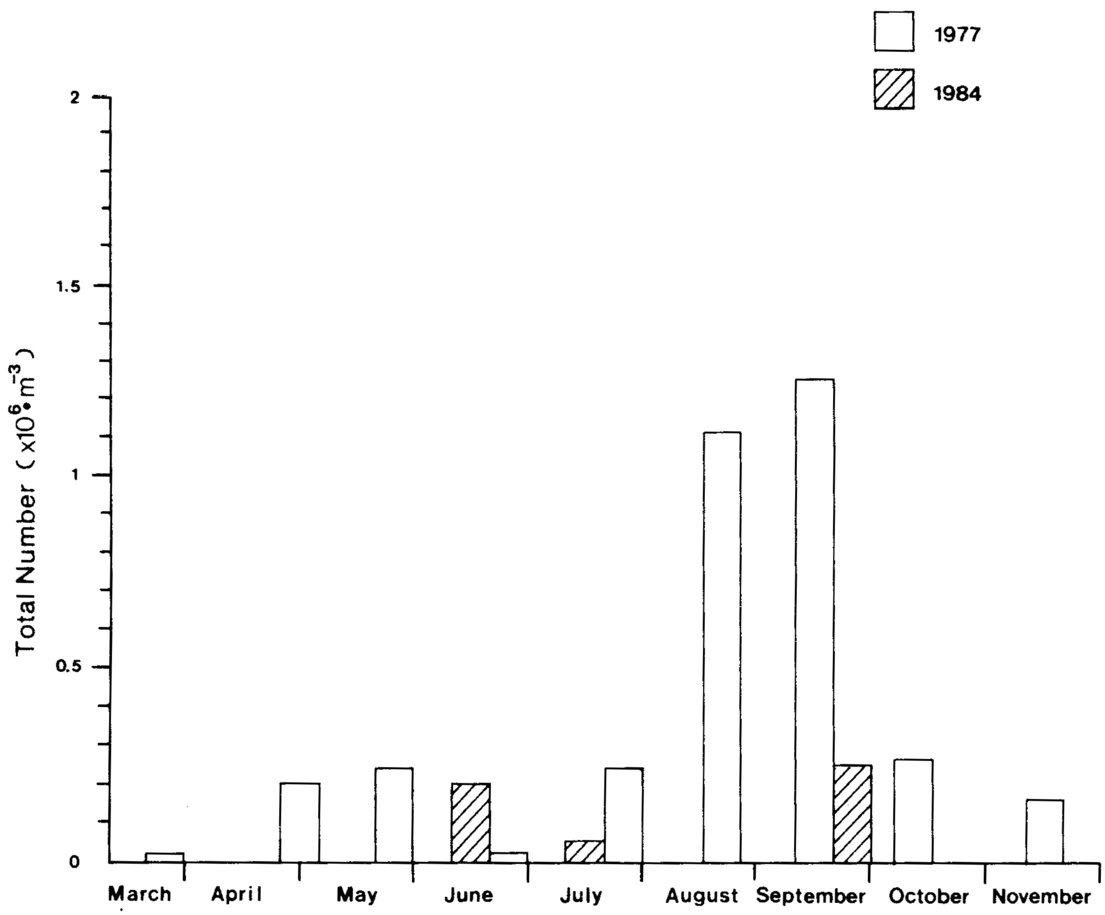


Figure 5.12 Abundance of Rotifera in Beaver Creek Reservoir in 1984 (present study) and in 1977 (Station BCR-1; Noton and Chymko 1978).

Rotifer numbers are known to vary dramatically from month to month (Pennak 1949), a variation that may be due in part to sampling problems. Rotifer species composition also may vary radically from year to year. In Beaver Creek Reservoir, however, the differences in species composition and total numbers between 1977 and 1984 cannot be considered biologically significant and do not warrant further discussion.

5.3.4.2 Cyclopoida

During the spring sample period, the cyclopoids were dominated by **Acanthocyclops vernalis**; a shift to a dominance by **Diacyclops thomasi** was noted during summer and fall. The increased abundance of **D. thomasi** in summer and fall and in general, compared to 1977, is a sequence noted in other Alberta lakes and may be indicative of an eventual dominance by **D. thomasi** (Anderson 1970a, 1972). **D. thomasi**, although usually smaller than either **Acanthocyclops vernalis** or **Mesocyclops edax**, is the more voracious predator and is capable of altering the species composition of the zooplankton quite markedly (Anderson 1970b).

Diacyclops navus, more commonly considered a temporary pond or small lake species, was not found in the 1984 samples. This species was found in Beaver Creek Reservoir occasionally in 1977 (Noton and Chymko 1978). Similarly, **Macrocyclops albidus**, which occurred only rarely in 1977, was not found in 1984 samples. The absence of the latter may be part of the general trend towards smaller species noted for all three waterbodies in the present zooplankton study.

5.3.4.3 Calanoida

Only one species of calanoid copepod, **Diaptomus oregonensis**, was collected from Beaver Creek Reservoir in 1984. Abundance was greatest during the fall sampling period and lowest during the spring period.

There has been a dramatic change in the calanoids present in Beaver Creek Reservoir since 1977 (Figure 5.13). In 1977, **Diaptomus leptopus** was the only calanoid present in the waterbody (Noton and Chymko 1978), whereas in 1984 **Diaptomus oregonensis** was the only calanoid present. Counts were somewhat higher in 1984 and, in spite of its much smaller body size, **D. oregonensis** produced more than twice the standing crop biomass in 1984 as did **Diaptomus leptopus** in 1977. Many fish species are known to selectively eliminate larger zooplankters (Brooks and Dodson 1965; Hrbacek & Novotna-Dvorakova 1965; Anderson 1980), and the increased presence of fathead minnows in Beaver Creek Reservoir may be responsible for some shift from larger to smaller species.

5.3.4.4 Cladocera

The cladoceran component of the zooplankton in Beaver Creek Reservoir was numerically dominated by **Bosmina longirostris** during all three sampling periods (Table 5.7). **Diaphanosoma leuchtenbergianum** was very abundant in the July sample. **Daphnia parvula** was the codominant species in the spring and fall samples.

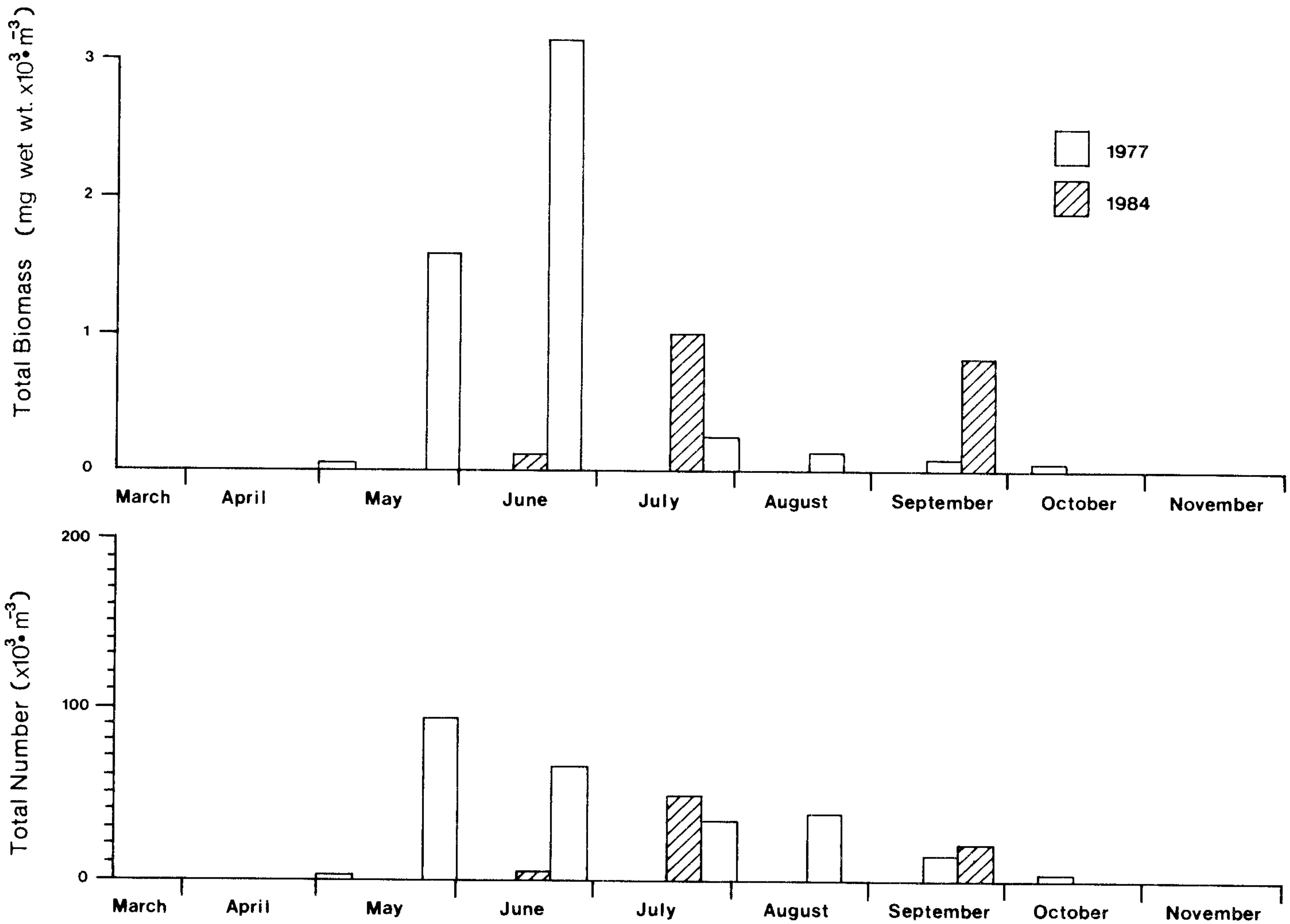


Figure 5.13 Total number and biomass of crustacean zooplankton in Beaver Creek Reservoir in 1984 (present study) and 1977 (Station BCR-1; Noton and Chymko 1978).

As noted for the calanoids above, there also has been a marked change since 1977 to smaller cladoceran species in Beaver Creek Reservoir. Although **Bosmina longirostris** numbers in 1984 were virtually the same as in 1977 (Noton and Chymko 1978), the slightly larger **Ceriodaphnia** spp. were present only in very low numbers in 1984. Larger species of **Daphnia** (**D. pulicaria**, **D. rosea**, **D. magna**) present in 1977 did not occur at all in 1984, being replaced by the much smaller **D. parvula.** Numbers of the latter in 1984 were much smaller than total **Daphnia** numbers in 1977. **Diaphanosoma leuchtenbergianum** numbers were much higher in July 1984 than in 1977. possibly the result of reduced competition from **Daphnia.**

5.3.4.5 Total Numbers and Biomass of Crustacean Plankton

Although the zooplankton in Beaver Creek Reservoir was sampled on fewer occasions in 1984 than in 1977, there has been an apparent shift from larger to smaller species (Table 5.7; Noton and Chymko 1978). These changes seem to have produced lower total numbers and a smaller biomass in late spring, and higher numbers and an increased biomass in summer and early fall (Figure 5.8). As noted above, an increase in the standing stock of very small zooplankters can be the result of increased predation by plankton-feeding fishes. This is the most likely explanation for the shift noted in this waterbody; however, Beaver Creek Reservoir was only one year old in 1977, and crustacean species composition in such reservoirs is known to take several years to stabilize. Consequently, factors other than plankton-feeding fish may have played important parts in producing changes in the zooplankton community.

5.3.5 ZOOBENTHOS

Beaver Creek Reservoir samples were dominated by Oligochaeta and Chironomidae (Figure 5.14). Variation in diversity (H') may be attributable more to differences in the proportions of these two taxa among stations, than to the presence or absence of other taxa. Diversity in spring at station BCR-B1 (1 m depth) was the second lowest of all measurements (Table 5.9) even though more taxa were collected in Ekman grab samples at this station than at any other. Oligochaeta contributed more than 80 % of the organisms collected on this occasion (Appendix D, Table D16). Maximal diversity occurred at stations when and where Chironomidae became codominant with Oligochaeta.

Taxonomic richness was greater at the 1 m depth than at either 3 m or 5 m depths (Table 5.9). This likely reflects the greater heterogeneity afforded by macrophytes at the shallowest depth.

Benthic density at all stations was maximal in fall samples (Table 5.9); this generally was the case for estimated biomass as well. Benthic density was consistently greater at the 1 m depth than the 3 m depth along both transects. Densities at the 5 m depth (station B3) were equivalent to 3 m samples (station B2 and B5), except during fall, at which time surprisingly high densities were recorded at the former station.

No consistent differences in density, biomass, diversity or taxonomic richness were apparent between transects 1 and 2. Detailed

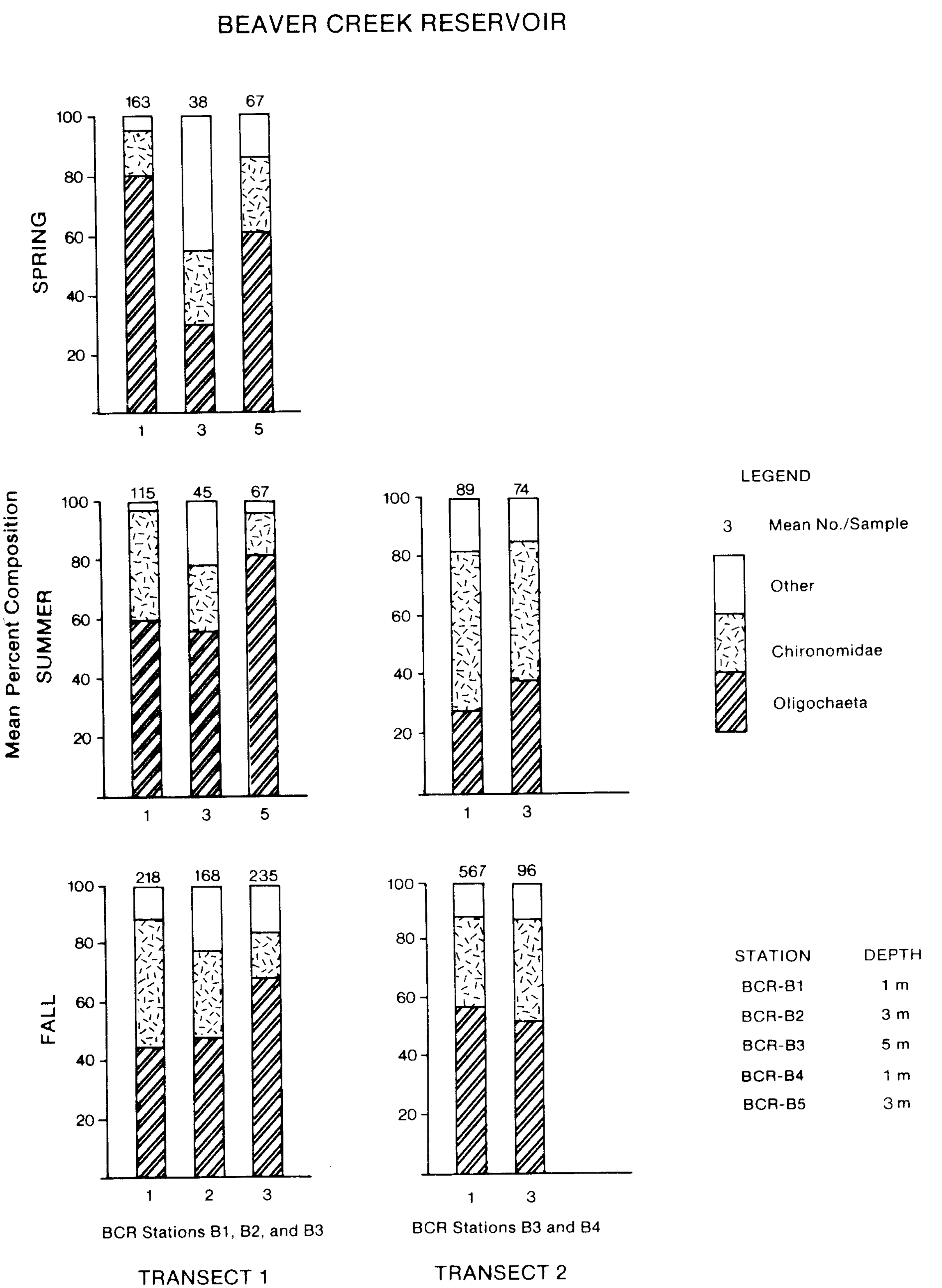


Figure 5.14 Relative abundance of major taxonomic groups of benthic invertebrates in Beaver Creek Reservoir, 1984.

Table 5.9 Mean density (no. per sample), mean biomass (mg per 0.1 m^2), diversity, and taxonomic richness of zoobenthos in Beaver Creek Reservoir, 1984.

Depth (m)		Transect 1[a]			Transect 2[b]	
		Spring	Summer	Fall	Summer	Fall
1	Density	163.2	115.3	217.9	89.0	566.7
	Biomass	64.9	31.7	198.5	26.5	257.3
	Diversity	1.051	1.311	1.773	1.789	1.869
	Richness	12	17[c]	19[c]	11[c]	13[c]
3	Density	37.9	45.1	168.1	74.3	96.1
	Biomass	71.8	34.6	266.5	147.5	93.0
	Diversity	2.062	1.768	1.983	1.564	1.619
	Richness	8	6	8	8	7
5	Density	66.6	67.3	235.3		
	Biomass	40.8	46.0	108.7		
	Diversity	1.512	0.913	1.577		
	Richness	7	4	8		

[a]Includes stations BCR-B1, BCR-B2 and BCR-B3

[b]Includes stations BCR-B4 and BCR-B5; stations added at the request of Syncrude Canada Ltd.

[c]Includes taxa collected in shoreline sweeps.

tables of taxonomic composition, size distribution, and biomass are presented in Appendix D, Table D16 to D20, and Table D34.

Beaver Creek Reservoir was studied in detail in 1977 by Noton and Chymko (1978). The present station BCR-B3 was similar in location to their station BC-1. Although sample variability was too great to permit comment on changes in abundance, some change in species composition apparently occurred during the interval between the two studies. In 1977, the large chironomid, **Chironomus**, contributed 50 to 70 % to samples during spring, summer, and fall. Oligochaeta made up a substantial proportion of the benthos only in fall. A third common organism was **Chaoborus**, a dipteran that is common in oxygen-poor and/or insectivorous fish-free waters. In the present study, Oligochaeta dominated at this station in all seasons, whereas Chironomidae (largely **Chironomus**) made up only 5 to 15 % of samples. **Chaoborus** was an insignificant constituent.

The transition from a **Chironomus/Chaoborus** dominated community to Oligochaeta/**Chironomus** may indicate improved hypolimnetic oxygen conditions and/or increased predation pressure resulting in reduced **Chaoborus** populations. An alternative hypothesis (a more likely but not necessarily exclusive hypothesis) is that the organic content of the substrate has increased and produced a shift in the **Chironomus**:Oligochaeta ratio. This has frequently been observed in lakes in transition from oligotrophy to eutrophy (Wetzel 1975).

5.3.6 FISH

5.3.6.1 Species Composition and Relative Abundance

Fisheries sampling on Beaver Creek Reservoir was conducted during June (boat electroshocking and seining) and July (gill netting and seining) (Table 2.1). Boat electroshocking was conducted on the reservoir (BCR-ES1) and within the diversion canal (BCR-ES2). Seining was conducted in June and July at stations established during previous studies. Seining results obtained during the June period were not included in CUE or percentage composition calculations; the high reservoir water levels at this time resulted in extensive shoreline flooding that markedly reduced the capture efficiency of this method.

Four species of fish were present in Beaver Creek Reservoir in 1984 (Table 5.10; Appendix E, Tables E5 to E7). In the combined catch by all methods, fathead minnow was the most abundant species, contributing 37.1%. White suckers and brook stickleback exhibited relatively equal representation. In seine captures (a more accurate indicator of forage species abundance), the order of relative abundance was fathead minnow (44.0%) brook stickleback (37.7%), and white sucker y-o-y (18.3%). Lake chub were absent from seine catches. White sucker adults and juveniles were the major contributors to the gill net and boat electroshocking catches (Table 5.10).

Table 5.10. Percentage composition of fish species recorded from Beaver Creek Reservoir, 1984.

Species (n)[a]	Capture Method			All Methods Combined (1160)
	Seine (977)	Gillnet (44)	Boat Electroshocker (139)	
White sucker	18.3	100.0	98.6[b]	31.0
Fathead minnow	44.0	0	0.7	37.1
Lake chub	0	0	0.7	< 0.1
Brook stickleback	37.7	0	0	31.7

[a]Number of fish captured (captured and observed for electroshocking)

[b]Includes 108 white suckers recorded from the diversion canal between Beaver Creek Reservoir and Ruth Lake.

A comparison of seine catches from station S3 in 1978, 1981, and 1984 suggests that shifts in species composition and abundance have taken place since reservoir formation in 1976. For example, white suckers (juveniles and y-o-y) apparently have undergone a substantial increase, both in their contribution to seine catches and their capture rates, since 1978 (Appendix E, Table E8). It is evident that successful recruitment to the white sucker population has occurred in recent years. The presence of suitable spawning habitat in Creek B1 (and the extensive use of these areas) may have led to this increased recruitment. Gill net capture data (selective for adults and larger juveniles) for the three study years indicate a reduction in numbers of adult white suckers from 1978 to 1981, followed by a stabilization of the population between 1981 and 1984 (G2; Appendix E, Table E9). Boat electroshocking at ES1 and ES2 captured mainly adult and juvenile white suckers. Capture rates for this sampling method were 3.0 and 4.1 fish·min^{-1} at ES1 and ES2, respectively. The 1984 capture data and the observation of approximately 300 to 500 adults spawning in Creek B1 show a substantial population of white suckers still exists in Beaver Creek Reservoir.

Fathead minnows and brook stickleback have dominated the catch in seines in all sampled years (Appendix E, Table E8). A comparison of 1984, 1981, and 1978 capture rates, however, suggests the numerical abundance of both these species has declined appreciably.

Lake chub have declined in abundance in the reservoir since 1978; in 1984 they were absent from seine captures (Appendix E8, Table E8). This species is better adapted to fluvial habitats such as Lower Beaver Creek and Creek B1 where it was abundant. The presence of adult lake chub in the gill net catch in fall 1978 (Appendix E, Table E9) suggests that older age-classes overwinter in Beaver Creek Reservoir, and then move into tributaries (e.g., Upper Beaver Creek, Creek B1) in spring for spawning and feeding.

Longnose suckers were present in low numbers in the 1978 gill net catch in Beaver Creek Reservoir (Appendix E, Table E9). Since longnose suckers have not been caught in subsequent studies, it is evident that this species is no longer present in the reservoir.

5.3.6.2 Age Structure of White Sucker Population

The length-frequency distribution of white suckers captured in Beaver Creek Reservoir is presented in Appendix E, Table E10. The fish were captured by a range of capture gear (gillnet, boat electroshocker, seine) in order to minimize the influence of gear selectivity.

Length frequency analysis indicates that the population sampled was made up of six year-classes ranging from 1984 (y-o-y) to 1979 (age five). Individuals from the age five group made a small contribution to the total sample. The age structure of the population in 1984 was similar to that in the reservoir in 1978 (O'Neil 1979) and 1981 (O'Neil 1982). The 1984 and earlier data indicate the presence of a fast-growing, short-lived population in Beaver Creek Reservoir. Data collected on the spawning run in Creek B1 in 1984 indicate that the majority of white suckers mature and commence spawning at age three. A similar conclusion was reached in 1978 based on a sample of white suckers directly from the reservoir. The majority of the sampled spawners was comprised of age three and age four individuals; age five fish were present but in low numbers. It is apparent that annual mortality increases sharply past age four and that few adults survive past age five. Substantial numbers of dead adults (primarily large individuals) were observed in the lower reaches of Creek B1 following the spawning run. This suggests that spawning mortality may be a factor in determining the lifespan of white suckers in the reservoir. Spawning mortality of white suckers has been documented in the MacKay River by Machniak et al. (1980), and in British Columbia by Geen et al. (1966).

5.4 RUTH LAKE

5.4.1 AQUATIC HABITAT

5.4.1.1 Description of Drainage Area

Ruth Lake is an elongated waterbody located approximately 1.5 km east of Beaver Creek Reservoir (Figure 2.3). Formerly a closed drainage, it now receives inflow from Beaver Creek Reservoir via a diversion channel entering at the northern end of the lake. A continuation of the channel exits from the southern end of the lake and drains into Poplar Creek Reservoir.

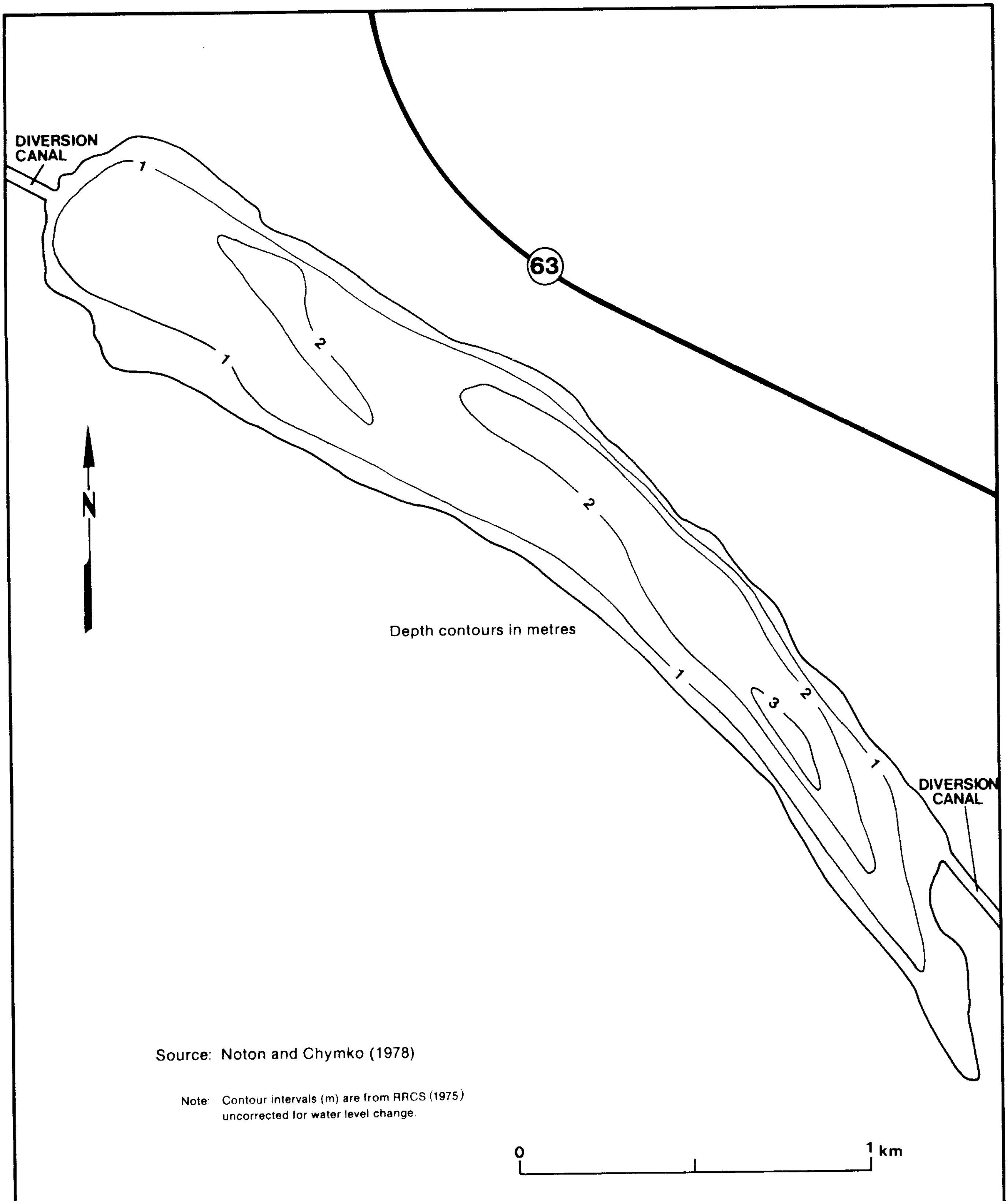
5.4.1.2 Physical Characteristics

The physical characteristics of Ruth Lake have been described by Noton and Chymko (1978) and Carmack and Killworth (1979). Ruth Lake is a shallow (maximum depth 3 m) waterbody approximately 3.8 km in length (Figure 5.15). A summary of the major morphometric features is presented below:

Morphometry of Ruth Lake (based on 1978 data)

Surface Elevation	309.7 m
Length	3.8 km
Area	150 ha
Volume	1.8×10^6 m^3
Mean Depth	1.2 m
Maximum Depth	approx. 3.0 m

source: adapted from Carmack and Killworth (1979).



Source: Noton and Chymko (1978)

Note: Contour intervals (m) are from RRCS (1975) uncorrected for water level change.

R.L. & L. Environmental Services Ltd.

Figure 5.15

RUTH LAKE BATHYMETRY

The substrate in Ruth Lake consists primarily of soft mud and organic material. Shorelines slope gently towards the forested perimeter of the lake. Cobble patches along the shoreline occur infrequently.

5.4.1.3 Macrophytes

The distribution of macrophyte species in Ruth Lake during July 1984 is shown in Figure 5.16. The relative abundance of the various forms is presented in Table 5.11.

Since the 1977 survey, the structure of the submersed vegetation community in Ruth Lake appears to have been further simplified. **Chara**, which apparently was common in 1974, is now present in small quantities and only in a few locations. **Myriophyllum** and **Ceratophyllum** dominate the majority of the area between the shoreline and the 2 m contour, forming extremely dense beds which reach the surface. Colonies of the blue-green algae, **Aphanizomenon**, which occurred in Beaver Creek Reservoir and in the upper end of Ruth Lake, were largely filtered out by the plants. Only a few colonies remained to enter the channel to Poplar Creek Reservoir. The areas occupied by **Nuphar** may have decreased since 1977 but the **Scirpus** islands seem to be stable. Colonization beyond the 2 m contour is not extensive probably due to low incident light levels. A detailed description of macrophyte assemblages at specific sampling sites is provided in Appendix F, Table F2.

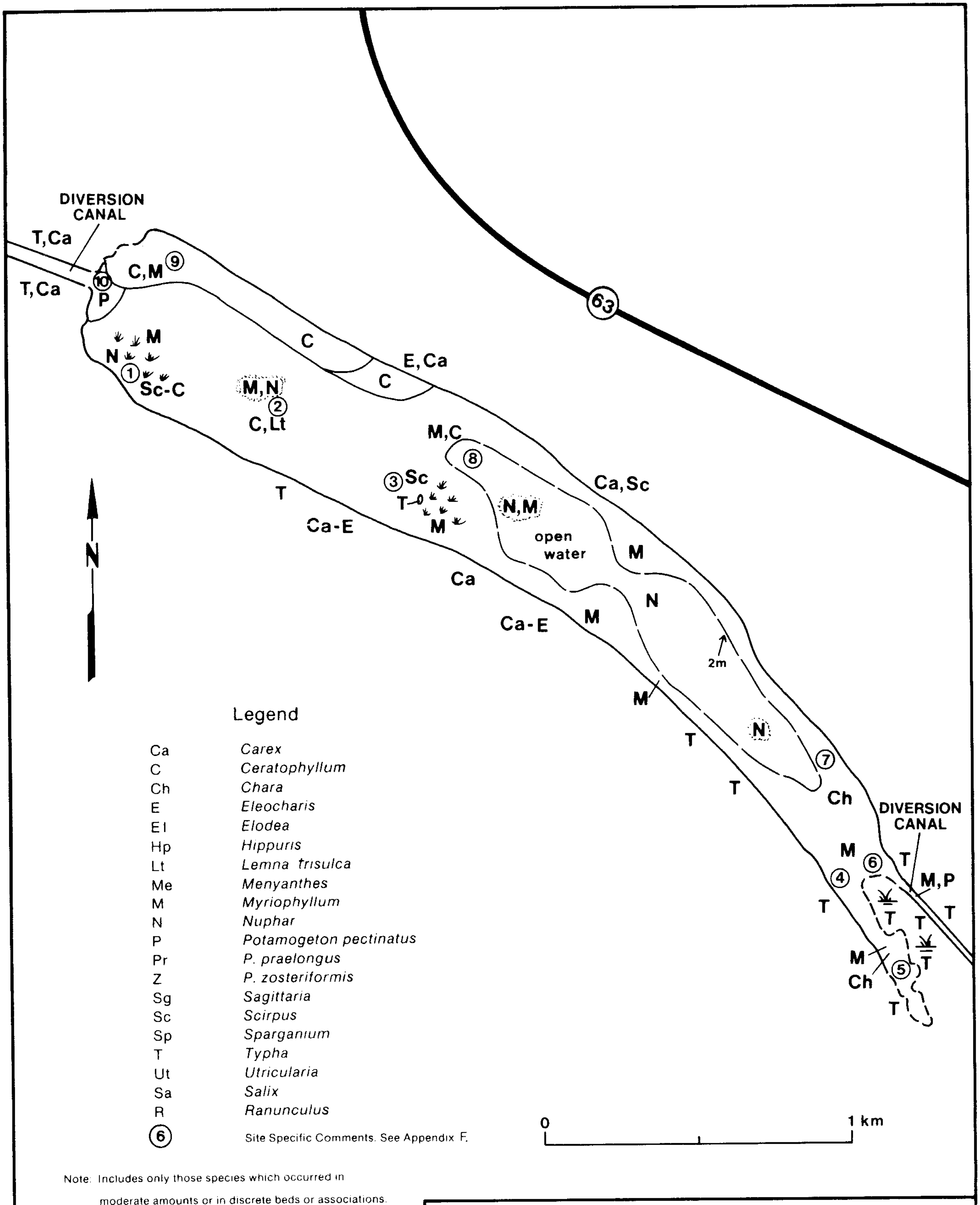


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Figure 5.16

RUTH LAKE
Macrophyte Distribution
1984

Table 5.11 Distribution pattern and relative abundance of macrophytes found in Ruth Lake, July 1984.

Species	Distribution Pattern
	Submersed
Ceratophyllum demersum	Abundant
Chara spp.	Present
Lemna trisulca	Present
Potamogeton pectinatus	Common
Potamogeton praelongus	Present
Potamogeton richardsonii	Present
Potamogeton zosteriformis	Common
Ranunculus spp.	Present
	Floating-Leafed
Lemna minor	Present
Nuphar variegatum	Common
	Emergent
Carex spp.	Common
Eleocharis spp.	Common
Typha latifolia	Abundant
Scirpus spp.	Abundant

5.4.2 WATER QUALITY

5.4.2.1 Physical Parameters

During this study, water temperatures in Ruth Lake at station RL-W ranged from 6.0 in September to 25.0°C in July (Table 5.2). Except in September, slight decreases in temperatures from the surface to the bottom were recorded. In June, July, and September 1977 the mean temperatures (water column) were 19.6, 19.9, and 12.0°C, respectively (Noton and Chymko 1978).

The pH ranged from 7.8 to 9.0. The maximum values which were recorded in July and September were notably higher than those recorded in the creeks or Beaver Creek Reservoir. The high values probably were the result of extensive primary production. A pH value of 9.3 during a bloom of blue-green algae was reported by Noton and Chymko (1978). Total non-filterable residue levels, with the highest level of 9.2 $mg \cdot L^{-1}$, were similar to those in Beaver Creek Reservoir. The Secchi disc visibilities in Ruth Lake in June, July, and September were 0.98, 2.0, and 1.5 m, respectively. In June the water was yellowish in colour.

Dissolved oxygen concentrations ranged from 3.4 to 10.6 $mg \cdot L^{-1}$ and showed increased levels from June to September at the surface and bottom depth. The dissolved oxygen concentration of 3.4 $mg \cdot L^{-1}$ was less than the ASWQO of 5.0 $mg \cdot L^{-1}$. Low dissolved oxygen levels are common in shallow productive lakes in Alberta. The oxygen saturation ranged from 36% in June at the bottom to 106% in July at the surface. In July 1977, supersaturated levels were recorded in July with values as high as 136% at 1 m depth (Noton and Chymko 1978). These researchers did not encounter saturation levels lower than 57% during the June to September period. Chemical oxygen demand levels (63 to 64 $mg \cdot L^{-1}$) in Ruth Lake were consistent during the sampling periods, and were slightly lower than those in Beaver Creek Reservoir.

5.4.2.2 Major Ions

The water type and ionic character is very similar to that described for Beaver Creek Reservoir (Table 5.2 and Figure 5.4). This is further exemplified by the similar total filterable residue levels in both water bodies. Slightly higher total filterable residue levels (248 to 356 $mg \cdot L^{-1}$) were reported for the same period in 1977 (Noton and Chymko 1978).

5.4.2.2 Nutrients

The total nitrogen concentrations ranged from 0.96 to 1.16 mg $N \cdot L^{-1}$ and slightly exceeded the ASWQO of 1.0 mg $N \cdot L^{-1}$. The levels were very similar to the composite sample results from Beaver Creek Reservoir with both waterbodies exhibiting the highest values in July. Nitrate + nitrite concentrations ranged from less than 0.003 mg $N \cdot L^{-1}$ (July) to 0.009 mg $N \cdot L^{-1}$ (June). The July and September values were lower than those recorded in Beaver Creek Reservoir. In June, July, and September 1977, notably higher levels of 0.084, 0.047, and 0.044 mg $N \cdot L^{-1}$, respectively, were reported by Noton and Chymko (1978).

Concentrations of total phosphorus ranged from 0.027 to 0.054 mg $P{\cdot}L^{-1}$ with the highest value recorded in June. These values were within the ASWQO of 0.05 mg $P{\cdot}L^{-1}$ but exceeded the 0.025 mg $P{\cdot}L^{-1}$ guideline established by Environment Canada. Generally, the concentrations in Ruth Lake were lower than those in the Beaver Creek Reservoir. In June, July, and September 1977, the values in Ruth Lake were notably higher than in the present study, with 0.112, 0.100, and 0.051 mg $P{\cdot}L^{-1}$, respectively, reported by Noton and Chymko (1978). Ortho-phosphorus concentrations ranged from 0.006 mg $P{\cdot}L^{-1}$ (September) to 0.028 mg $P{\cdot}L^{-1}$ (July), and paralleled those recorded in the Beaver Creek Reservoir. In 1977, the ortho-phosphorus levels were lower than in the present study with values of 0.016, 0.022, and less than 0.016 mg $P{\cdot}L^{-1}$ in June, July, and September, respectively (Noton and Chymko 1978).

Reactive silica concentrations ranging from 1.05 to 4.70 $mg{\cdot}L^{-1}$ showed the same seasonal relationship as in Beaver Creek Reservoir; the highest values were recorded in June and the lowest levels in July. Similar conditions prevailed in 1977 except that the highest value during that period was recorded in September (Noton and Chymko 1978). Total organic carbon concentrations ranging from 28.5 to 30.0 $mg{\cdot}L^{-1}$ were similar to those in Beaver Creek Reservoir.

5.4.2.4 Trace Metals and Other Substances

The concentrations of trace metals and elements were very similar to those described for Beaver Creek Reservoir. Iron and manganese concentrations ranged from 0.11 to 0.35 $mg \cdot L^{-1}$, and 0.010 to 0.050 $mg \cdot L^{-1}$, respectively, and are lower than those in Beaver Creek Reservoir. Iron concentrations in June and July slightly exceeded the ASWQO of 0.30 $mg \cdot L^{-1}$. Metal concentrations were similar in Ruth Lake and Beaver Creek Reservoir in 1977 (Noton and Chymko 1978). In the present study, phenol concentrations, which were similar to those recorded in the reservoir, exceeded the ASWQO of 0.005 $mg \cdot L^{-1}$. Oil and grease levels which also were similar to the values in Beaver Creek Reservoir, were considerably lower than those reported in 1977 by Noton and Chymko (1978), when concentrations as high as 156.2 $mg \cdot L^{-1}$ were reported in July.

5.4.3 PHYTOPLANKTON

Phytoplankton cell count and cell volume data for Ruth Lake are presented in Appendix G, Table G2. During the three seasons sampled in 1984, numerical abundance of phytoplankton was highest during the summer, and lowest during the fall (Figure 5.17). Standing crop of phytoplankton expressed as bio-volume was highest in the late spring and decreased progressively through the summer and fall.

In mid-June, the phytoplankton in Ruth Lake was dominated by Euglenophyta which contributed approximately 28% of the total cell volume in the sample (Figure 5.17). The major contributors in this group included two **Trachelomonas** spp., and **Euglena acus.** Chlorophyta, dominated by **Sphaerocystis schroeteri,** was the second most abundant

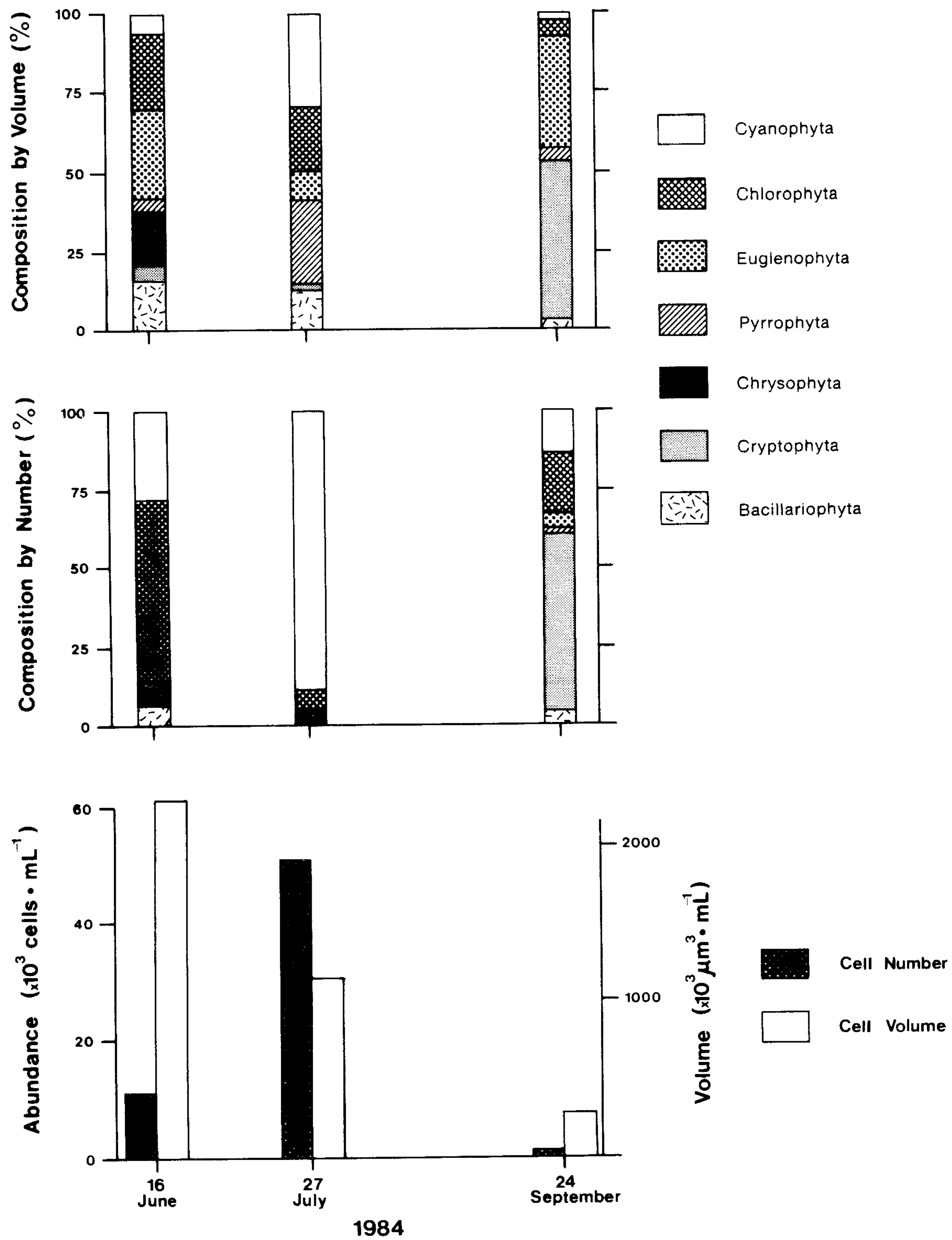

Figure 5.17 Abundance and percent composition of phytoplankton in Ruth Lake, 1984.

division, contributing about 23% of the total bio-volume. Chrysophyta, represented solely by **Dinobryon divergens**, contributed 19% to the total.

In the summer sample, the phytoplankton was dominated by Cyanophyta (primarily **Aphanizomenon flos-aquae** and **Anabaena** sp.) followed closely by Pyrrophyta (primarily **Ceratium hirundinella**) (Figure 5.17). These two divisions contributed approximately 29% and 27% of the total cell volume, respectively. **Ceratium hirundinella** previously has been observed to do well during blue-green algal blooms (Trew et al. 1978). On a numerical basis, Cyanophyta was by far the most abundant division, contributing about 93% of total cell numbers in the sample.

In the fall, the phytoplankton standing crop was dominated by Cryptophyta (primarily **Rhodomonas minuta** and two **Cryptomonas** spp.), which contributed about 50% of the total cell volume (Figure 5.17). The second highest contribution on a bio-volume basis was by Euglenophyta (primarily **Trachelomonas** sp.) which accounted for about 35% of the total cell volume. On a numerical basis, the phytoplankton was comprised primarily of Cryptophyta (57% of total cell numbers), Chlorophyta (20%) and Cyanophyta (15%).

Seasonal variation in bio-volume for the major species of phytoplankton in Ruth Lake is presented in Figure 5.18. The three species which exhibited the greatest bio-volume in the June sample (i.e., **Dinobryon divergens**, **Trachelomonas planctonica**, and **Sphaerocystis**

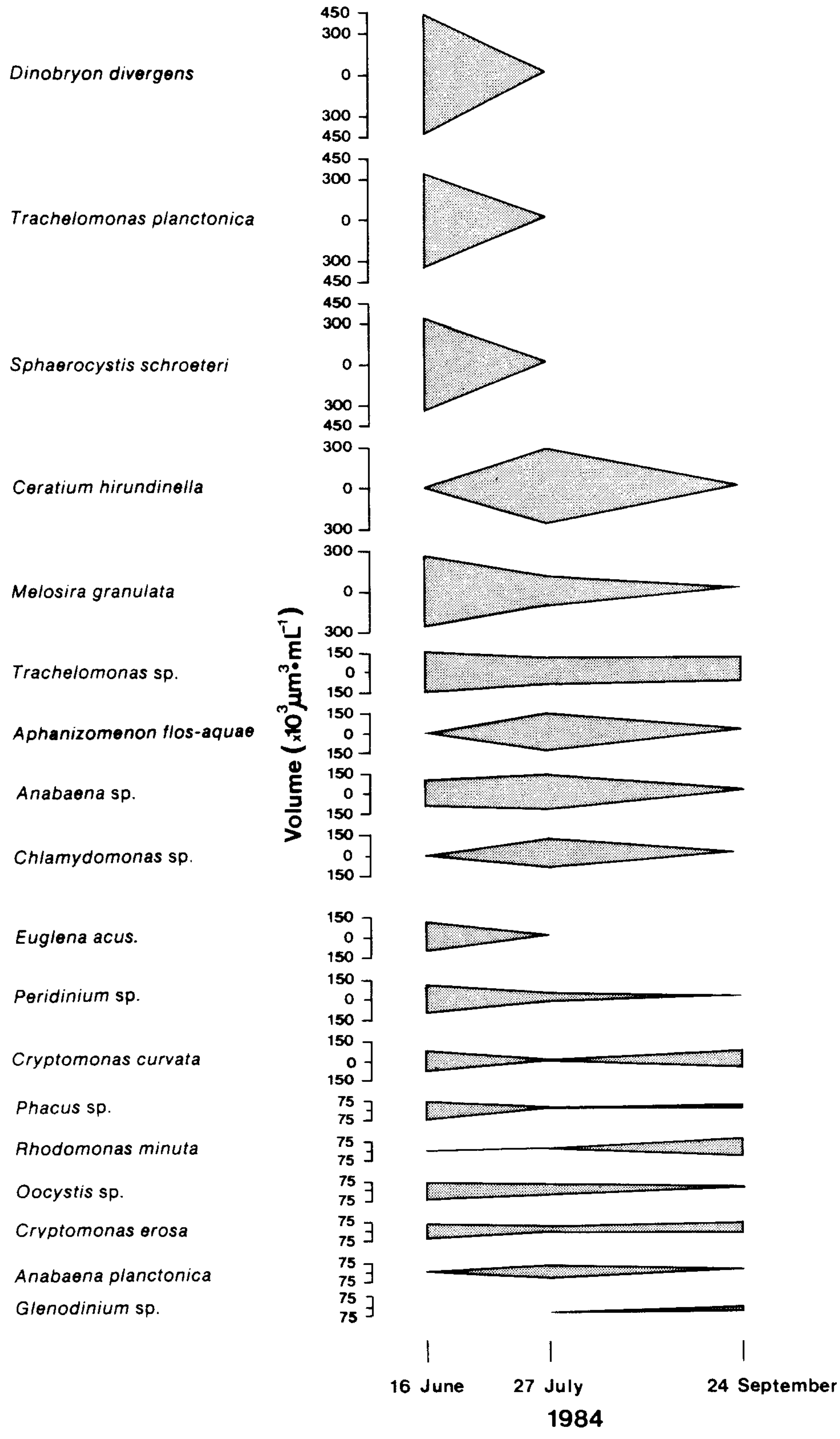

Figure 5.18 Seasonal variation (by volume) of dominant phytoplankton in Ruth Lake, 1984.

schroeteri) were not represented in the counts from the summer and fall samples. Similarily, three of the species that were abundant in the summer (namely **Ceratium hirundinella**, **Aphanizomenon flos-aquae**, and **Chlamydomonas** sp.) were absent from, or did not contribute appreciably to, the total cell volume in the spring and fall samples.

The phytoplankton populations in Ruth Lake have been studied previously in 1974 (Syncrude Canada Ltd. 1975) and in 1977 (Noton and Chymko 1978). Data collected during these studies showed that the phytoplankton standing crops on a numerical basis had increased substantially during the period 1974 to 1977 (Noton and Chymko 1978); this increase was attributed to the high level of macronutrients (N, P, S) in the water after diversion of Beaver Creek. Although based only on three seasonal samples, the present study indicates that phytoplankton cell numbers were lower in 1984 than in 1977. Although some of the variation may be explained by differences in sampling methodology (vertically integrated sample in 1984 vs. grab sample in 1977), the shallow depth of the lake at the sampling station (i.e., about 2 m) would reduce any differences related to sampling methodology. It is possible that the apparent reduction in algal production between 1977 and 1984 may be related to lower macronutrient levels in the lake. Although available phosphorus levels (i.e., ortho-phosphorous) were comparable between the two years, nitrate + nitrite nitrogen levels were an order of magnitude less in summer and fall of 1984 than in comparable periods in 1977 (i.e., about 0.003 mg $N \cdot L^{-1}$ in 1984 vs. 0.044 to 0.047 mg $N \cdot L^{-1}$ in 1977). Also, the reactive silica in the summer and fall was four to seven times lower in 1984 when compared to 1977.

5.4.4 ZOOPLANKTON

The species composition, numerical abundance, and calculated biomass (excepting nauplii) of crustacean plankton collected at the regular sampling station RL-Z in Ruth Lake are summarized in Table 5.12. Aliquot counts and calculated totals for each sample are included in Appendix C, Table C2. The species composition and numerical abundance of rotifers in the zooplankton samples are summarized in Table 5.13. The total numbers of species identified on all three sampling dates are:

Rotifera	-	15
Cladocera	-	6
Cyclopoida	-	4
Calanoida	-	1
Chaoboridae	-	0

There were fewer commonly occurring crustacean species and more rotiferan species in Ruth Lake in 1984 than in 1977 (Noton and Chymko 1978), and most of the crustacean species that would be considered "common" according to the criteria set out by these authors (Ibid.p.56) were much less abundant in 1984.

5.4.4.1 Rotifera

The rotifers in Ruth Lake were dominated by **Keratella** spp. on all sampling dates, followed closely by **Polyarthra** spp. in the June sampling.

Table 5.12 Species composition, numerical abundance, and calculated biomass of crustacean plankton from Ruth Lake (Station RL-Z), 1984. Unbracketed values are number·m^{-3}. Bracketed values are biomass expressed as mg wet weight·m^{-3}.

Species[a]	**16 June**	**24 July**	**24 Sept.**
COPEPODA			
CALANOIDA			
Diaptomus oregonensis LILLJEBORG 1889 A+C	6 961 (120.1)	135 (1.9)	342 (32.2)
diaptomid nauplii	21 384	4 288	1 313
CYCLOPOIDA			
Acanthocyclops vernalis FISCHER 1853 A+ adv.C	215 (3.9)	0	0
Diacyclops thomasi (FORBES) 1882 A+ adv.C	40 (2.4)	0	40 (1.4)
Mesocyclops edax (FORBES) 1891	255 (7.6)	0	40 (1.3)
Microcyclops varicans rubellus LILLJEBORG 1901 A	167 (1.3)	0	0
cyclopoid copepodids, immature C	7 637 (41.7)	3 063 (13.3)	382 (2.0)
cyclopoid nauplii	26 476	11 329	8 950
CLADOCERA			
Bosmina longirostris (O.F. MÜLLER) 1785	4 240 (8.6)	135 (0.7)	88 (1.0)
Ceriodaphnia lacustris BIRGE 1893	0	16 (0.1)	0
Daphnia parvula FORDYCE 1901	294 (5.5)	8 (0.1)	8 (0.3)
Diaphanosoma leuchtenbergianum FISCHER 1850	167 (6.7)	406 (7.5)	0
Acroperus harpae BAIRD 1843	88 (1.0)	0	0
Chydorus sphaericus (O.F. MÜLLER) 1785	636 (4.4)	24 (0.2)	0
CERATOPOGONIDAE (larvae)	40	0	0
OTHER TAXA (Ostracodes, immature)	127	8	0
Total[b]	**20 700** **(203.2)**	**3 787** **(23.8)**	**900** **(38.2)**

[a] A=adult; C=copepodid, usually I to III; adv.C=advanced copepodids, usually IV & V.
[b] excluding nauplii and non-crustaceans.

Table 5.13 Species composition and numerical abundance of rotifers in the zooplankton of Ruth Lake (Station RL-Z), 1984.

Species	**16 June ($No. \cdot m^{-3}$)**	**24 July ($No. \cdot m^{-3}$)**	**24 Sept. ($No. \cdot m^{-3}$)**
Keratella cochlearis (GOSSE 1851)	23 166	22 148	18 457
Keratella earlinae AHLSTROM 1943	160 382	9 419	1 273
Keratella quadrata (O.F. MÜLLER 1786)	21 384	1 400	191
Notholca acuminata (EHRENBERG 1832)	0	127	127
Trichotria pocillum (O.F. MÜLLER 1776)	1 782	0	0
Euchlanis dilatata EHRENBERG 1832	1 782	127	0
Brachionus quadridentatus (HERMANNS 1783)	0	127	40
Synchaeta pectinata (?) EHRENBERG 1832	0	0	509
Synchaeta oblonga (?) EHRENBERG 1831	0	1 018	1 018
Filinia longiseta (EHRENBERG 1834)	1 782	382	382
Polyarthra dolichoptera IDELSON 1925	49 897	764	1 273
Polyarthra vulgaris CARLIN 1943	1 782	1 782	509
Conochilus unicornis ROUSSELET 1892	0	382	0
Lecane (monostyla) bulla (GOSSE 1886)	0	509	0
Lecane luna (O.F. MÜLLER 1776)	0	0	40
unidentified rotifers	3 564	0	1 273
Total	**265 521**	**38 185**	**25 092**

In July and September, species other than **Keratella** spp. were low in abundance. As in Beaver Creek Reservoir, **K. earlinae** was the dominant among **Keratella** spp. in June, but the dominance shifted to **K. cochlearis** in September. **Polyarthra** appeared to be comprised of two species, of which **P. dolichoptera** was usually more common (see Table 5.13). A positive resolution of speciation within **Polyarthra** would require detailed study.

Although species diversity among rotifers in Ruth Lake may have increased slightly since 1977, total abundance seems to have declined, especially in July and September (Figure 5.19). Both diversity and abundance can vary from year to year (see discussion in section 5.3.4.1), but there may be another explanation for the change in Ruth Lake. Neither predation by cyclopoids or **Asplanchna priodonta**, nor competition from grazing cladocerans would seem to explain the reduction in rotifer numbers, since crustacean numbers were greatly reduced in 1984 and **Asplanchna** was not seen in the samples at all. Higher than usual precipitation, however, may have resulted in high flushing rates, especially in June, and this may have flushed out many rotifers, their food organisms, or both. The shallow nature of Ruth Lake would increase the likelihood of such flushing action during periods of high precipitation.

5.4.4.2 Cyclopoida

During the spring of 1984, the cyclopoid copepods in Ruth Lake were dominated by **Mesocyclops edax**, followed closely by **Acanthocyclops**

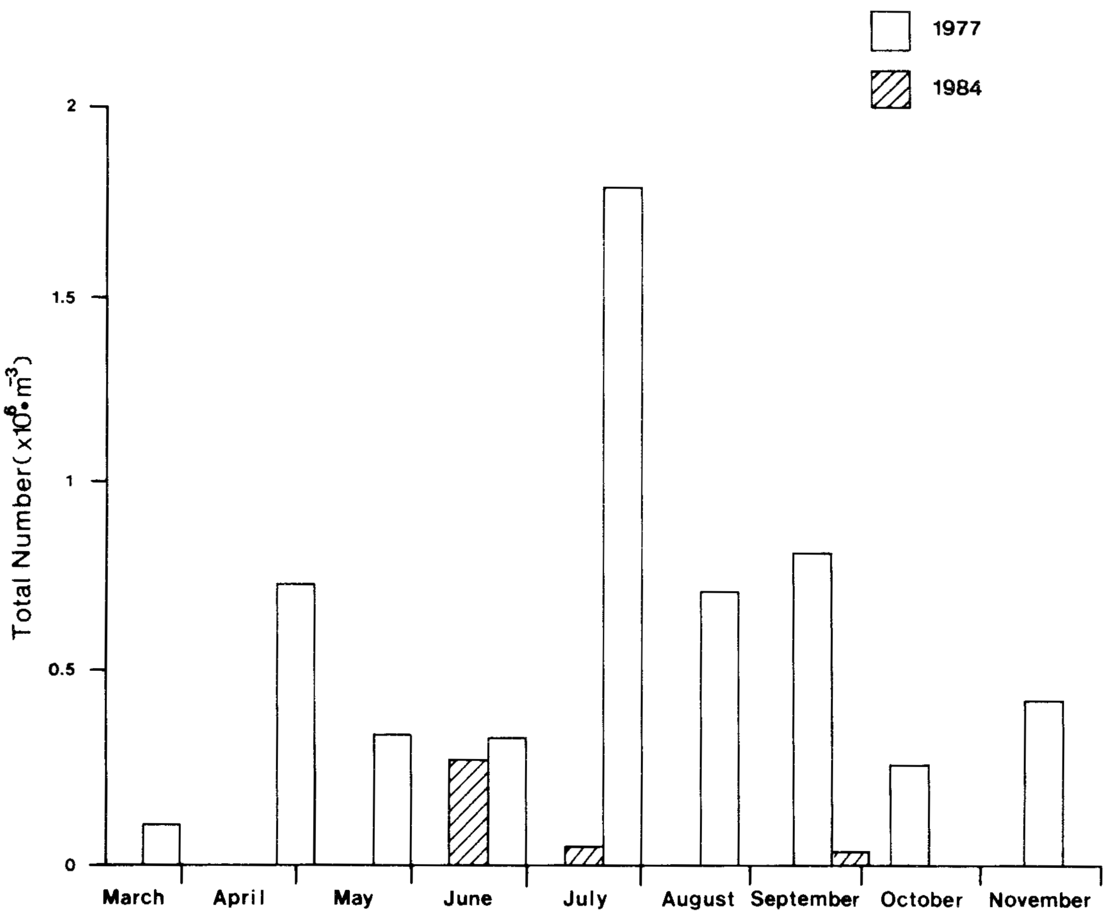

Figure 5.19 Abundance of Rotifera in Ruth Lake in 1984 (present study) and in 1977 (Station RL-2; Noton and Chymko 1978).

vernalis. In July, adult cyclopoids were not observed in the samples, and in September, only **M. edax** and **Diacyclops thomasi** were present in low numbers.

There has been a dramatic reduction in the total numbers of cyclopoid copepods in Ruth Lake in comparison to 1977 (Table 5.12; Noton and Chymko 1978). Cyclopoid nauplii, on the other hand, were more similar in abundance. These facts, coupled with a lack of evidence of predators likely to feed on small zooplankters (e.g., **Chaoborus** spp.), suggest that a lack of sufficient food during the developmental period may be a cause of cyclopoid population decline. The increased presence of fathead minnows is another potential explanation for the decline of larger cyclopoids, an explanation which seems plausible when the reduction in numbers or disappearance of most other crustaean species present in 1977 is taken into account.

5.4.4.3 Calanoida

Diaptomus oregonensis was the most frequently occurring species of crustacean plankton on all three sampling dates in Ruth Lake. Numbers of this species were considerably higher than in 1977 (Noton and Chymko 1978). The other commonly occurring calanoid in 1977, **Diaptomus leptopus**, was not found in 1984. This shift in species composition and abundance may also reflect increased feeding by fathead minnows. Furthermore, in many small lakes the presence of **Diaptomus leptopus** has a depressing effect on numbers of smaller existing species of **Diaptomus**

(Anderson and Donald 1980), thereby possibly explaining the lower numbers of **D. oregonensis** in 1977 when **D. leptopus** was present.

5.4.4.4 Cladocera

The cladoceran plankton in Ruth Lake was dominated by **Chydorus sphaericus** in the spring, **Diaphanosoma leuchtenbergianum** in the summer, and **Bosmina longirostris** in the fall. Neither of the large species of **Daphnia** reported in Ruth Lake in 1977 (Noton and Chymko 1978) was found in 1984, the larger species having been replaced by the much smaller **Daphnia parvula**. However, even this smaller species was present in appreciable numbers only in June. **Diaphanosoma leuchtenbergianum** was present in moderate numbers in June and July, but was not nearly so common as in 1977. **Chydorus sphaericus** was similar in abundance in both 1977 and 1984, but this species is not usually considered a truly planktonic form. Its presence is a reflection of the shallow nature of Ruth Lake.

5.4.4.5 Total Numbers and Biomass of Crustacean Plankton

The general shift from larger to smaller species noted for Beaver Creek Reservoir was a feature also common to Ruth Lake. In spite of this, however, the June biomass and total abundance was higher in 1984 than in 1977 (Figure 5.20). July and September figures for both biomass and numbers, on the other hand, were much lower in 1984. Since only three dates were sampled in 1984 compared to seven in 1977, a more detailed comparison is not valid. Both biomass and numbers fluctuated

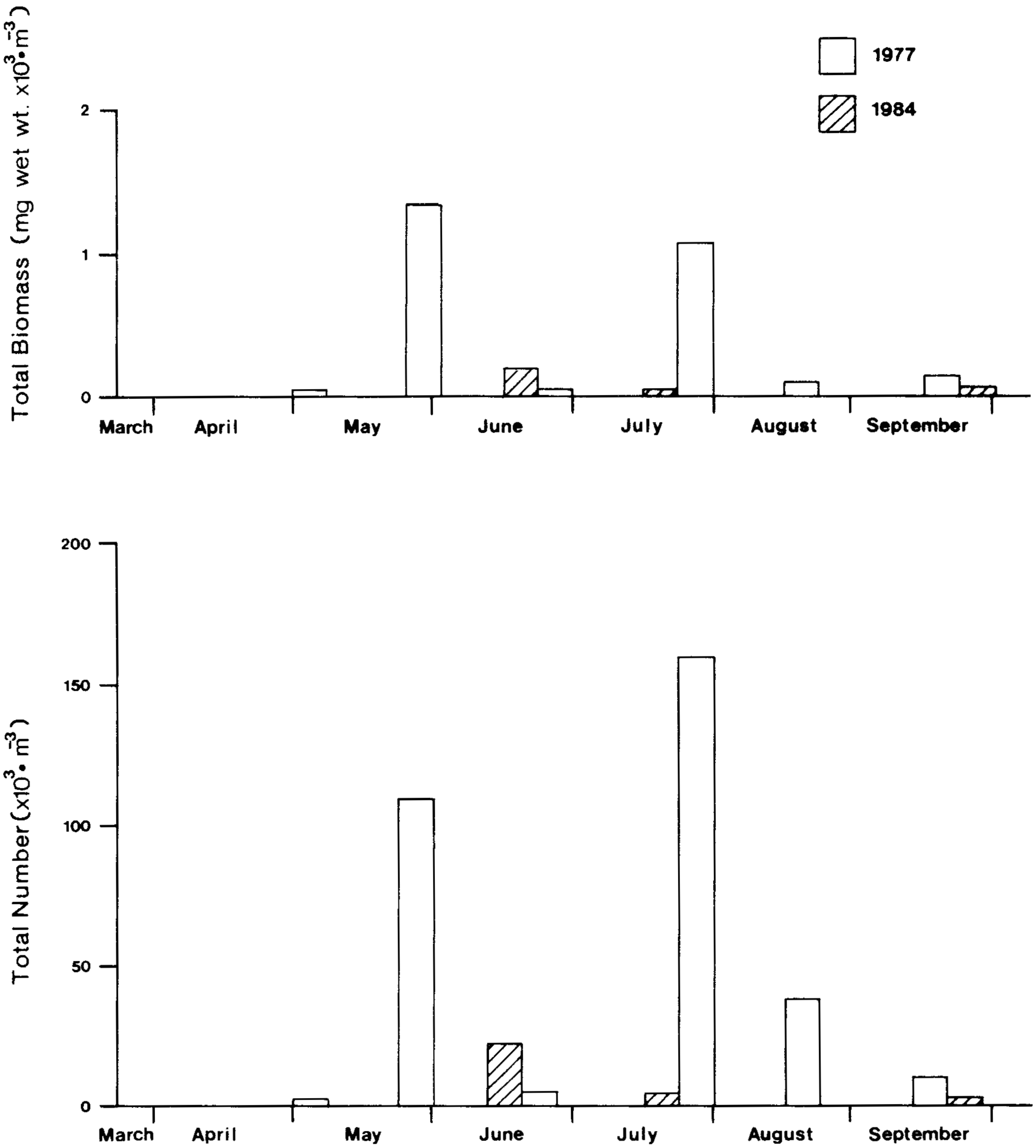

Figure 5.20 Total number and biomass of crustacean zooplankton in Ruth Lake in 1984 (present study) and in 1977 (Station RL-2; Noton and Chymko 1978).

greatly from month to month in 1977, but it seems unlikely that the midsummer or early spring peaks were as great in 1984 as in 1977. The main reason for this conclusion rests in the absence or dramatic decline in numbers of the principal species contributing to these peaks in 1977.

The main changes in the Ruth Lake zooplankton from 1975 to 1984 are probably the result of the two main factors: the flushing effect of water diverted through the lake, starting in 1976, and the increased presence of fathead minnows, undoubtedly due in part to the confluence of Ruth Lake with the two reservoirs.

The 1984 data and the 1974-1975 data included in the report of Noton and Chymko (1978) suggest that the large numerical peaks reached in summer 1977 may not be the general trend for Ruth Lake. The 1974, 1975, and 1977 data indicate that a spring peak may be the usual course of events. Such a spring peak would not have been detected by the three sampling dates used in 1984. The biomass data for the three earlier study years indicate that standing crop biomass has been higher than that measured in 1984.

5.4.5 ZOOBENTHOS

The benthic fauna of Ruth Lake was the most impoverished of the three lentic waterbodies investigated. Although density, diversity, biomass, and taxonomic richness all increased from spring to fall (Table 5.14), only three and four taxa were collected in spring and summer

Table 5.14 Mean density (no. per 0.1 m^2), mean biomass (mg per 0.1 m^2), diversity, and taxonomic richness of zoobenthos in Ruth Lake, 1984.

	Spring	Summer	Fall
Density	7.6	17.9	213.2
Biomass	12.0	11.7	118.6
Diversity	0.477	1.084	2.125
Richness	3	13[a]	20[a]

[a]Includes taxa collected in shoreline sweeps.

Ekman grab samples, respectively, and 18 taxa were collected in fall. Shoreline sweep samples yielded an additional nine and two taxa in summer and fall, respectively (Appendix D, Table D21). In comparison, the fewest taxa collected at other stations was seven (Poplar Creek Reservoir) in spring and 11 (Beaver Creek Reservoir) in summer. In fall, however, an equitable distribution of abundance among taxa produced the highest estimate of diversity of any lentic station, even though fall richness was not greater than that of other stations.

Samples were dominated by moderate sized chironomids in all seasons (Appendix D; Table D35) although planorbid snails became more abundant in fall samples.

The benthos of Ruth Lake previously has been sampled in 1977 (Noton and Chymko 1978) and in 1975 (Syncrude Canada Ltd. 1975). Chironomidae also dominated the samples in both of these studies. The previous studies also have shown that the benthic community was impoverished in spring, as was found in 1984. However, sphaeriid clams appeared to be more abundant during the previous surveys than in the present study.

5.4.6 FISH

5.4.6.1 Species Composition and Relative Abundance

Three species of fish were collected in Ruth Lake in 1984 (Table 5.15). In the combined catch (all sample methods), fathead minnow

(69.0%) was most abundant followed by brook stickleback (22.6%) and white sucker (8.4%). In seine collections fathead minnows and brook stickleback remained numerically dominant and exhibited slightly greater percentage compositions due to the reduced contribution of white suckers (mainly y-o-y). White suckers (adults and juveniles) contributed the largest portion to the gill net (100%) and boat electroshocking (50.0%) catches (Table 5.15).

Table 5.15. Percentage composition of fish species recorded from Ruth Lake, 1984.

Species (n)[a]	Capture Method: Seine (2015)	Gillnet (74)	Boat Electroshocking (224)	Combined Total (2313)
White sucker	0.4	100.0	50.0	8.4
Fathead minnow	74.7	0	40.6	69.0
Brook stickleback	24.9	0	9.4	22.6

[a]Number of fish captured (captured and observed for electroshocking)

Seine CUE's indicate a general decline in the abundance of white sucker y-o-y and early-age juveniles has occurred from 1981 to the present (Appendix E, Table E8). Low numbers of y-o-y were found in both 1981 and 1984 surveys and may indicate that a limited degree of spawning success was achieved in Ruth Lake. Gill net CUE's exhibited a fourfold increase in capture rate over the same period (Appendix E, Table E9). Most of the fish captured, however, were larger juveniles which is probably indicative of a heavy rearing/feeding use of Ruth Lake rather than of other functions such as spawning.

Fathead minnow and brook stickleback were abundant in Ruth Lake relative to Poplar Creek and Beaver Creek reservoirs (Appendix E, Table E6). Fathead minnow was the dominant species in Ruth Lake in all years (Appendix E, Table E8). Both fathead minnows and brook stickleback, however, exhibited substantially reduced densities in 1984 relative to 1978, indicating populations of both species decreased in the intervening period. The presence of numerous y-o-y of these species in 1984, indicates reproducing populations are still resident in Ruth Lake.

5.4.6.1 Age Structure of White Sucker Populations

The length frequency distribution of white suckers captured in Ruth Lake is presented in Appendix E, Table E10. Length-frequency analysis indicates that the population sample was comprised of four year-classes (1980 to 1983). Since young-of-the-year (1984 year-class) also were collected during the study, it is apparent that the population supports a total of five year-classes. The majority of the population sample was made up of immature age-classes (age one and age two individuals). The limited presence of older age-groups is unexplained; however, it has been documented in earlier studies (O'Neil 1979, 1982). Ruth Lake may serve primarily as a rearing area for the Beaver Creek Reservoir spawning population.

5.5 POPLAR CREEK RESERVOIR

5.5.1 AQUATIC HABITAT

5.5.1.1 Description of Drainage Area

Poplar Creek Reservoir is located south of Ruth Lake and receives inflow from Ruth Lake via a diversion channel entering the northern end of the reservoir (Figure 2.3). The reservoir was formed in 1975 by the construction of a dam across a small stream (i.e., Ruth Creek) flowing through a ravine toward Poplar Creek. A causeway constructed across the reservoir separates it into north and south basins. Water exits the reservoir from the southern end via a diversion canal. It then enters the Poplar Creek spillway, a concrete structure 200 m in length and with a vertical drop of 60 m. A weir at the crest of the spillway permits regulation of water levels in Poplar Creek Reservoir. A stilling basin, which drains into Poplar Creek, is located at the base of the spillway.

5.5.1.2 Physical Characteristics

The physical characteristics of Poplar Creek Reservoir have been described by Noton and Chymko (1978), and Carmack and Killworth (1979). The reservoir is moderately deep (maximum depth 19 m), with an irregular shoreline and a maximum length of 3.3 km (Figure 5.21). A

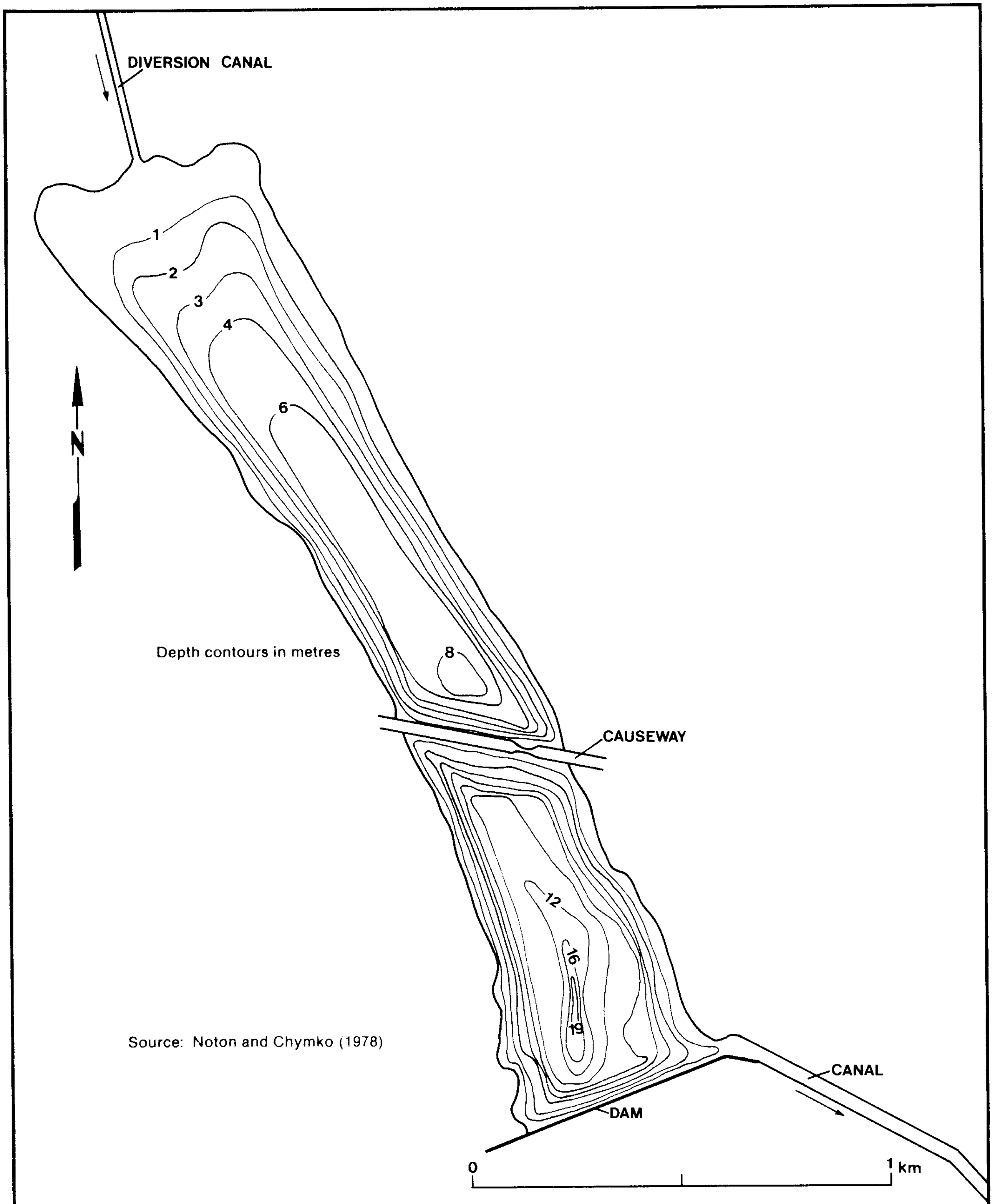

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Figure 5.21

POPLAR CREEK RESERVOIR BATHYMETRY

summary of the major morphometric features is presented below:

Morphometry of Poplar Creek Reservoir (based on 1978 data)

Surface Elevation	308.5 m
Length	3.3 km
Area	140 ha
Volume	4.9 X 10^6 m^3
Mean Depth	3.5 m
Maximum Depth	approx. 19 m

source: adapted from Carmack and Killworth (1979).

The north basin features a gently sloping shoreline and relatively shallow, off-shore depths (1 to 8 m). The substrate in this area consists of organic material. Shoreline topography and substrate conditions differ markedly in the south basin of the reservoir (i.e., steeper shoreline, depths ranging from 8 to 12 m, substrates composed of clay, sand, and organic debris). Substrate along the dam face consists of sand, gravel, and clay.

5.5.1.3 Macrophytes

The distribution of macrophyte species in Poplar Creek Reservoir during July 1984 is shown in Figure 5.22. The relative abundance of the various forms is presented in Table 5.16. Submersed vegetation occurred only at depths less than 2 m. This restricts growth of these plants to a narrow band (often less than 10 m wide) along the east and west shores. The bottom within this restricted area is quite firm (clay-sand-gravel) which does not facilitate extensive plant growth. Dense macrophyte beds occurred only at the north end of the reservoir in areas with soft sediment

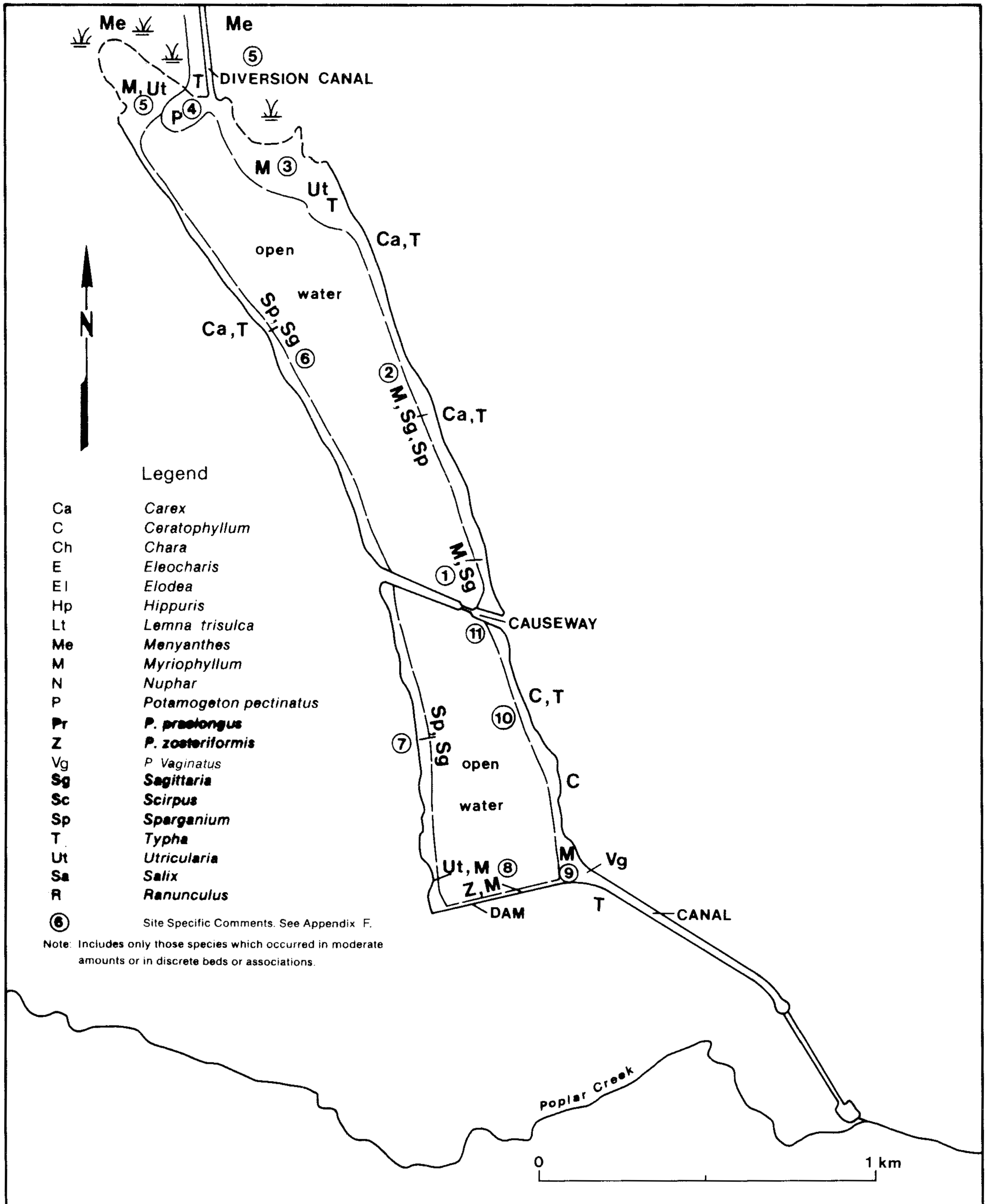

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Figure 5.22

POPLAR CREEK RESERVOIR
Macrophyte Distribution
1984

Table 5.16. Distribution pattern and relative abundance of macrophytes found in Poplar Creek Reservoir, July 1984.

Species	Distribution Pattern
	Submersed
Chara spp.	Present
Myriophyllum exalbescens	Common
Potamogeton pectinatus	Present[a]
Potamogeton pusillus	Present
Potamogeton praelongus	Present[b]
Potamogeton vaginatus	Present[a]
Potamogeton zosteriformis	Present[c]
Utricularia vulgaris	Present[b]
	Floating-Leaved
Sagittaria latifolia	Common
Sparganium spp.	Common
	Emergent
Carex spp.	Abundant
Hippuris vulgaris	Present
Menyanthes trifoliata	Present[d]
Polygonum amphibium	Present
Scirpus validus	Present
Typha latifolia	Common

[a]Found locally in area of discharge canal.

[b]Found locally at site 3

[c]Found along face of dam

[d]Locally abundant at north end of reservoir

substrate. The extent of the **Menyanthes** bed appeared unchanged since 1977. At the time of the present survey, these plants were growing in less than 0.5 m of water. The shoreline plant community was dominated by **Carex** spp.; isolated colonies of **Typha** and small amounts of **Scirpus** were noted also. The **Potamogeton berchtoldii** (**P. pusillus**) seems to have almost disappeared since it was reported in 1977 (Noton and Chymko 1978).

Detailed descriptions of macrophyte assemblages at specific sampling sites is provided in Appendix F, Table F3.

5.5.2 WATER QUALITY

5.5.2.1 Physical Parameters

In Poplar Creek Reservoir (station PCR-W), temperature and oxygen measurements revealed a typical stratification pattern (Tables 5.2 and 5.17; Figure 5.23). The bottom of the thermocline, which occurred at 7 m in June, declined to 9 m in September. The stratification was similar to that described for July 1977 by Noton and Chymko (1978). The reservoir was isothermal by 23 October 1984 (M. MacKinnon pers. comm.). The water column was isothermal on 15 October in 1977. In June of the present study, the temperatures declined from 23.0°C at the surface to 4.5°C at the bottom. By July, the temperature at the surface cooled by 1.0°C but increased to 9.0°C at the bottom, and in September top and

Table 5.17 Summary of temperature, dissolved oxygen, specific conductance and pH levels in Poplar Creek Reservoir (Station PCR-W) during June, July and September, 1984.

Parameter	Temperature (°C)			Dissolved Oxygen						Specific Conductance ($\mu S \cdot cm^{-1}$)			pH		
Depth (m)	June	July	Sept.	June		July		Sept.		June	July	Sept.	June	July	Sept.
				$mg \cdot L^{-1}$	% Sat.	$mg \cdot L^{-1}$	% Sat.	$mg \cdot L^{-1}$	% Sat.						
0	23.0	22.0	10.0	10.7	122	9.4	105	8.5	75	500	420	445	7.8	8.2	7.8
1	23.0	22.0	10.0	10.5	120	9.3	104	8.7	75	500	420	445	7.7	8.3	7.7
2	20.0	21.0	9.5	9.5	102	7.4	83	8.5	74	515	430	450	7.9	7.6	
3	19.0	20.0	9.5	5.8	63	6.5	70	8.2	72	545	430	460	7.8	7.6	7.9
4	15.5	19.0	9.5	5.8	57	4.4	47	8.0	70	630	435		7.5	7.8	
5	14.5	18.0	9.0	4.7	45	3.8	39	7.7	66	670	485	460	7.5	7.8	7.8
6	12.0	15.0	9.0	1.8	16	2.9	28	7.6	65	680	620	460	7.4	7.5	
7	11.0	11.0	9.0	0.5	4	1.1	9	7.5	64	700	680		7.4	7.5	7.8
8	9.0	11.0	9.0	0.0	0	0.9	7	7.4	63	715	670	460	7.4	7.5	
9	7.5	10.0	9.0	0.0	0	0.8	6	7.3	63	715	680	460	7.3	7.7	7.8
10	6.0	10.0	7.0	0.0	0	0.6	5	2.3	18	770	670		7.4	7.9	
11	6.0	10.0	6.5	0.0	0	0.4	3	2.1	16	750	650	645	7.4	7.7	7.5
12	5.0	9.5	6.0	0.0	0	0.3	2	2.0	15	750	650	720	7.3	7.8	7.5
13	5.0	9.0	6.0	0.0	0	0.3	1	2.0	15	750	650	720	7.4	7.9	7.5
14	4.5	9.0	6.0	0.0	0	0.2	1	1.9	15	780	660		7.4	7.5	
15	4.5	9.0	6.0	0.0	0	0.2	1	1.8	14	780	650	750	7.6		7.5
16			5.5					1.7	13			750			
17			5.5					1.6	12			750			7.7
18			5.0					1.5	11			750			

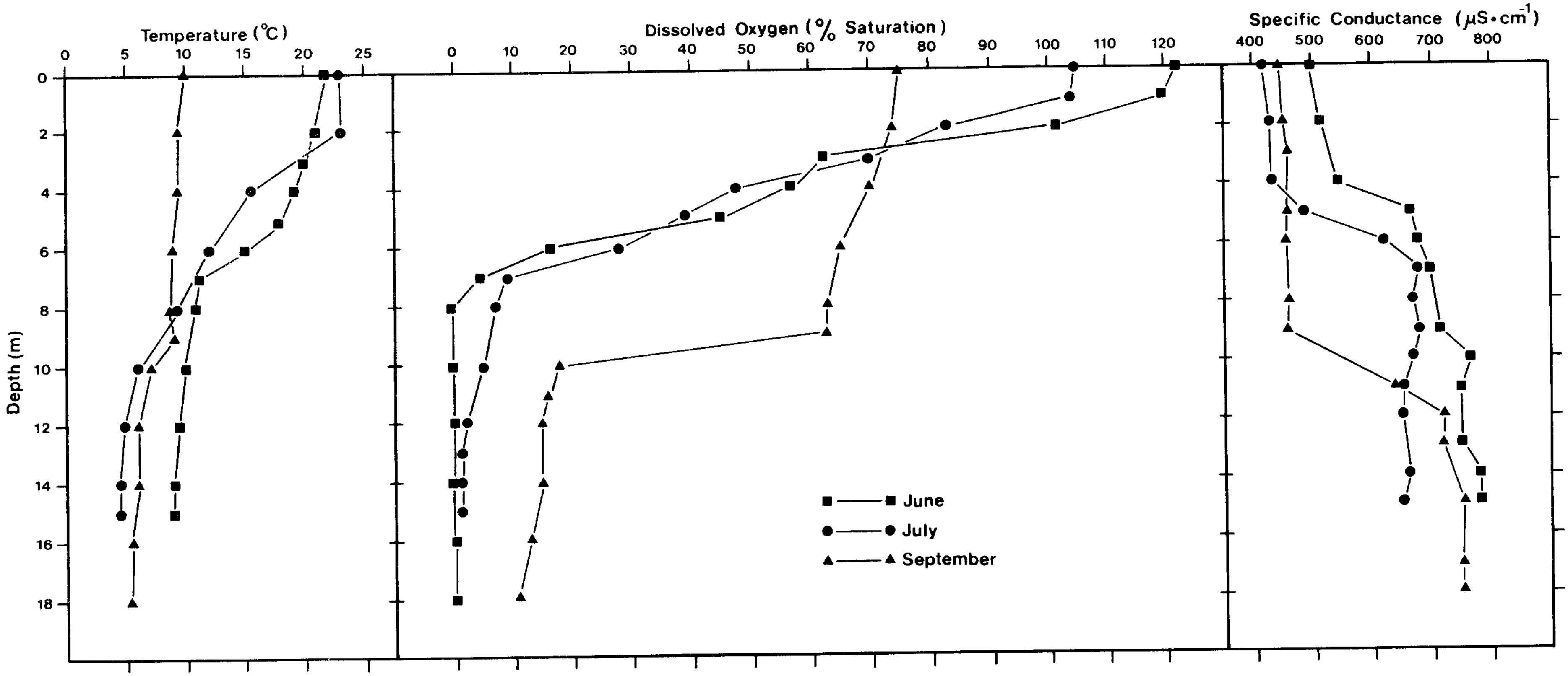


Figure 5.23 Depth profiles of temperature, dissoved oxygen, and specific conductance in Poplar Creek Reservoir during June, July, and September, 1984.

bottom temperatures cooled to 10.0°C and 5.0°C, respectively. During the June to September period in 1977, the maximum surface temperature (21°C) was not reached until July.

The oxygen saturation levels showed a pattern similar to that of temperature. In June and July the hypolimnion, between 8 and 18 m, was essentially anaerobic. In 1977, anaerobic conditions were present in June, July, and September (Noton and Chymko 1978). In the present study, the anaerobic conditions were further exemplified by the presence of hydrogen sulphide gas which was apparent at 7, 8, and 12 m depths in June, July, and September, respectively.

In Poplar Creek Reservoir pH was alkaline (ranging from 7.3 to 8.3). Changes in pH between the surface and the bottom were very slight. The high value probably resulted from a high rate of primary production.

Total non-filterable residue concentrations ranged from 1.6 to 24.8 $mg \cdot L^{-1}$; the highest levels occurred near the bottom of the reservoir. Similar conditions prevailed in 1977 particularly during September (Noton and Chymko 1978). The Secchi disc visibilities were 1.2 m and 0.85 m in July and September, respectively. Water collected from the hypolimnion had a black tinge when observed through the clear plastic Van Dorn water sampler, while the epilimnetic water was yellowish under the same condition.

5.5.2.2 Major Ions

Results from the composite samples indicated that the concentrations of most ions were higher in Poplar Creek Reservoir than in Ruth Lake (Figure 5.2). Specific conductance profiles revealed an important difference in the ionic character of the waters in the epilimnetic and hypolimnetic zones (Figure 5.23). The specific conductance levels were considerably higher in the hypolimnion than in the epilimnion with the highest value of 770 $\mu S \cdot cm^{-1}$ reached in June. The increase in salinity in the hypolimnion mainly was due to marked increases in the concentrations of bicarbonate, sodium, chloride and calcium ions. In July, ionic dominance in the epilimnion was $HCO_3^- > Na^+ > Ca^{++} > Mg^{++} > Cl^-$ $> SO_4^= > K^+$. In the hypolimnion, the pattern was characterized by increased chlorides (i.e., became the third most dominant ion). In September, the ionic dominance in the epilimnion and the hypolimnion remained the same as described for July. During the June to September period, water in Poplar Creek Reservoir was of the sodium bicarbonate type.

5.5.2.3 Nutrients

Total nitrogen concentrations above the thermocline (1.12 to 1.24 mg $N \cdot L^{-1}$) and below the thermocline (1.03 to 2.45 mg $N \cdot L^{-1}$) increased from June to September. Results from composite samples were higher than those recorded in Ruth Lake. In Poplar Creek Reservoir, the total nitrogen levels were higher in the hypolimnion than in the epilimnion, with values as high as 2.45 mg $N \cdot L^{-1}$ in September. All values only slightly exceeded the ASWQO of 1.0 mg $N \cdot L^{-1}$. Nitrate + nitrite concentrations above the thermocline (0.020 to 0.062 mg $N \cdot L^{-1}$) and below the thermocline (0.004 to 0.011 mg $N \cdot L^{-1}$) showed a different seasonal variation. In the epilimnion, the values paralleled the total nitrogen pattern while in the hypolimnion the highest values occurred in June and July.

Total phosphorus concentrations in the epilimnion (0.027 to 0.41 mg $P \cdot L^{-1}$) and hypolimnion (0.190 to 0.550 mg $P \cdot L^{-1}$) increased from June to September. During this period the concentrations in the hypolimnion were approximately ten times higher than above the thermocline, probably the result of a reducing environment. The values above and below the thermocline exceeded the Environment Canada guideline of 0.025 mg $P \cdot L^{-1}$. Ortho-phosphorus concentrations (0.049 to 0.088 mg $P \cdot L^{-1}$) obtained from the composite samples showed increases from June to September. In September, the ortho-phosphorus concentration (0.005 mg $P \cdot L^{-1}$) at 5 m was notably lower than the level (0.071 mg $P \cdot L^{-1}$) at 15 m. In 1977, total phosphorus and ortho-phosphorus concentrations in the hypolimnion were higher than in the epilimnion (Noton and Chymko 1978).

Concentrations of reactive silica exhibited a pattern similar to that of total phosphorus. Above the thermocline, the July value of 1.50 $mg \cdot L^{-1}$ increased to 4.00 $mg \cdot L^{-1}$ in September while below the thermocline the values increased from 6.50 to 7.80 $mg \cdot L^{-1}$ for the same period. Slightly higher levels of reactive silica in the hypolimnion also were reported in 1977 by Noton and Chymko (1978). Total organic carbon concentrations ranged from 20.2 to 25.0 mg·L^{-1} and showed no discernible trends.

5.5.2.4 Trace Metals and Other Substances

The concentrations of trace metals and elements generally were below the detection limits even though a reducing environment was present in the hypolimnion. Total iron and total manganese showed the most apparent increases in concentration in the hypolimnion as compared to the epilimnion. In July, total iron concentrations increased from 0.25 mg·L^{-1} at 2 m to 4.50 mg·L^{-1} below the thermocline; the latter value exceeded the ASWQO of 0.30 mg·L^{-1}. During the same period, manganese levels increased from 0.030 mg·L^{-1} at 2 m to 1.660 mg·L^{-1} in the hypolimnion which exceeded the ASWQO of 0.05 mg·L^{-1}. In June, mercury concentrations at 2 m (0.0016 mg·L^{-1}) and 11 m (0.0010 mg·L^{-1}) exceed the ASWQO of 0.0001 mg·L^{-1}. Cyanide concentrations exceeded the ASWQO of 0.01 mg·L^{-1} in July at 2 m (0.042 mg·L^{-1}) and September at 15 m (2.200 mg·L^{-1}). Cyanide, ubiquitous in the aquatic environment, generally is found in trace amounts. The values recorded in Poplar Creek Reservoir, which are considered natural since no anthropogenic input is known, are high and should be checked in future studies. With respect to other parameters, phenol concentrations consistently exceeded the ASWQO of 0.005 mg·L^{-1} with values as high as 0.017 mg·L^{-1}. Oil and grease levels were low, with the highest value being 3.6 mg·L^{-1}.

5.5.3 PHYTOPLANKTON

Phytoplankton cell count and cell volume data for Poplar Creek Reservoir are presented in Appendix G, Table G3. During the three seasons sampled in 1984, numerical abundance of phytoplankton was lowest during the late spring sample period, and highest in the summer (Figure 5.24). Bio-volume of phytoplankton was lowest in the spring, but was similar in the summer and fall sampling periods (Figure 5.25).

In mid-June, the phytoplankton of Poplar Creek Reservoir was dominated by Cyanophyta which contributed approximately 32% to the total cell volume in the sample (Figure 5.24). The dominant species in the group was **Aphanizomenon flos-aquae** which alone accounted for 21% of the total. The second most abundant taxa in the spring was Euglenophyta which was comprised mainly of **Trachelomonas planctonica** and **Phacus** sp. This division contributed about 27% of the total cell volume in the sample. On a numerical basis, the Cyanophyta (64% of total cell numbers) and Chlorophyta (28%) were the predominant divisions.

In the summer sample, Cyanophyta and Euglenophyta continued to be the two most predominant divisions, contributing about 45% and 32% of the total cell volume, respectively (Figure 5.24). The dominant species in each of these divisions were the same as in the spring samples. On a numerical basis, the Cyanophyta by far dominated the sample, contributing about 86% of the total cell numbers. The relative abundance

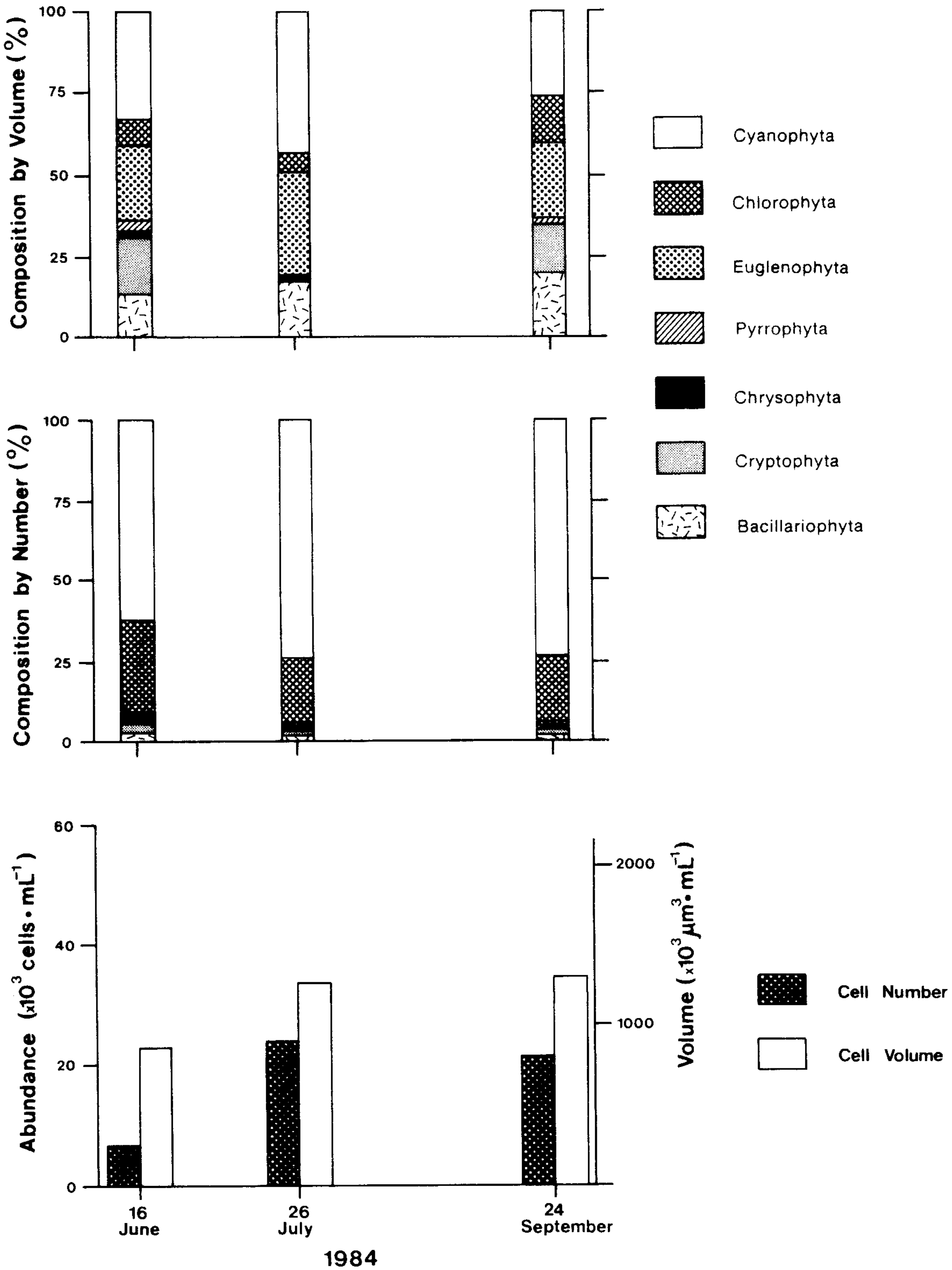


Figure 5.24 Abundance and percent compostion of phytoplankton in Poplar Creek Reservoir, 1984.

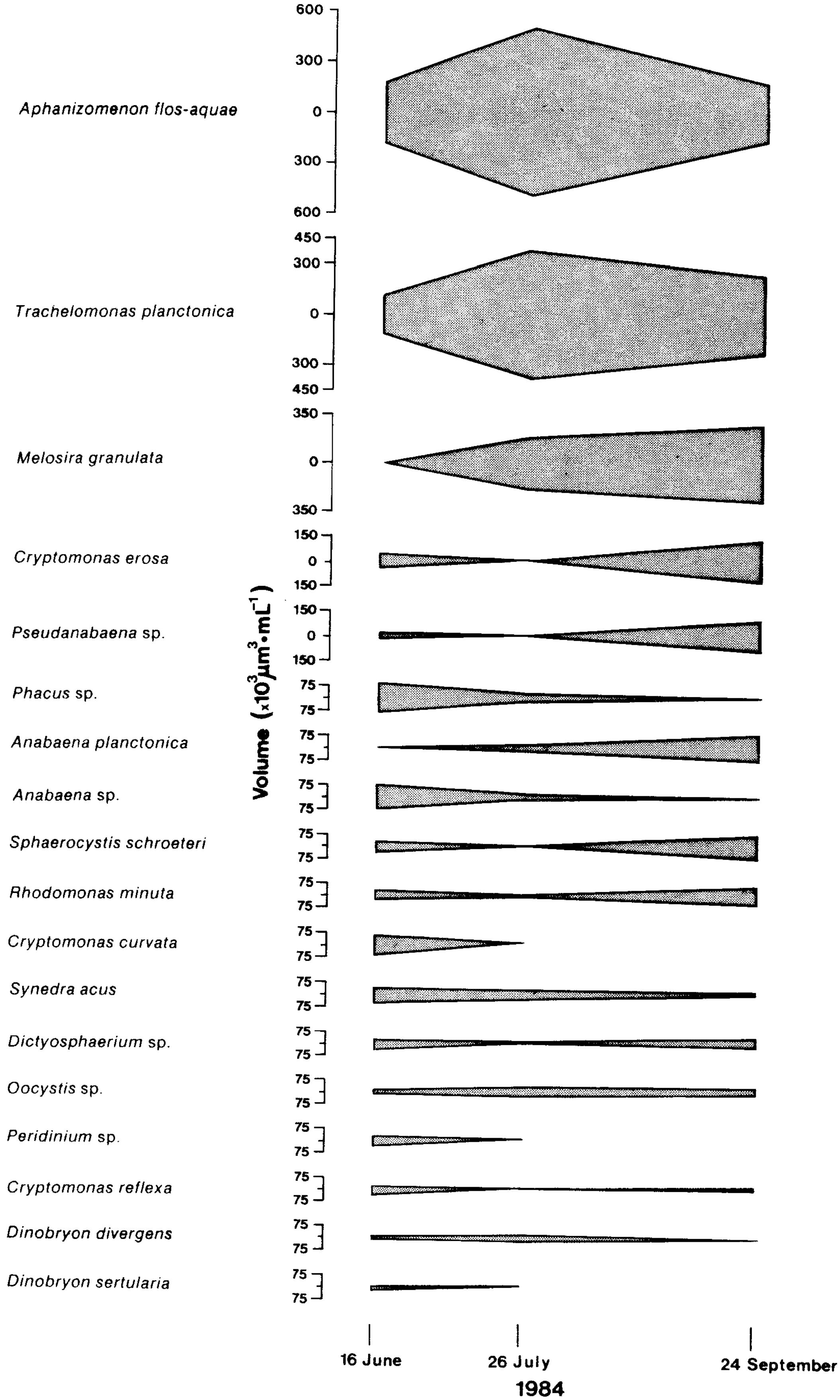


Figure 5.25 Seasonal variation (by volume) of dominant phytoplankton in Poplar Creek Reservoir, 1984.

of Chlorophyta decreased to about 10% of the total. The other divisions present each contributed less than 2% to the total.

In the fall, the bio-volume of phytoplankton in Poplar Creek Reservoir was more evenly distributed among the divisions present. Cyanophyta remained the most abundant, contributing 27% of the total cell volume. **Aphanizomenon flos-aquae** continued to dominate this division, but **Pseudanabaena** sp. contributed a greater proportion of the total cell volume than in previous seasons. The Euglenophyta, primarily composed of **Trachelomonas** sp., again was the second most abundant group (23% of total cell volume), but was followed closely by Bacillariophyta (20%), Chrysophyta (15%), and Chlorophyta (14%). On a numerical basis, the fall phytoplankton samples were again composed primarily of Cyanophyta (75% of total numbers) and Chlorophyta (21%) (Figure 5.24).

Seasonal variation in the bio-volume contribution for major phytoplankton species is shown in Figure 5.25. Both **Aphanizomenon flos-aquae** and **Trachelomonas planctonica** increased in abundance from spring to summer, then decreased in the fall. **Melosira granulata**, a large diatom, was not present in the routine counts in the spring sample, but increased in abundance over the summer and fall period. The relative contribution of most of the other major species present decreased from the spring to summer period, then increased again prior to fall; this is a reflection of the dominance in the sample by **Aphanizomenon**.

Comparisons with phytoplankton data collected in 1977 (Noton and Chymko 1978) indicate that phytoplankton composition followed a somewhat similar pattern during the spring and summer of both years; however, the numbers of Cyanophyta remained high, whereas they decreased considerably in the comparable period (i.e., late September) in 1977. The reason for the difference is not apparent, but may be related to differences in thermal regime or macronutrient levels between the two years.

5.5.4 ZOOPLANKTON

The species composition, numerical abundance, and calculated biomass (excepting nauplii) of crustacean plankton collected at the regular sampling station PCR-Z in Poplar Creek Reservoir are summarized in Table 5.18. Aliquot counts and calculated totals for each sample are included in Appendix C, Table C3. The species composition and numerical abundance of rotifers in the zooplankton samples are summarized in Table 5.19. The total numbers of species identified on all three sampling dates are:

Rotifera	-	17
Cladocera	-	8
Cyclopoida	-	3
Calanoida	-	1
Chaoboridae	-	2

There were fewer commonly occurring crustacean species and more rotiferan species in Poplar Creek Reservoir in 1984 than in 1977 (Noton and Chymko 1978). Of the species occurring in 1984 which would have been considered "common" according to the criteria of these authors, most were less abundant than in 1977. **Daphnia parvula** numbers were

Table 5.18 Species composition, numerical abundance, and calculated biomass of crustacean zooplankton from Poplar Creek Reservoir (Station PCR-Z), 1984. Unbracketed values are number·m^{-3}. Bracketed values are biomass expressed as mg wet weight·m^{-3}.

Species[a]	**16 June**	**24 July**	**24 Sept.**
COPEPODA			
CALANOIDA			
Diaptomus oregonensis LILLJEBORG 1889 A[a]+C	1 391 (38.7)	177 (18.7)	4 259 (363.0)
diaptomid nauplii	1 268	2 673	60
CYCLOPOIDA			
Acanthocyclops vernalis FISCHER 1853 A+ adv.C	532 (9.4)	655 (25.0)	155 (2.3)
Diacyclops thomasi (FORBES) 1882 A+ adv.C	109 (4.0)	873 43.7)	836 26.7)
Mesocyclops edax (FORBES) 1891	1 050 (36.6)	450 (27.8)	155 (12.8)
cyclopoid copepodids, immature C	3 505 (17.8)	14 730 (159.2)	2 579 (20.2)
cyclopoid nauplii	4 460	2 673	1 779
CLADOCERA			
Bosmina longirostris (O.F. MÜLLER) 1785	2 005 (14.5)	21 577 (155.1)	4 358 (42.3)
Ceriodaphnia lacustris BIRGE 1893	0	150 (2.0)	0
Ceriodaphnia quadrangula (O.F. MÜLLER) 1785	0	55 (1.2)	0
Macrothrix hirsuticornis NORMAN & BRADY 1867	4 (0.0)	0	0
Daphnia parvula FORDYCE 1901	146 (3.1)	10 952 (117.4)	2 296 (49.4)
Diaphanosoma leuchtenbergianum FISCHER 1850	127 (2.9)	1 077 (30.7)	75 (2.3)
Alona guttata SARS 1862	4 (0.0)	0	0
Chydorus sphaericus (O.F. MÜLLER) 1785	14 (0.3)	27 (0.2)	0
DIPTERA			
CHAOBORIDAE			
Chaoborus flavicans (MEIGEN) 1830	45	27	4
Chaoborus punctipennis (SAY) 1823	55	9	4
Chaoborus instar I (unident.)	0	27	0
Total[b]	**8 887** **(127.3)**	**50 723** **(581.0)**	**14 713** **(519.5)**

[a] A=adult; C=copepodid, usually I to III; adv.C=advanced copepodids, usually IV & V.
[b] excluding nauplii and non-crustaceans.

much higher in 1984, and **Mesocyclops edax** numbers were slightly higher than at site PCR-1 in 1977, but lower than at site PCR-2 in 1977. Several species of larger crustaceans which occurred commonly in 1977 were not found at all in 1984 samples (**Diaptomus leptopus, Daphnia galeata mendotae, Daphnia pulicaria, Daphnia rosea**), nor did **Diacyclops navus** occur in 1984. Although **Chaoborus** larvae were not listed as present in zooplankton samples in 1977 by Noton and Chymko (1978), the larvae of two species were quite common in the Poplar Creek Reservoir zooplankton samples in 1984.

5.5.4.1 Rotifera

The abundance and composition of the rotiferan forms are summarized in Table 5.19. The rotifers in Poplar Creek Reservoir were dominated by **Keratella** spp. throughout the sample period. The shift from **K. earlinae** as the dominant in June to **K. cochlearis** as the dominant in September was evident in Poplar Creek Reservoir, as it was in nearby Beaver Creek Reservoir and Ruth Lake. In comparison with the previous study (Noton and Chymko 1978), total numbers were higher in June and September compared to 1977, but greatly decreased in July (Figure 5.26). In view of the greatly fluctuating rotifer numbers noted in 1977 by Noton and Chymko (1978), present values are not considered to be biologically significantly different from those in 1977. High numbers of **Chaoborus** larvae in July could have been responsible, in part, for the very low numbers of rotifers present at that time.

Table 5.19 Species composition and numerical abundance of rotifers in the zooplankton of Poplar Creek Reservoir (Station PCR-Z), 1984.

Species	**15 June ($No.\cdot m^{-3}$)**	**24 July ($No.\cdot m^{-3}$)**	**23 Sept. ($No.\cdot m^{-3}$)**
Keratella cochlearis (GOSSE 1851)	22 013	82	124 361
Keratella earlinae AHLSTROM 1943	43 918	1 050	2 006
Keratella quadrata (O.F. MÜLLER 1786)	6 629	109	2 054
Notholca acuminata (EHRENBERG 1832)	0	123	0
Euchlanis dilatata EHRENBERG 1832	41	82	0
Euchlanis mikropous KOCH-ALTHAUS 1962	0	123	0
Trichocerca multicrinis (KELLICOTT 1897)	0	191	0
Brachionus calycifloris PALLAS 1766	887	0	0
Brachionus quadridentatus (HERMANNS 1783)	382	0	334
Asplanchna priodonta GOSSE 1850	737	109	1 528
Synchaeta pectinata (?) EHRENBERG 1832	3 873	0	4 012
Synchaeta oblonga (?) EHRENBERG 1831	0	0	1 003
Gastropus (?) sp.	0	109	0
Filinia longiseta (EHRENBERG 1834)	191	0	6 137
Polyarthra dolichoptera IDELSON 1925	900	123	2 054
Polyarthra vulgaris CARLIN 1943	22 150	0	0
Conochilus unicornis ROUSSELET 1892	0	0	1 337
Total	**101 844**	**1 978**	**144 826**

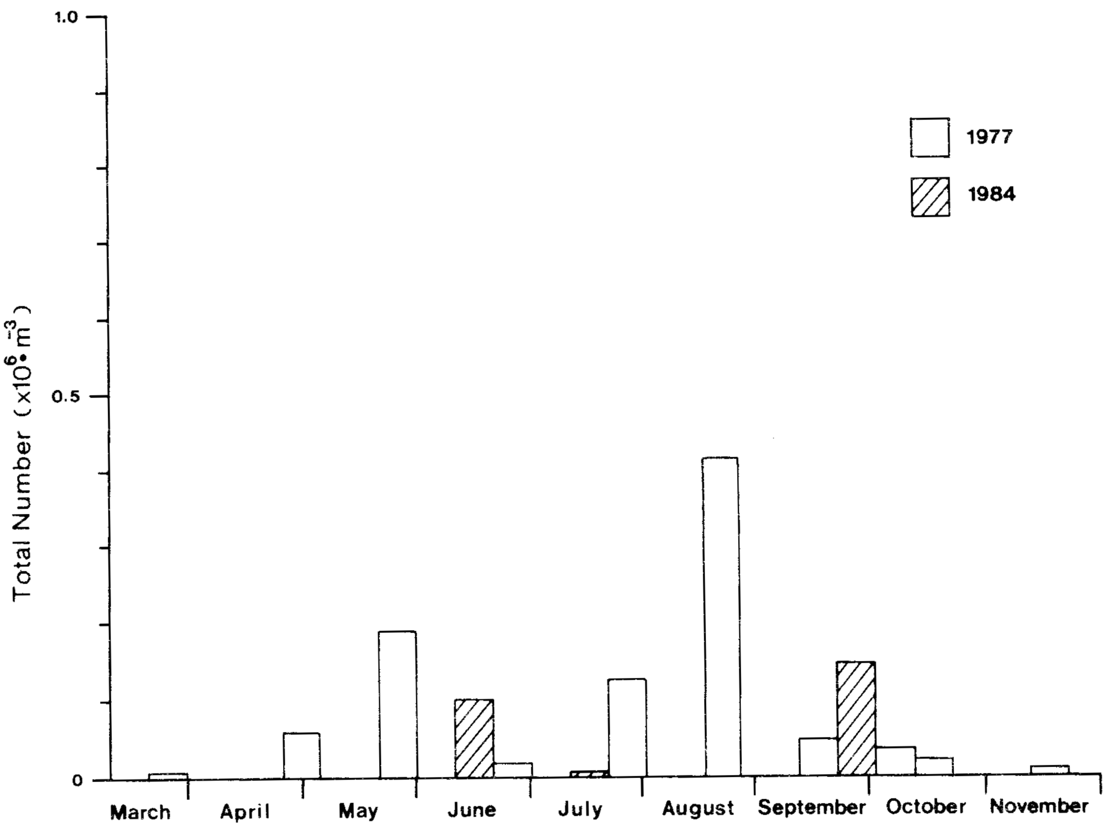


Figure 5.26 Abundance of Rotifera in Poplar Creek Reservoir in 1984 (present study) and 1977 (Station PCR-1; Noton and Chymko 1978).

5.5.4.2 Cyclopoida

During 1984 there was a shift in dominance in the cyclopoid fauna from **Acanthocyclops vernalis** in June to **Diacyclops thomasi** in September. **Mesocyclops edax** showed a pattern similar to **A. vernalis.** This pattern, in general, was similar to that observed in Poplar Creek Reservoir in 1977 (Noton and Chymko 1978). Cyclopoid adult numbers were considerably smaller in 1984 than those reported for 1977. Lower cyclopoid adult numbers in 1984 could be due, in part, to heavier feeding by fathead minnows or other small plankton feeding fish. Numbers of cyclopoid copepodid stages I - III were higher in 1984 than in 1977. **Diacyclops navus** occurred in small numbers in Poplar Creek Reservoir in 1977, but was not found in the 1984 samples. It is difficult to distinguish early copepoidids of **A. vernalis** from **D. navus**; therefore, it is certainly possible that the latter species still occurs in this waterbody in low numbers.

5.5.4.3 Calanoida

The only calanoid found in the 1984 samples was **Diaptomus oregonensis**. Although samples were collected on only three dates, the population structure suggests two main growth and reproduction periods - one in late spring and one in early fall (Table 5.18). Total numbers of this species were much lower than those reported by Noton and Chymko (1978). **Diaptomus leptopus,** found in low numbers in spring in 1977, did not occur in the 1984 samples. The absence of **D. leptopus** in spring may have permitted a spring pulse of **D. oregonensis**, and the presence of the predaceous **Chaoborus** larvae in 1984 may have been partly responsible for the lower total numbers of **D. oregonensis**.

5.5.4.4 Cladocera

There seems to have been a shift to smaller body size among Poplar Creek Reservoir cladocerans. Of the three most common species collected in 1984, **Daphnia parvula** numbers were much greater than in 1977, **Bosmina longirostris** numbers were about the same, and **Diaphanosoma leuchtenbergianum** numbers were lower. The three larger **Daphnia** spp., (i.e., **D. pulicaria**, **D. rosea**, and **D. galeata mendotae**), which made up a large part of the late spring and early summer zooplankton biomass in 1977, were not found in 1984. Other cladoceran species contributed little to the total crustacean biomass in 1984.

5.5.4.5 Chaoboridae

Two species of **Chaoborus** were identified in the zooplankton sampling from Poplar Creek Reservoir. **C. flavicans**, the larger of the two, and **C. punctipennis** were present in similar numbers on all three samples dates. In July, however, nearly half of all larvae were first instars. **Chaoborus** larvae were not indicated as present in the zooplankton by Noton and Chymko (1978), although **C. flavicans** was reported as abundant in the benthic samples. **Chaoborus** larvae may remain in or near the sediments when the water above is well oxygenated, but may move up into the water more actively as oxygen levels decrease. The presence of these larvae in the plankton of Poplar Creek Reservoir in 1984 is indicative of low oxygen in the hypolimnetic water and/or the relative absence of plankton feeding fish in the deeper open waters. **Chaoborus** larvae are known to have a large impact on the species composition and abundance of crustacean plankters (e.g., Anderson 1980, 1981; Anderson and Raasveldt 1974). Lake conditions contributing to the increased presence of **Chaoborus** in the limnetic zone may indirectly influence the diversity and abundance of zooplankton.

5.5.4.6 Total Numbers and Biomass of Crustacean Plankton

In the three months for which data comparisons are possible between 1984 and 1977 (i.e., June, July, and September) for Poplar Creek Reservoir, there is little change in either numerical abundance or crustacean biomass (Figure 5.27). The biomass contributions from larger numbers of early cyclopoid copepodids and **Daphnia parvula** in 1984 appear to have compensated for the reduced biomass resulting from declines in several other species.

5.5.5 ZOOBENTHOS

Three taxa dominated the benthos of Poplar Creek Reservoir. Oligochaeta and Chironomidae were equally well represented at shallow depths (1 to 3 m) during all three seasons sampled (Figure 5.28). At

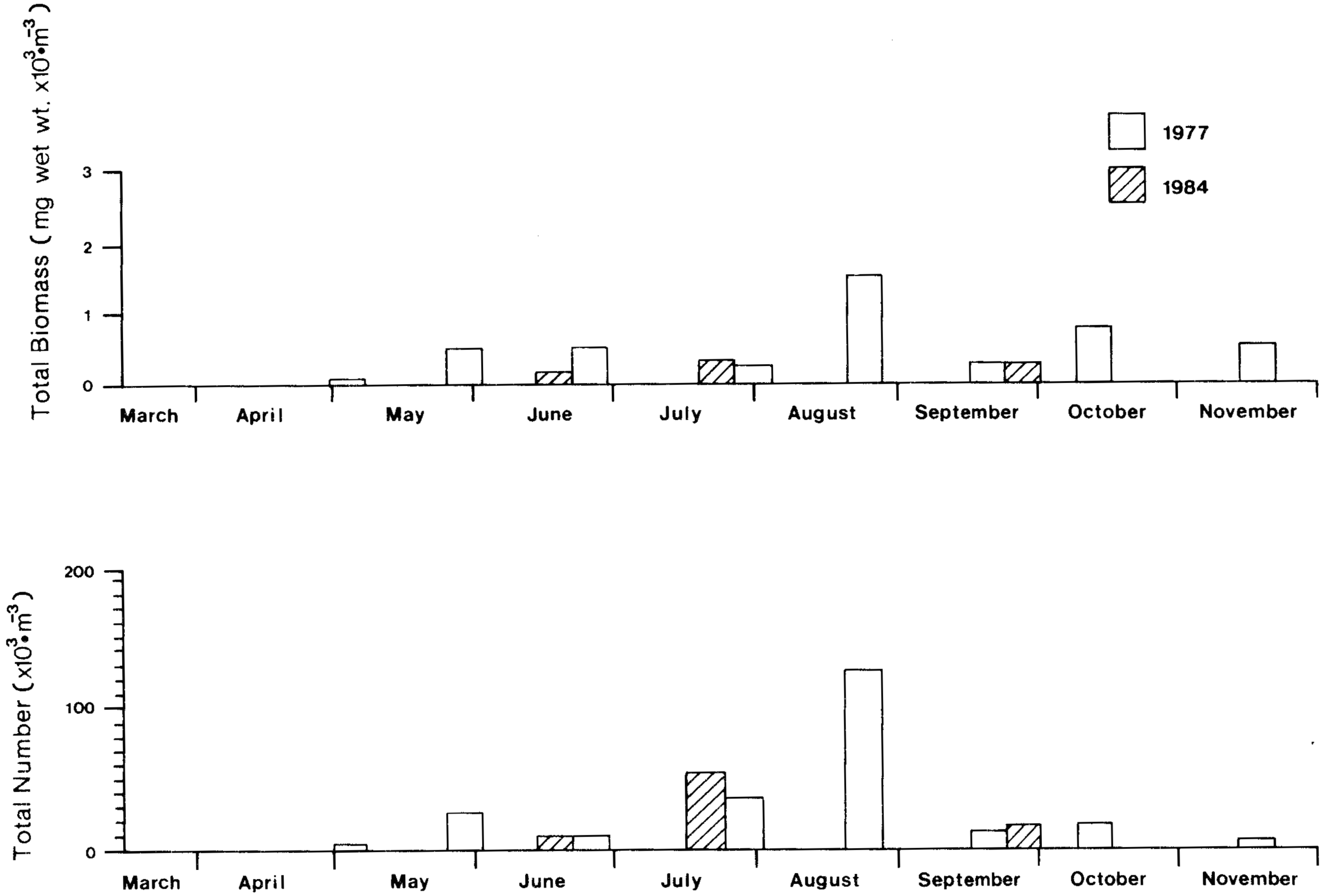


Figure 5.27 Total number and biomass of crustacean zooplankton in Poplar Creek Reservoir in 1984 (present study) and 1977 (Station PCR-1; Noton and Chymko 1978).

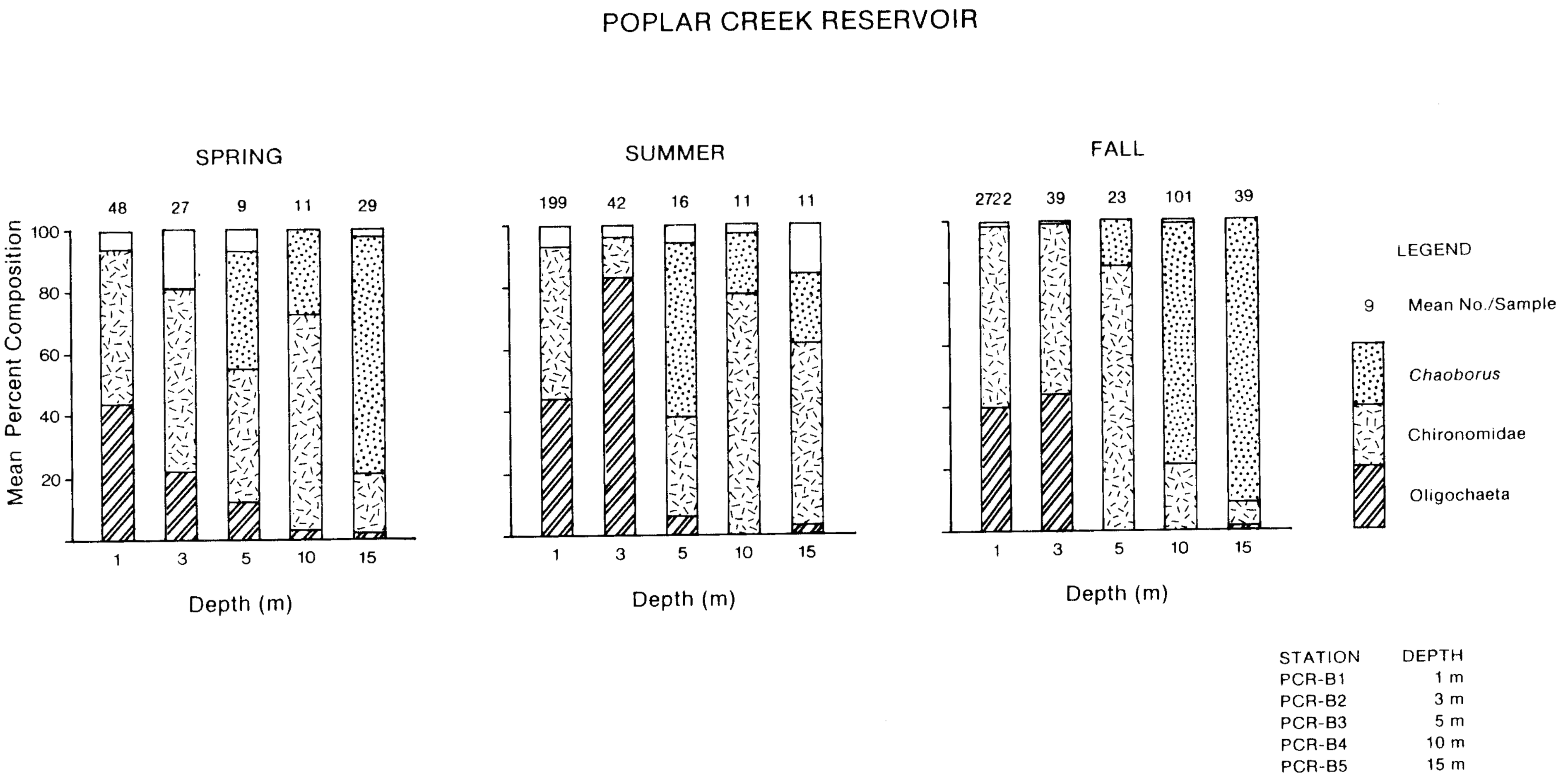


Figure 5.28 Relative abundance of major taxonomic groups of benthic invertebrates in Poplar Creek Reservoir, 1984.

depths of 5 m or greater, **Chaoborus** appeared in significant proportion, and was the most abundant organism at the deepest station in both spring and fall. Oligochaeta was present in very low densities at depths greater than 5 m.

Diversity was greatest at intermediate depths (3 to 5 m) in spring and summer, partially reflecting the codominance of the three major taxa (Table 5.20). Greatest numbers of taxa were collected from the 1 m sample station. Richness was greatest in fall at this station, but was maximal in spring at deeper stations.

Benthic densities and biomass generally increased from spring to fall, and decreased with increasing depth (Table 5.20). Detailed tables of taxonomic composition, size distribution and biomass are presented in Appendix D; Tables D22 to D26 and D36).

Noton and Chymko (1978) examined the benthos of Poplar Creek Reservoir at monthly intervals in 1977. The transect of the present study corresponds in location to their "special benthos" stations 1 to 5, although specific depths sampled differ slightly. The location of station PCR-B5 (15 m depth) sampled in 1984 was roughly similar to Noton and Chymko's PCR-1 and special benthos station 1. These authors reported very low densities of animals (usually less than 10 individuals per Ekman grab). Density estimates at the 15 m station usually slightly exceeded their values during comparable seasons; this probably reflects retention of small animals due to use of a finer mesh sieve bucket in the present study

Table 5.20 Mean density (no. per sample), mean biomass (mg per 0.1 m^2), diversity, and taxonomic richness of zoobenthos in Poplar Creek Reservoir, 1984.

Station	Depth		Spring	Summer	Fall
PCR-B1	1	Density	47.7	199.3	2 722.3
		Biomass	39.8	84.5	976.8
		Diversity	1.363	1.521	1.219
		Richness	7	18[a]	26[a]
PCR-B2	3	Density	27.0	42.3	38.6
		Biomass	17.3	30.8	28.3
		Diversity	1.689	0.819	0.992
		Richness	7	4	2
PCR-B3	5	Density	8.6	16.4	22.6
		Biomass	11.9	91.6	96.4
		Diversity	1.752	1.906	0.600
		Richness	5	5	2
PCR-B4	10	Density	11.3	10.9	101.3
		Biomass	88.7	105.2	154.3
		Diversity	1.163	1.034	0.583
		Richness	4	4	4
PCR-B5	15	Density	28.5	10.9	38.9
		Biomass	63.7	52.0	64.0
		Diversity	1.173	1.795	0.466
		Richness	7	6	3

[a]Includes taxa collected in shoreline sweeps.

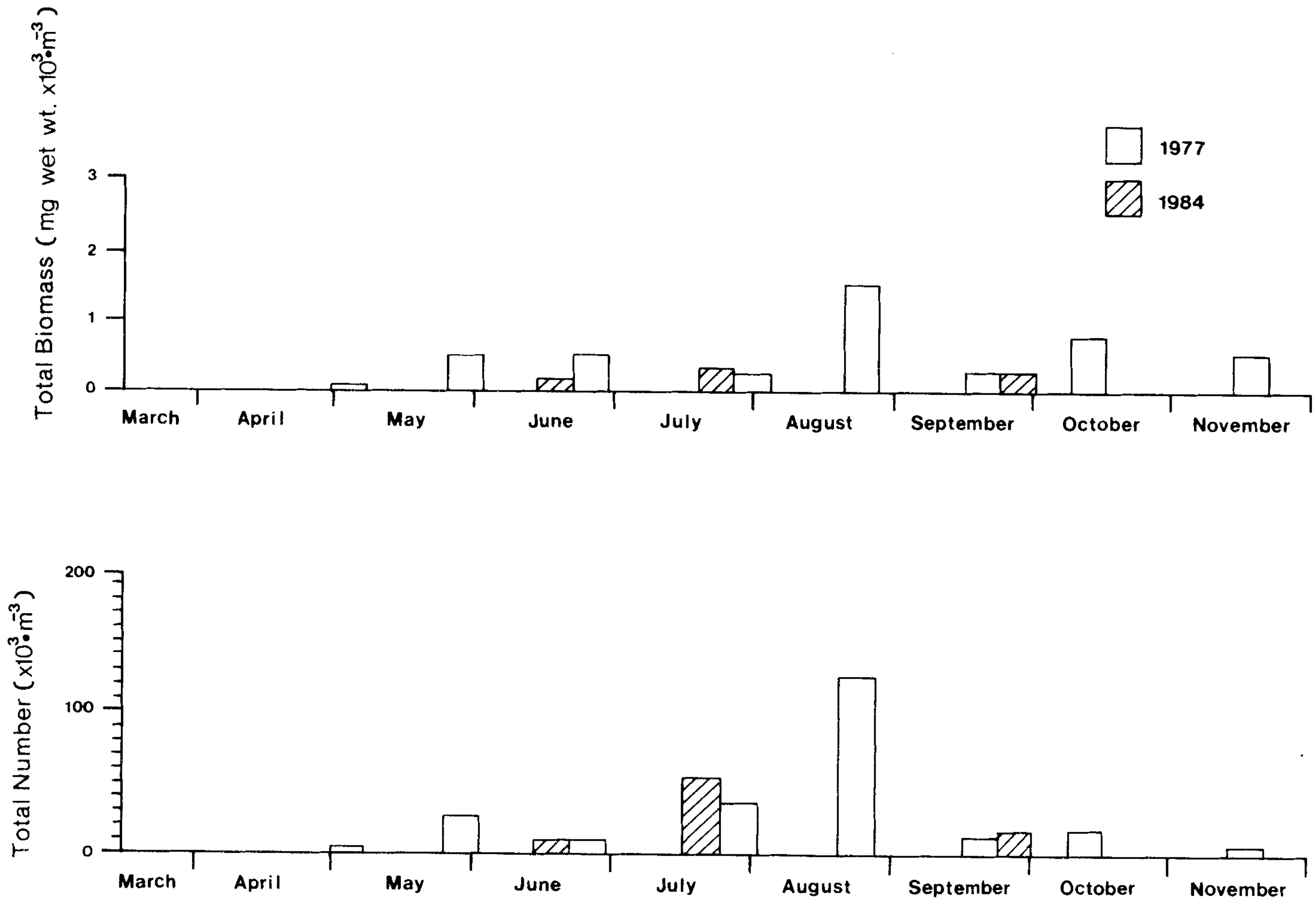
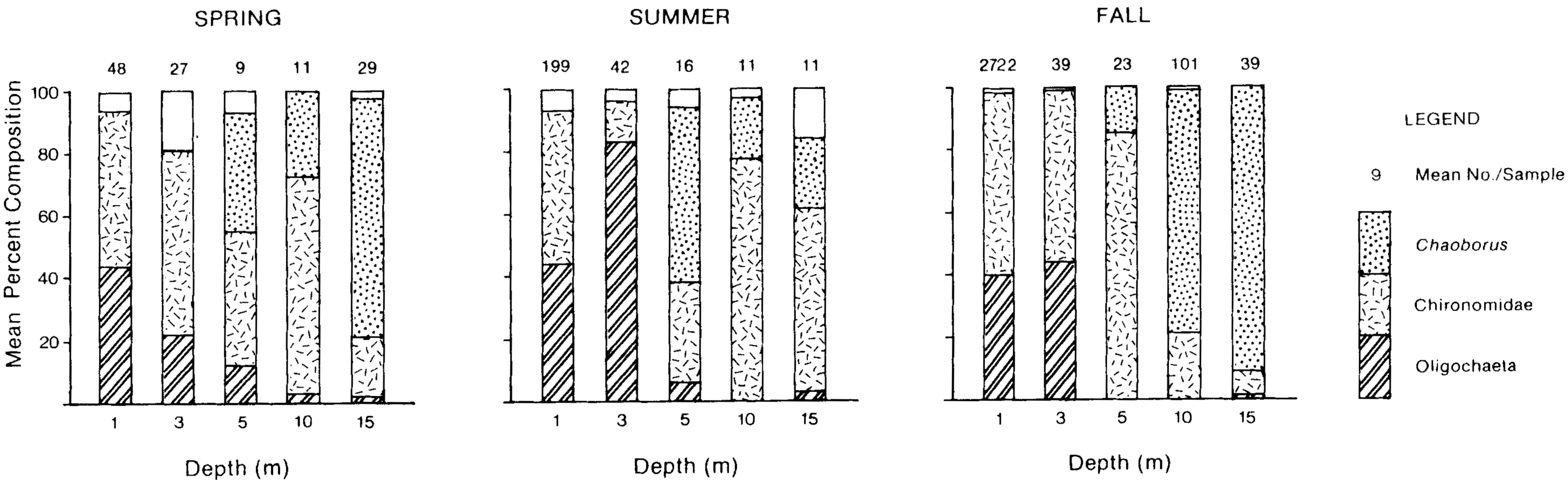


Figure 5.27 Total number and biomass of crustacean zooplankton in Poplar Creek Reservoir in 1984 (present study) and 1977 (Station PCR-1; Noton and Chymko 1978).

POPLAR CREEK RESERVOIR



STATION	DEPTH
PCR-B1	1 m
PCR-B2	3 m
PCR-B3	5 m
PCR-B4	10 m
PCR-B5	15 m

Figure 5.28 Relative abundance of major taxonomic groups of benthic invertebrates in Poplar Creek Reservoir, 1984.

(0.250 mm vs. 0.650 mm). Similar results were obtained comparing 1984 summer samples across depth with those of their August 1977 special benthos transect.

Relative abundance of species has changed since the 1977 survey. Noton and Chymko (1978) found a preponderance of Chironomidae across their summer transect. Oligochaeta occurred in greatest abundance at moderate (6 to 8 m) depths, but never in proportions exceeding 25%. **Chaoborus** were present in all months except June, but were only abundant in fall. In August, they were found at all but the greatest depths (only four animals were collected from that station), but were most abundant at 8 m depths. In contrast, the present study showed dominance of Oligochaeta in shallow regions, and proportionately more abundant **Chaoborus** at depths of 5 m or more during the three seasons sampled. A shift towards increasing representation by Oligochaeta suggests increasing organic content of the substrate (see Section 5.3.5), and probably represents maturation of the reservoir. Increased organic material also produces greater use of oxygen during decomposition, and this may be expected to contribute substantially to any hypolimnetic oxygen deficit that may occur during summer stratification. **Chaoborus** are adapted to minimal substrate oxygen conditions; their increased abundance at shallower depths suggests that the duration of summer anoxia is becoming extended, possibly because of organic enrichment of the reservoir.

5.5.6 FISH

5.5.6.1 Species Composition and Relative Abundance

Three fish species were present in Poplar Creek Reservoir in 1984 (Appendix E, Tables E6 and E7). Brook stickleback (85.1%) was the most abundant species in the combined catch (all sample methods) followed by white sucker (11.2%) and fathead minnow (3.7%). The catch in seines was comprised almost totally (95.8%) of brook stickleback with fathead minnow being a minor (4.2%) component in the catch. White suckers were absent from the seine catch; however, adult and juvenile white suckers dominated (100%) the catch from gill nets (Table 5.21).

Table 5.21. Percentage composition of fish species recorded from Poplar Creek Reservoir, 1984.

Species (n)[a]	Capture Methods: Seine (190)	Capture Methods: Gillnet (24)	Combined Total (214)
White sucker	0	100.0	11.2
Fathead minnow	4.2	0	3.7
Brook stickleback	95.8	0	85.1

[a]Number of fish captured

Catch per unit effort (CUE) data derived for seining efforts suggest that densities of fathead minnows and brook stickleback have declined substantially since 1981 (Appendix E, Table E8). Fathead minnow capture rates declined slightly from 1978 to 1981; in 1984 this species was nearly absent from the catch. Brook stickleback exhibited a substantial increase in CUE from 1978 to 1981; however, in 1984, densities of this species had declined to below 1978 levels. The reasons for the reduced populations of these species are unknown. The presence, in 1984, of y-o-y and juveniles of both species suggests successful recruitment to these populations still occurs in Poplar Creek Reservoir, although apparently at reduced levels relative to previous years.

White suckers (adults and juveniles) were present in the 1984 gillnet catch at densities comparable to those recorded in 1981 (Appendix E, Table E9). Capture rates, however, were relatively low (in both years) in comparison to Beaver Creek Reservoir and Ruth Lake. The absence of y-o-y of this species, indicates primarily a feeding use of the reservoir, with this population likely originating from upstream waterbodies (i.e., Beaver Creek Reservoir or Ruth Lake) within the diversion system.

5.5.6.2 Age Structure of White Sucker Population

The length-frequency distribution of white suckers captured in Poplar Creek Reservoir is presented in Appendix E, Table E10. Although low numbers of white suckers were captured in the reservoir, the data indicate that the population sample was comprised of four year-classes: 1983 (age one), 1982 (age two), and 1981 (age three), and 1980 (age four). Most of the fish sampled were in the age one to age three range. A preponderance of the younger age-groups also was noted in earlier studies (O'Neil 1979; 1982). It appears that Poplar Creek Reservoir serves only a rearing function (for the Beaver Creek Reservoir population).

Alternatively, the reservoir may not be capable of supporting white suckers (entering from the upper diversion system) beyond a certain size (i.e., due to habitat limitations).

5.6 POPLAR CREEK

5.6.1 AQUATIC HABITAT

5.6.1.1 Description of Drainage Area

Poplar Creek was integrated into the Beaver Creek diversion system in 1976 following completion of the Poplar Creek spillway (Figure 2.4). A 1.8 km section of Poplar Creek downstream of the spillway has been channelized to accommodate increased flows from the diversion system. Approximately 200 m of the altered section occurs below Highway 63 (including two drop structures). The channelized section extends 1.6 km upstream to the diversion stilling basin. Nine drop structures are located in this section. Upstream of the stilling basin and below Highway 63 the stream returns to its original channel. The headwaters of Poplar Creek are located in the Thickwood Hills. From this source, the stream flows north then east for 28 km prior to its confluence with the outflow from the Beaver Creek Diversion System. This section upstream of the stilling basin is referred to as Upper Poplar Creek and the section downstream is referred to as Lower Poplar Creek.

5.6.1.2 Streamflows During Study Period

A Water Survey of Canada gauging station is located on Lower Poplar Creek (at the Highway 63 crossing). It is situated approximately 2.3 km upstream from the confluence of Poplar Creek with the Athabasca River (Figure 2.4). The hydrograph for the period 1 May to 27 September 1984 is illustrated in Figure 5.29. The peak discharge in this period was 12.5 $m^3 \cdot s^{-1}$ which occurred on 6 June. Two minor peaks occurred during the summer months (3.09 $m^3 \cdot s^{-1}$ on 8 July and 0.94 $m^3 \cdot s^{-1}$ on 14 August). From late August to the end of the recording period, stream discharge was low and stable (range: 0.3 to 0.4 $m^3 \cdot s^{-1}$).

Field measurement of discharge was undertaken on Poplar Creek at station PC-W3 situated upstream of the stilling basin (Figure 2.4). Discharge at this station was compared to the total flow recorded at the lower gauging station (Appendix B, Table B3). Discharge from Upper Poplar Creek (above the diversion system) contributed 16.5% (18 June), 20.4% (26 July) and 31.8% (23 September) of the total flow in the system on these dates. Actual flow rates in Upper Poplar Creek during the three measurement periods were as follows: 0.69 $m^3 \cdot s^{-1}$ (18 June), 0.30 $m^3 \cdot s^{-1}$ (26 July), and 0.07 $m^3 \cdot s^{-1}$ (23 September).

5.6.1.3 Habitat Zonation

Prior to alteration resulting from the Beaver Creek Diversion, aquatic habitat in Poplar Creek was evaluated by Griffiths (1973) and

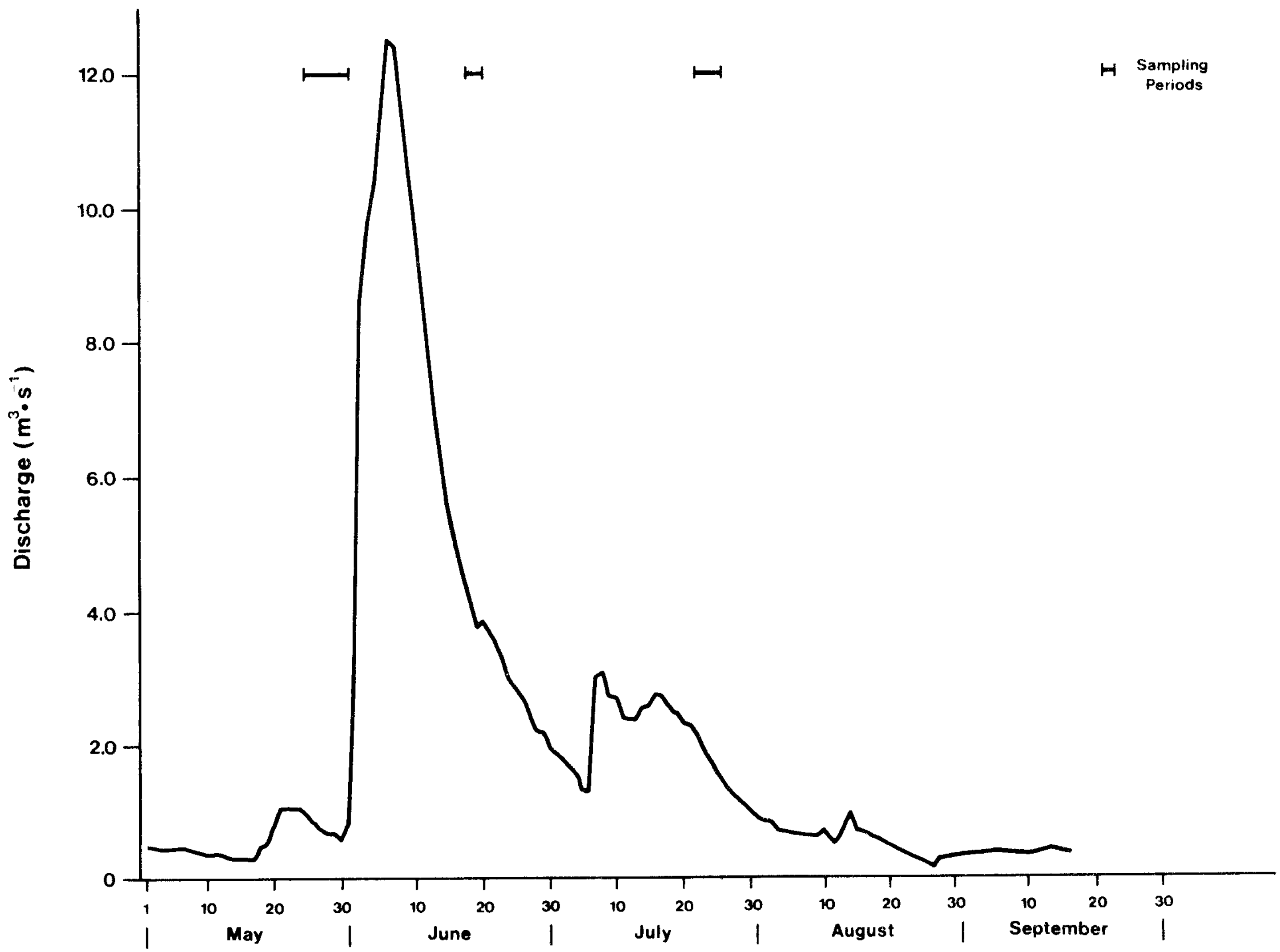


Figure 5.29 Poplar Creek hydrograph, 1 May to 16 September 1984 (based on preliminary Water Survey of Canada data for Station No. 07DA007).

Syncrude Canada Ltd. (1975). Griffiths (1973) assigned a preliminary Class 4 rating (Canada Land Inventory system) to Poplar Creek; this indicates the presence of low quality habitat. Syncrude Canada Ltd. (1975) conducted a systematic habitat evaluation of Poplar Creek. Transects were located from the vicinity of Ruth Creek downstream to near the confluence of Poplar Creek with the Athabasca River. On the basis of these data, Poplar Creek was separated into two discrete reaches (Syncrude Canada Ltd. 1975). The lower reach, which was 4.25 km in length, extended upstream from the mouth to a location near the present stilling basin. This reach was characterized by low gradient ($3.2\ m{\cdot}km^{-1}$), a predominance of Flat habitat, and sand-silt substrate. Associated fish sampling indicated that this reach was not utilized to a appreciable extent by sportfish species (e.g., Arctic grayling). The upper reach extended upstream from below the stilling basin to beyond Ruth Creek (Figure 2.4). This section, which was 1.42 km in length, was characterized by a higher gradient ($5.3\ m{\cdot}km^{-1}$). As such, it contained a greater diversity of cover types (riffles, pools, etc.) and substrates (gravel, cobble, sand/silt).

Noton and Chymko (1978) re-evaluated habitat conditions in Poplar Creek in 1977, one year following channel alteration. The upper reach displayed negligible change since 1974, apart from a rise in water level in the section immediately above the stilling basin (approximately 100 m in length). This was due to the ponding of water behind the initial drop structure (Drop Structure No. 11). Substantial changes were noted in the downstream reach due to channelization and placement of 11 drop structures. The newly created channel was wider, shallower, exhibited higher velocities (localized), and was more diverse with respect to the distribution of cover types and substrate. Two major cover types were described within the channelized section: riffle situated immediately below drop structures, and pool (Flat according to present scheme) in the intervening reach between drop structures. Following the diversion, three reaches were evident: 1) original channel downstream of Highway 63; 2) channelized section; and 3) original channel upstream of the stilling basin. O'Neil (1979, 1982) conducted fishery investigations within these various reaches to define differences in the type and extent of use by fish populations.

In the present study gradient mapping and on-site investigations were conducted in order to delineate and describe habitat reaches. Five discrete habitat reaches were identified (Figure 5.30). Of the five reaches, two (R2, R3) were investigated in detail in the present study. The results obtained at habitat stations located in these reaches (H1 to H3) are described in Table 5.22.

Reach 1 (km 0 to 2.1)

Reach 1 is a low gradient reach (2.5 $m \cdot km^{-1}$) extending from the Poplar Creek-Athabasca River confluence to approximately 200 m below the Highway 63 crossing. Apart from the initial section immediately below Drop Structure No. 1 (which features accelerated bank erosion) the channel does not appear to have been altered from its pre-diversion state. Reach 1 is characterized by predominantly Flat habitat and sand-silt

Table 5.22 Summary of physical habitat characteristics at sampling stations on Poplar Creek, September 1984.

Station	Date	Water Temp(°C) (Time)(h)	Channel Features at Transect: Rooted Width (m)	Wetted Width (m)	Local Gradient (%)	Mean Depth (cm)	Mean Velocity ($cm \cdot s^{-1}$)	Discharge ($m^3 \cdot s^{-1}$)	Cover Type Distribution (%): Riffle	Run	Flat	Pool Type 1	2	3	4	5
H1-T1[c]	6 Sept.	11 (1200)	19.0	10.6	0.5	65 (56-74)	7 (5-12)	11.6[a]	-	-	100	-	-	-	-	-
-T2[c]	6 Sept.	11 (1020)	14.5	10.6	1.5	21 (19-25)	21 (9-30)	-	-	80	-	20	-	-	-	-
-T3[c]	6 Sept.	11 (1120)	15.0	12.0	5.0	17 (13-25)	25 (18-38)	-	71	-	-	29	-	-	-	-
-T4[d]	6 Sept.	11 (1320)	16.0	9.4	-	35 (26-42)	11 (5-18)	-	-	55	-	45	-	-	-	-
-T5[d]	6 Sept.	11 (1245)	14.2	9.7	5.0	11 (7-15)	76 (53-99)	-	89	-	-	11	-	-	-	-
H2-T1	23 Sept.	4.5 (1034)	11.6	6.1	0.25	27 (13-32)	4 (1-7)	-	-	-	100	-	-	-	-	-
-T2	23 Sept.	-	18.0	8.0	L0.25	104 (67-150)	2 (1-3)	-	-	-	100	(Beaver pond)			-	-
-T3	23 Sept.	4.5 (1125)	9.0	6.0	L0.25	150+	-	-	-	-	100	(Beaver pond)			-	-
-T4	23 Sept.	4.5 (1139)	6.8	6.8	0.25	57 (46-64)	3	-	-	-	100	(Beaver pond)			-	-
-T5	23 Sept.	4.5 (1202)	7.5	6.8	0.25	59 (50-69)	3 (2-4)	-	-	-	100	(Beaver pond)			-	-
H3-T1	22 Sept.	6 (1550)	9.0	7.0	0.5	13 (0-23)	9 (0-17)	0.7	-	58	42	-	-	-	-	-
-T2	22 Sept.	6 (1700)	9.2	5.0	1.0	12 (4-23)	17	-	45	29	-	26	-	-	-	-
-T3	22 Sept.	6 (1710)	8.4	5.1	1.0	27 (13-32)	15 (4-25)	-	36	14	-	50	-	-	-	-

Station	Bank Features (RUB/LUB): Cond. (%)	Stab. (No.)	Under. (cm)	Slope (Deg.)	Cover (No.)	Depth (cm)	Over. (cm)	Substrate Distribution (%): Sand	Silt	FG	MG	CG	VCG	SC	LC	SB	LB (BR)	EMB. (No.)	Aquatic Veg.: Macro. (No.)	Algae (No.)
H1-T1	0/0	4/4	0/0	150/150	2/2	0/0	0/0	57	16	-	-	-	-	-	9	9	9	3	2	1
-T2	0/0	4/4	0/0	145/155	1/1	5/0	0/0	-	-	-	-	-	-	-	28	72	-	2-4	1	1
-T3	0/0	4/4	0/0	150/155	1/1	0/0	0/0	-	-	-	-	-	-	-	33	67	-	5	1	1
-T4	20/20	3/3	0/0	160/140	2/2	0/0	0/0	-	-	-	-	-	-	-	53	47	-	4	1	5
-T5	0/0	4/4	0/0	150/160	1/1	0/0	0/0	-	-	-	-	-	-	-	-	-	100	5	1	5
H2-T1	30/40	2/1	0/0	130/150	2/1	0/0	0/0	- 100 -		-	-	-	-	-	-	-	-	N/A[e]	1	2
-T2	40/100	2/1	0/0	160/90	2/2	0/0	0/0	- 100 -		-	-	-	-	-	-	-	N/A	1	1	
-T3	80/20	3/2	0/0	95/145	2/2	134/0	25/0	- 100 -		-	-	-	-	-	-	-	-	N/A	1	1
-T4	80/70	3/1	0/0	120/120	2/2	47/33	35/50	- 100 -		-	-	-	-	-	-	-	-	N/A	1	1
-T5	60/80	2/2	0/10	105/105	2/3	3/31	40/25	- 100 -		-	-	-	-	-	-	-	-	N/A	1	1
H3-T1	60/60	2/2	0/0	110/130	1/1	0/0	0/30	17	-	-	-	66	17	-	-	-	-	1	1	1
-T2	30/40	3/2	0/70	125/90 (40)[b]	2/3	0/34	0/35	20	-	-	-	40	20	-	20	-	-	3-4	1	1
-T3	70/10	1/4	0/8	75/90 (55)[b]	2/2	0/24	0/32	61	-	-	-	-	-	39	-	-	-	3	1	1

[a]WSC Station No. 07DB001 (preliminary data; 6 September).
[b]Angle of undercut in parentheses.
[c]Transects below Drop Structure No. 5.
[d]Transects below Drop Structure No. 11.
[e]N/A - not applicable.
Note: Description of terms in Table 2.2.

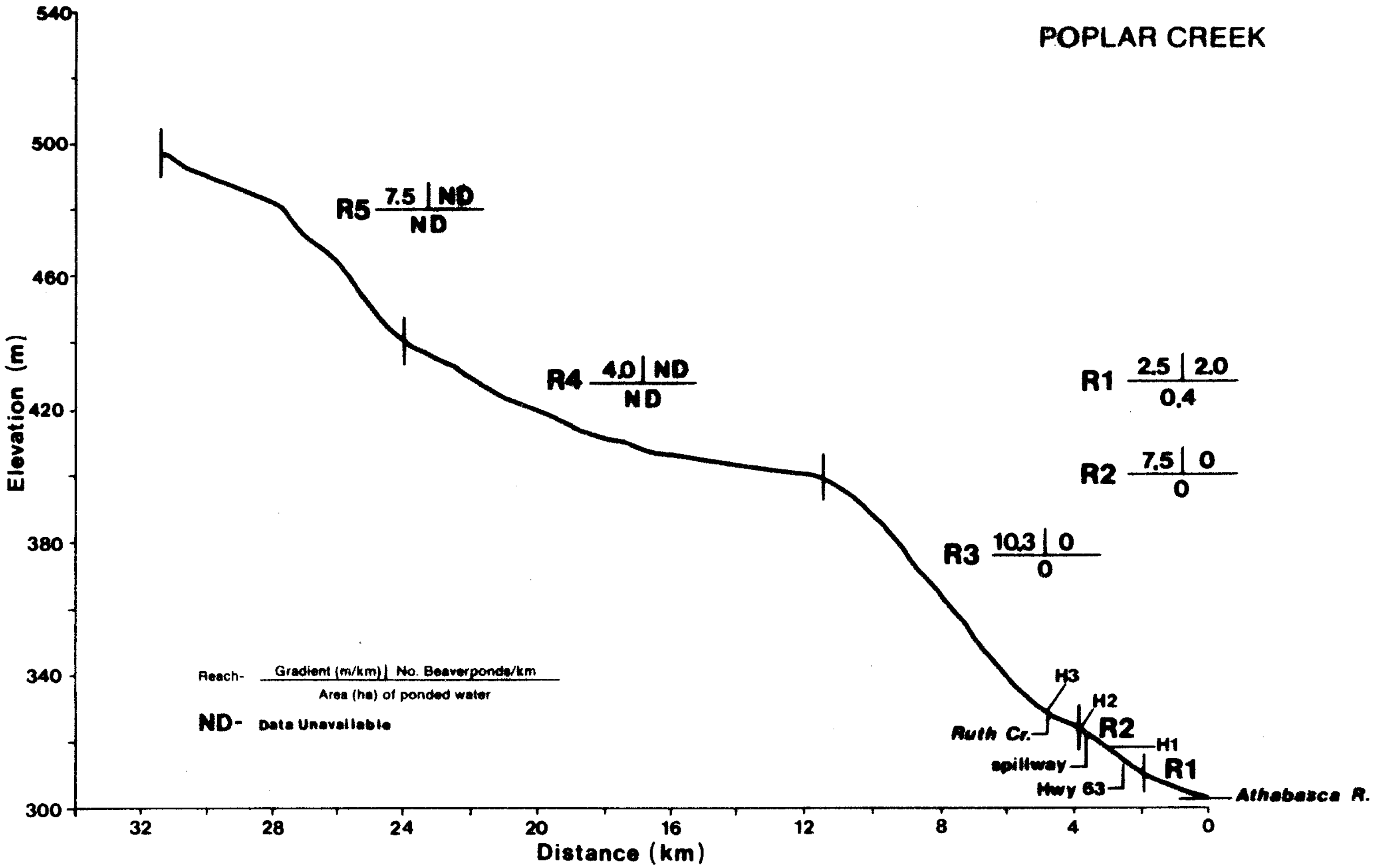


Figure 5.30 Longitudinal profile and habitat zonation, Poplar Creek.

substrate. Vegetative debris accumulations in the channel and dense bank vegetation (willow, alder, overstory species) also are characteristic.

Reach 2 (km 2.1 to 3.9)

Reach 2, 1.8 km in length, includes the channelized section of Poplar Creek (Plate 9). The distribution and diversity of cover types within the section are related to and controlled by the presence of 11 drop structures (Figure 2.4). Three major habitat cover types are associated with each of the drop structures. Riffle cover type occurs within and immediately downstream of drop structures, followed by Run. Noton and Chymko (1978) determined that these cover types in combination contributed 20% of the channel distance between drop structures. Flat cover type encompasses the majority (approximately 80%) of the habitat between drop structures. Data from station H1 provide a description of physical characteristics of the three major cover types (Riffle, Run, Flat). Transects T3 and T5 were situated in Riffle habitat at the top end of drop structures No. 5 and 11, respectively. Transects T2 and T4 were situated in Run habitat below T3 and T5, respectively. Transect T1 was located in Flat cover type below Drop Structure No. 5.

Channel width at the five transects was variable. Rooted width ranged from 14.2 m to 19.0 m. Wetted width varied between 9.4 m and 12.0 m. Lower values were associated with the upper transects (i.e., DS No. 11). Mean depths at transects varied according to cover type: Riffle (11 to 17 cm), Run (21 to 35 cm), and Flat (65 cm). The local gradient (i.e., determined on-site) in each cover type was as follows: Riffles (5%), Run (1.5%), and Flat (0.5%). Mean current velocities at the two Riffle transects was 25 $cm \cdot s^{-1}$ and 76 $cm \cdot s^{-1}$. Lower mean velocities were recorded at Run transects (11 $cm \cdot s^{-1}$ and 21 $cm \cdot s^{-1}$). The lowest value was measured at the Flat transect (7 $cm \cdot s^{-1}$).

Differences in substrate dominance were evident amongst the transects. Substrates at Riffle dominated transects (T3, T5) consisted largely of small (25.6 to 51.2 cm) and large (51.2 cm^{+}) boulder although large cobble (12.8 to 25.6 cm) also was well represented. Substrate material in Run dominated transects (T2, T4), although extremely coarse in nature, was noticeably smaller than in Riffle habitat (i.e., due to absence of large boulders). Substrate at the Flat transect was dominated by sand (57%) and silt (16%). Lesser amounts of the larger, coarse textured categories also were present. Sediment coverage of coarse substrate was negligible in Riffle cover types, low to moderate in Run, and high in Flat areas.

Macrophyte densities within the wetted channel were negligible at all transects except T1 (Flat habitat) where low densities were noted. Algal density was negligible at all of the lower transects (at DS No. 5). Algal coverage exceeded 75% at the upper transects (at DS No. 11), possibly due to the proximity to the stilling basin (i.e., input of nutrients from Poplar Creek Reservoir). Stream banks at all stations exhibited little erosion; resistance to further erosion was rated as high (i.e., due to rip-rap and/or vegetation cover).

Reach 3 (km 3.9 to 11.5)

Reach 3 is a high gradient reach (10.3 $m \cdot km^{-1}$) commencing upstream of the stilling basin. Data from Station H3 typifies the habitat conditions in the reach (Table 5.22). Station H2 was situated within a beaver controlled section exhibiting low gradient (0.25% on-site). This section is sufficiently different from high gradient habitat upstream and the channelized reach downstream to be classified as a separate sub-reach within Reach 3. It appears to be a remnant of the original low gradient reach discussed by Syncrude Canada Ltd. (1975). Channel features within the sub-reach were described as follows: wetted width was 6.7 m, mean depth was 80^{+} cm, and mean velocity was 3 $cm \cdot s^{-1}$. Habitat diversity in the section was low (100% Flat), and the substrate consisted entirely of a sand-silt mixture.

Within Reach 3 proper, major channel features were as follows: wetted width was 5.7 m, mean depth was 17 cm, and mean velocity was 13.7 $cm \cdot s^{-1}$. The overall cover type distribution indicates the presence of relatively diverse habitat: 27% Riffle, 34% Run, 14% Flat, and 25% Pool. All pools observed were of low quality (i.e., Class 1) largely due to insufficient depth and cover. The substrate in Reach 3 also displayed considerable variability. Coarse textured material was dominant (67%); sand contributed the remainder (33%). The coarse material was distributed as follows: 35% coarse gravel (1.6-3.2 cm); 12% very coarse gravel (3.2-6.4 cm); 13% small cobble (6.4-12.8 cm); and 7% large cobble (12.8-25.6 cm). Macrophyte and algal densities within the channel were negligible.

5.6.2 WATER QUALITY

5.6.2.1 Physical Parameters

In Poplar Creek at stations PC-W3, PC-W2, and PC-W1, the water temperatures ranged from 5.0°C (September) to 24.0°C in July (Table 5.2) The pH was alkaline with values ranging from 7.5 to a high of 8.6 at station PC-W1 in July. During the same period in 1977 the pH ranged from 8.0 to 8.3 (Noton and Chymko 1978). The dissolved oxygen levels ranged from 8.2 to 11.0 $mg{\cdot}L^{-1}$. The oxygen saturation ranged from 72 to 100% in June and showed no distinct trends among the stations. In 1977, oxygen saturation levels were similar, within the 89 to 100% range. At station PC-W1 total non-filterable residue values ranged from 2.8 to 28.0 $mg{\cdot}L^{-1}$. The highest value occurred in July, even though during this period the flow in the creek was one-third that in June. Noton and Chymko (1978) reported considerably lower values (ranging from <0.5 to 1.5 $mg{\cdot}L^{-1}$) at a station near PC-W1. Poplar Creek water was brown in colour due to dissolved organics.

5.6.2.2 Major Ions

The ionic character of the Poplar Creek water was similar among stations, and particularly so between PC-W2 and PC-W1 (Figure 5.4). Most ions showed increased concentrations from June to September. At PC-W2 and PC-W1 the ionic dominance was distinct with HCO_3^- $> Na^+ > Ca^{++} > Cl^- > Mg^{++} > SO_4^= > K^+$. At PC-W3, however, chloride, which was fifth in dominance in June, rose sharply to become the second most dominant anion in July and September. Sodium concentrations also showed increases during this period. The increased influence of groundwater is the likely source of both parameters. The ions characteristic of station PC-W2 indicated that the quality of water entering from Poplar Creek Reservoir had no apparent effect on the water quality in the creek, even though there was a three to six times greater flow contribution from the reservoir than from the natural flow in the creek at PC-W3. This suggests that the water leaving the reservoir must be from the epilimnetic zone. The ionic quality of the water at PC-W2 during July and September is very similar to that associated with the respective months in the Poplar Creek Reservoir. It appears that during stratification, saline hypolimnetic water does not discharge into Poplar Creek.

5.6.2.3 Nutrients

Total nitrogen concentrations were very similar among the three stations in Poplar Creek. The values ranged from 0.83 to 1.29 mg $N{\cdot}L^{-1}$ and slightly exceeded the ASWQO of 1.0 mg $N{\cdot}L^{-1}$, with the highest concentrations occurring in July in each sampling period. In addition, the concentrations generally increased from PC-W3 to PC-W1 during each sampling period except June. The nitrate + nitrite concentrations (ranging from <0.003 to 0.122 mg $N{\cdot}L^{-1}$) generally increased from June to September; values also increased downstream from PC-W3 to PC-W1 during each sampling period.

Concentrations of total phosphorus ranged from 0.021 to 0.060 mg P·L^{-1} and slightly exceeded the ASWQO of 0.05 mg P·L^{-1} but were within the Environment Canada guideline of 0.100 mg P·L^{-1}. At each station the lowest values occurred in September. The maximum concentrations generally were found in July even though there was a marked decrease in stream discharge in this period compared to June. For each sampling period the concentrations were highest at PC-W3. During July and September, the concentrations of total phosphorus in the epilimnetic water of Poplar Creek Reservoir were lower than those reported for PC-W3. Total phosphorus concentrations generally showed a direct relationship with the hydrograph. At PC-W1, ortho-phosphorus concentrations ranged from 0.005 mg P·L^{-1} (September) to 0.038 mg P·L^{-1} (June). Noton and Chymko (1978) reported a level of less than 0.016 mg P·L^{-1} in September at a station near PC-W1.

Reactive silica concentrations ranged from 1.30 to 8.40 mg·L^{-1}; highest levels occurred in September at the three stations. Similar concentrations were found in 1977 by Noton and Chymko (1978).

Concentrations of total organic carbon in Poplar Creek ranged from 25.1 to 36.7 mg·L^{-1}. The levels were similar to those recorded near station PC-W1 for the June to September period in 1977 (Noton and Chymko 1978).

5.6.2.4 Trace Metals and Other Substances

At station PC-W1, the concentrations of trace metals and elements in Poplar Creek were below the detection limits. Total iron (0.62 to 0.78 $mg{\cdot}L^{-1}$) and total manganese (0.040 to 0.080 $mg{\cdot}L^{-1}$) exceeded the respective ASWQO of 0.30 and 0.050 $mg{\cdot}L^{-1}$. With respect to the other parameters, phenol levels (0.006 to 0.026 $mg{\cdot}L^{-1}$) exceeded the ASWQO of 0.005 $mg{\cdot}L^{-1}$. Oil and grease levels were low ranging from 1.0 to 1.7 $mg{\cdot}L^{-1}$. In July 1977, the oil and grease concentration near station PC-W1 was 14.4 $mg{\cdot}L^{-1}$ (Noton and Chymko 1978).

5.6.3 ZOOBENTHOS

Stations sampled in Poplar Creek corresponded to locations that have been examined on a continuing basis since 1974 (Boerger 1983). Detailed description of the stations was provided by Noton and Chymko (1978).

In 1984, as in other years subsequent to creek diversion and opening of the Poplar Creek Reservoir spillway, densities downstream of the spillway (PC-B1 and PC-B2) generally exceeded densities at upstream stations (PC-B3 and PC-B4) (Appendix D, Tables D27 to D30).

Simuliidae[1] were a dominant component of the fauna at all stations in spring (Figure 5.31); however, absolute densities of simuliids were at least fourteenfold greater at downstream stations than upstream of the spillway. Chironomidae, Oligochaeta and, to a lesser extent, **Baetis** (Ephemeroptera) were other important components of the biota at B3 and B4. In spring, station B1 had greatest taxonomic richness, but B3 and B4 had much greater diversity owing to a more equitable distribution of abundance among taxa (Table 5.3).

Density, biomass, and richness increased at all stations from spring to summer. Diversity increased at the two downstream stations, but decreased slightly at upstream stations. Simuliidae remained dominant at B1, but declined in importance at the other three stations.

Hydra and Chironomidae were important summer taxa at B2. Stations B3 and B4 showed increased densities and proportions of **Baetis** and Chironomidae (Figure 5.31).

In fall 1984, marked increases in density were observed at stations B2, B3 and B4, but a decline was observed at B1. Biomass declined at all stations except B4, reflecting the dominance of small chironomids in the creek at this time (Appendix D, Table D27). Simuliidae were present only

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[1]Dr. P.H. Adler (**ex** University of Alberta) kindly identified an auxiliary sample collected from PC-B2 (June). This contained seven **Simulium vittatum** complex (cytotype IS-7), three **S. venustum** complex (cytotype CC), one **S. verecundum** complex ACD) and four **S. furculatum** complex (cytotype unknown).

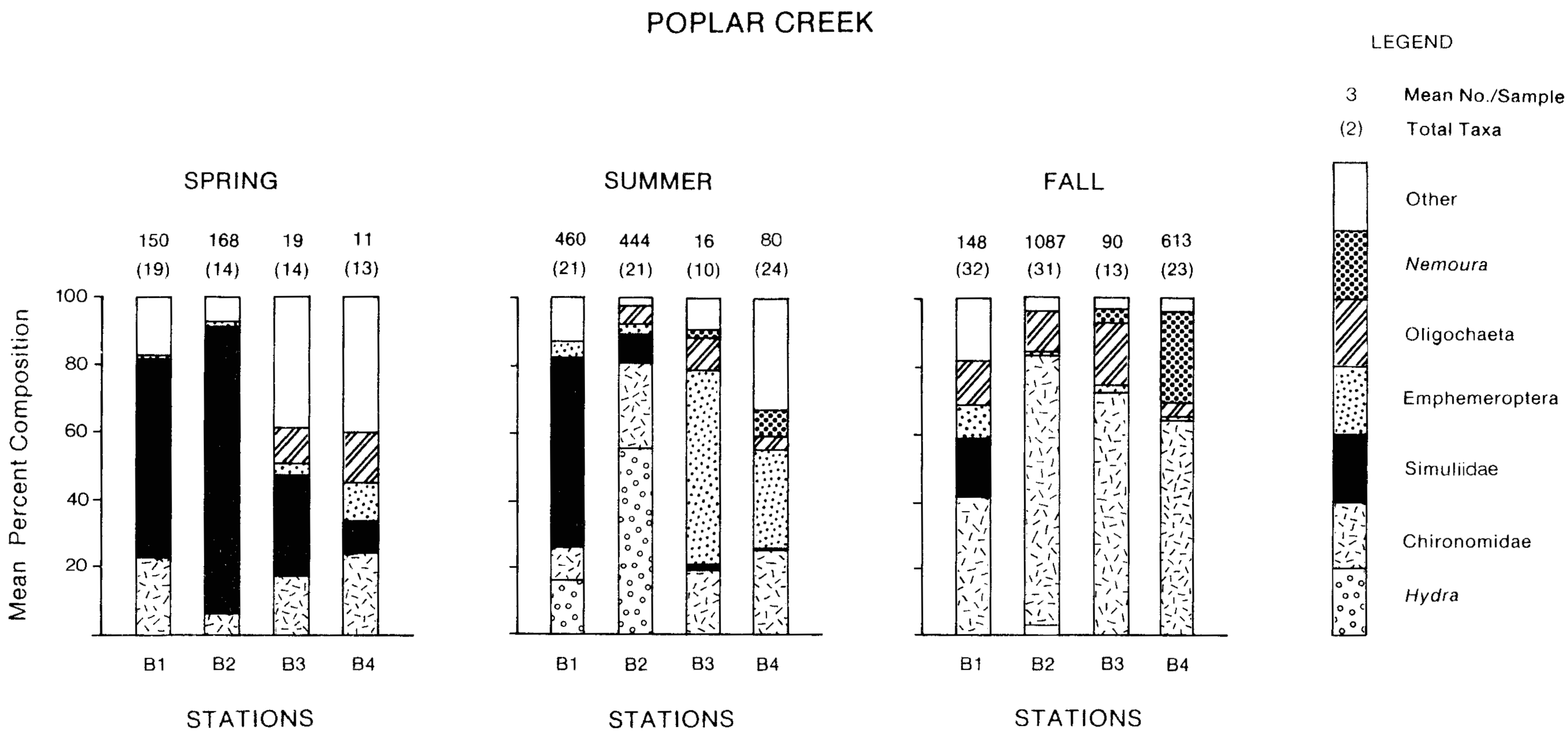

Figure 5.31 Relative abundance of major taxonomic groups of benthic invertebrates in Poplar Creek, 1984.

at station B1. Oligochaeta were important constituents of fall samples at all four stations. A significant portion of the increased density at B4 was attributed to the presence of the stonefly, **Nemoura**. Taxonomic richness increased substantially in fall samples at B1 and B2, but diversity increased only at the former station (Table 5.3). Stations B3 and B4 exhibited little change in richness, but showed a decline in diversity.

Poplar Creek has been sampled quantitatively during at least seven years prior to the present study (Boerger 1983). However, since different samplers and protocols have been used among studies, comparisons can only be made in a general context. Artificial substrate samplers (barbeque baskets containing varying numbers of stones) were used between 1979 and 1982. Such samplers can produce overestimates of abundance and taxonomic richness; the degree of bias varies with fluctuations in current velocity (Ciborowski and Clifford 1984). Earlier sampling was undertaken with Hess or Surber samplers (Noton and Chymko 1978). These authors selected sampling areas consisting of uniformly small gravel substrate. In the present study (and possibly in earlier surveys), collections were made within the dominant microhabitat type of each station; this consisted of moderate-sized boulder areas at stations B1 and B2, and cobble areas at B3 and B4.

These differences in methodology may partially explain the greater variability in year-to-year density estimates for zoobenthos (Boerger 1983). Summer 1984 samples, which can be compared with the largest data base (that of Boerger 1983), produced density estimates that were similar to estimates for 1980-1982 at stations B1 and B2, 50 % less than 1980-1982 at B3, and slightly greater than that at B4. Summer estimates for 1977 were very high, owing to the appearance of many very young Simuliidae in the samples (Noton and Chymko 1978). Taxonomic richness was at the upper end of the range of yearly estimates for stations B1, B2, and B4 in 1984. This is to be expected since present estimates were augmented by data from sweep samples; however, richness at station B3 was substantially less than minimum estimates for any prior year (14 taxa in 1974 and 1977; Boerger 1983). This, together with the reduced density estimates, may suggest some form of perturbation occurred at this station.

Taxonomic composition in 1984 was remarkably consistent with that of earlier studies. Filter-feeding organisms (Simuliidae and Hydra) dominated at B1 and B2, whereas **Baetis** and Chironomidae made up the greatest proportion of samples at B3 and B4. Noton and Chymko (1978) attributed the high abundance of Simuliidae to increased organic inputs from Poplar Creek Reservoir; however, the distribution of this taxon is not consistent with their interpretation. Although abundance of filter feeding animals does become very great at lentic outlets, densities typically decline very quickly with increasing distance from the source of organic input (Sheldon and Oswood 1977; Oswood 1979; Ciborowski unpublished data). Densities 1.5 km downstream of an outflow (i.e., the distance of station B1 from the Poplar Creek spillway) would be expected to diminish to less than 15 % of densities 150 m downstream (data from Sheldon and Oswood 1977; Ciborowski personal observation).

Furthermore, MacKay River station M6-B, which was physically similar to downstream stations on Poplar Creek, supported black fly densities equivalent to or greater than those at B1 and B2. However, at station M6-B, there was no equivalent lentic input upstream. The upper MacKay River and Lower Poplar Creek both possess rapid current velocities, coarse and relatively silt-free substrate, and receive ample solar radiation for periphytic development. The latter component can provide a constant input of high quality seston, on which Simuliidae feed. It is noteworthy (and consistent with earlier studies) that Simuliidae persisted longer and at greater densities at station B1 than at B2. Boerger (1983) suggested this may be a result of the effects of epilimnetic discharge on the thermal regime immediately downstream of the spillway. It is equally possible, however, that net seston quality increases with increasing distance downstream of the spillway, owing to greater length of river substrate available for periphytic production. Such a change in quality rather than quantity would not be reflected by measurement of total organic carbon, which appears to remain constant along Poplar Creek (Boerger 1983; present study).

5.6.4 FISH

Five stations were sampled by backpack electrofishing during the 1984 survey (Figure 2.4). All stations (except EF3) were sampled during each period; EF3 was not sampled in the summer survey due to high water levels that presented conditions unsuitable for wading.

Nine fish species were recorded in Poplar Creek during 1984 surveys (Table 5.23); of these, three were sportfish species (Arctic grayling, northern pike, and burbot), two were coarse fish species (longnose and white sucker), and four were forage species (fathead minnow, lake chub, northern redbelly dace, and brook stickleback) .

Species diversity in Poplar Creek decreased in an upstream direction (Table 5.23). At the lowermost stations (EF6, EF5 and EF3), six species of fish were recorded. Five species were recorded at EF2 and three species at EF1, the uppermost sample station. White sucker, fathead minnow, and lake chub were captured at all sampling stations; brook stickleback was present at all stations except EF1. The remaining species were recorded only from the channelized reach. These species exhibited a sporadic distribution and likely were more closely associated with the Athabasca River (i.e., enter the lower reaches of Poplar Creek for foraging purposes).

5.6.4.1 Sportfish Species

The three species of sportfish recorded in Poplar Creek in 1984 were Arctic grayling, northern pike, and burbot (Table 5.23). All were recorded in the channelized section of Poplar Creek in 1978; in 1981 only burbot were recorded.

Only three Arctic grayling were captured in 1984. These individuals, all of which were juveniles, were taken in Riffle-Run habitat

Table 5.23. Percentage composition of various fish species in backpack electrofishing collections from Poplar Creek, 1984 (all seasons combined).

Species[a] (n)[b]	Location PC-EF1 (75)	PC-EF2 (372)	PC-EF3 (637)	PC-EF5 (908)	PC-EF6 (634)	All Stations Combined (2626)
AG	0	0	0.5	0	0	0.1
NP	0	0	0	0	0.2	L0.1[c]
LING	0	0	0	L 0.1	0	L0.1
LNS	0	0	0.2	2.1	8.4	2.8
WS	28.0	11.8	11.0	63.7[d]	26.0[d]	34.5
FHM	66.7	46.5	54.1	23.5[e]	15.3[e]	32.3
LKC	5.3	1.9	5.2	6.1	39.7	13.4
NRD	0	0.8	0	0	0	0.1
BS	0	39.0	29.0	4.6	10.4	16.7

[a]For species code explanation, see text Table 3.6.

[b]Number of fish captured and observed.

[c]L = less than.

[d]Does not include numerous (>10 000) fry observed. Identified subsamples consisted of approximately 98% white sucker y-o-y and 2% fathead minnow y-o-y.

[e]Does not include numerous (>5 000) fry observed. Identified subsamples consisted of approximately 98% white sucker y-o-y and 2% fathead minnow y-o-y.

below DS 10 and 11 on 31 May. Arctic grayling were not encountered during the late September sampling period; high flows prevented sampling in late July. In 1978, O'Neil (1979) captured moderate numbers of Arctic grayling during May, July, and October. These individuals were distributed below the upper drop structures (similar to 1984) and farther upstream into the unchannelized section. During the 1981 study in Poplar Creek, this species was absent from the catch (O'Neil 1982). It is evident that the distribution of Arctic grayling in Poplar Creek is extremely variable on a seasonal and year-to-year basis. A preliminary review of flow data during, and in the weeks prior to, the sampling periods in the three study years was undertaken. It is apparent that the sample periods with the highest catches were preceeded by periods of seasonally higher flows. This was particularly evident in 1978. Conversely, low capture rates generally occurred when sample periods were preceded by extended periods of low flow (mid-July 1981). It is apparent that Arctic grayling in Poplar Creek are seasonal migrants from the Athabasca River (i.e., entering primarily for feeding purposes). Their absence during the low flow periods likely is due to reduced habitat suitability (insufficient depth and cover, high water temperatures, etc.) and/or restricted access past drop structures.

Northern pike were infrequent residents of Poplar Creek during 1984. One individual, a spent male, was captured in a large pool below DS1 in the spring. In 1978, adult northern pike in spawning condition were recorded in Poplar Creek during the spring period. Based on the limited amount of suitable spawning habitat and the absence of y-o-y in summer and fall captures in 1978, 1981, and 1984, the presence of a noteworthy spawning run into the channelized section of Poplar Creek and upstream of the diversion is unlikely.

Burbot made a minor contribution to the electrofishing catch in 1984. One individual (a juvenile) was collected below DS6 in the fall. In 1978, a small number of adults and juveniles were present in the summer and fall, respectively, in the channelized section of Poplar Creek. It is apparent that burbot move into the system, likely from the Athabasca River, for feeding and rearing purposes.

5.6.4.2 Coarsefish Species

White sucker and longnose sucker were collected from Poplar Creek in 1984 (Table 5.23). White sucker was the most abundant species, contributing 34.5% to the total catch (Table 5.23). This species was recorded at all stations and during all periods with the exception of station EF1 during the spring period (Appendix E, Table E4). The absence of all species from that station in the spring likely resulted from the low suitability of this area for overwintering, and the presence of large impassible beaver dams located farther downstream in the system (i.e., in EF2). In the spring, juvenile white suckers were recorded immediately downstream from the lowermost beaver dam in EF2, but were absent from the catch above the dam. This dam was breached by freshet conditions in early July. White sucker juveniles and y-o-y were captured upstream of the dam in the summer survey suggesting these individuals had moved upstream into the area. Capture rates of white suckers ranged from 5.6 fish·min^{-1} in the spring to 34.0 fish·min^{-1} in the summer and 6.0 fish·min^{-1} in the fall (Appendix E, Table E4). The high capture rates during summer reflect the appearance in the catch of y-o-y white suckers. This capture rate does not include the estimated 15 000 or more observed in low velocity areas along the periphery of the channelized section. Identification of a subsample of these individuals indicated that approximately 98% were white sucker y-o-y, with the remainder identified as fathead minnow y-o-y. The abundance of white sucker y-o-y indicates successful spawning in Poplar Creek during 1984. The spawning run of adults in May, however, was not recorded; all white suckers captured in this period were juveniles. Since water temperatures during the 1984 spring survey were relatively high (12°C), spawning likely had been completed prior to initiation of the study. In 1978, pre-spawning aggregations of white suckers were recorded in lower Poplar Creek during mid-May. These adults were absent from subsequent summer and fall surveys, and were thought to be a migratory spawning population originating from the Athabasca River.

Capture rates for longnose suckers were variable, relating to difference in seasonal distribution and abundance (Appendix E, Table E4). This species was substantially less abundant in Poplar Creek than white sucker (Table 5.23). Longnose suckers were captured in low numbers in the spring, and only from sample stations within the channelized reach. Most of these individuals were juveniles, with a small number of adults present. The low occurrence of y-o-y of this species in summer and fall captures suggests that the spawning use of this system is limited, although rapid emigration of y-o-y after hatching may occur.

During summer and fall the catch of longnose suckers was comprised mainly of juveniles. These juveniles exhibited a preference for Riffle-Run habitat at, and immediately below, drop structures. The greatest density (4.1 fish·min^{-1}) was recorded in the fall at ES6. The fact that juvenile longnose suckers were abundant in the fall yet were rarely encountered in summer suggests that these groups are seasonal migrants from the Athabasca River.

5.6.4.3 Forage Species

In 1984, several forage species (i.e., cyprinids and sticklebacks) were captured in Poplar Creek. In order of decreasing abundance, they were as follows: fathead minnow, brook stickleback, lake chub and northern redbelly dace (Table 5.23).

Overall, fathead minnow was the most abundant forage species in Poplar Creek, contributing 34.5% to the total electrofishing catch (Table 5.23). Although fathead minnow was the dominant species at upper stations (EF1-EF3), it exhibited a general decline in percentage composition with increased downstream distance. Capture rates for this species were highest during the spring period in EF3 when 33.4 fish·min^{-1} were recorded (Appendix E, Table E4). The catch at this time consisted mainly of mature adults although juveniles also were abundant. In the summer, fathead minnow y-o-y were numerous in sections EF5 and EF6. The location or extent of fathead minnow spawning in Poplar Creek is unknown. The abundance of y-o-y in the lower electrofishing stations and absence from stations above the spillway confluence suggests a majority of spawning may occur in Poplar Creek Reservoir.

Brook stickleback were common in Poplar Creek during 1984 surveys (Table 5.23). This species was most abundant in spring surveys at stations EF2 and EF3, when respective CUE's of 15.5 and 17.3 $fish{\cdot}min^{-1}$ were recorded (Appendix E, Table E4). Brook stickleback were not recorded in captures from EF1 suggesting the distribution of this species is limited to the lower sections of Poplar Creek. In 1984, catches declined substantially during the summer and fall periods, perhaps due to a downstream movement out of the area. In 1978, brook stickleback were absent in the spring catch and increased in abundance over the July to September period. Although the reason for the difference between years is unknown, it likely was due to differences in seasonal discharge patterns. Results of the 1978 study indicated that the brook stickleback population in Poplar Creek originated from Poplar Creek Reservoir.

Lake chub were frequently encountered during electrofishing surveys in Poplar Creek (Table 5.23). During both sample periods, highest capture rates were recorded at the lowermost sampling station (EF6) (Appendix E, Table E4). This species occurred infrequently at sample stations upstream of the spillway confluence. A certain portion of the lake chub in Poplar Creek are evidently seasonal migrants from the

Athabasca River. The presence of adult lake chub (in spawning colouration) at lower stations in the spring indicates a probable spawning use of the system. Spawners observed in the beaver pond at the lower end of EF2 may orginate from a small resident population in upper Poplar Creek, or result from the entrapment of those individuals by beaver dams in the area.

Northern redbelly dace made a minor contribution to the electrofishing catch in Poplar Creek (Table 5.23). This species was recorded only in EF2 during the summer and fall surveys. These data suggest the occurrence of a small resident population in Upper Poplar Creek; alternatively, these individuals may have entered from the Athabasca River.

SECTION 6.0

HORSESHOE LAKE

6.1 AQUATIC HABITAT

6.1.1 PHYSICAL CHARACTERISTICS

Horseshoe Lake is a small (0.34 km^2), irregularly shaped waterbody, situated near the Athabasca River on the eastern edge of Lease 17 (Figures 1.1 and 2.5). A channel, constructed prior to the development of Lease 17, drains from the northeastern edge of the lake to the Athabasca River. During periods of high discharge in the Athabasca River, flows are reversed in the channel resulting in temporary inundations that increase the amount of aquatic habitat in the lake. An additional, secondary outlet (a natural drainage) exits from the northwestern tip of the lake and follows an irregular course to the northeast prior to joining the Athabasca River.

An aerial reconnaisance of Horseshoe Lake conducted during the fall of 1984 indicated outflow in the outlet channel was controlled by three large beaver dams; flows over the beaver dams were not apparent. In the secondary outlet, discharge at this time terminated in a series of stagnant pools approximately 300 m from the confluence with the Athabasca River.

The majority of the surface area of Horseshoe Lake was covered with abundant growths of emergent and floating aquatic vegetation (Plate 10).

6.1.2 MACROPHYTES

The survey of distribution and relative abundance of macrophytes in Horseshoe Lake in 1984 revealed that Horseshoe Lake was shallow and was occupied by submersed and floating plants in all areas (Figure 6.1, Table 6.1). **Nuphar** was extremely dense to the extent that it impeded the passage of a canoe during surveys. Only a few areas were not covered by **Nuphar**. The composition of the understory varied according to location; however, no definite pattern was identified. The presence of abundant **Elodea longivaginata** (male), an uncommon species in the province, was of particular interest. Horseshoe Lake, at present, is the most northerly documented occurrence of the species in the province. It was most abundant in the east and west arms of the lake. Detailed descriptions of the macrophyte assemblages at the sampling sites are provided in Appendix F, Table F4.

6.2 WATER QUALITY

6.2.1 PHYSICAL PARAMETERS

The water temperatures in Horseshoe Lake at station HL-W ranged from 5.0^{o}C (September) to 22.0^{o}C (July) at the surface (Table 6.2). Temperatures decreased by 1.5 to 2.0^{o}C from the surface to the bottom (depth of 1 m) of the lake during June and July; in September the lake was isothermal. The pH ranged from acidic (6.9 at the bottom in July) to alkaline (7.9 at the surface in September). The dissolved oxygen

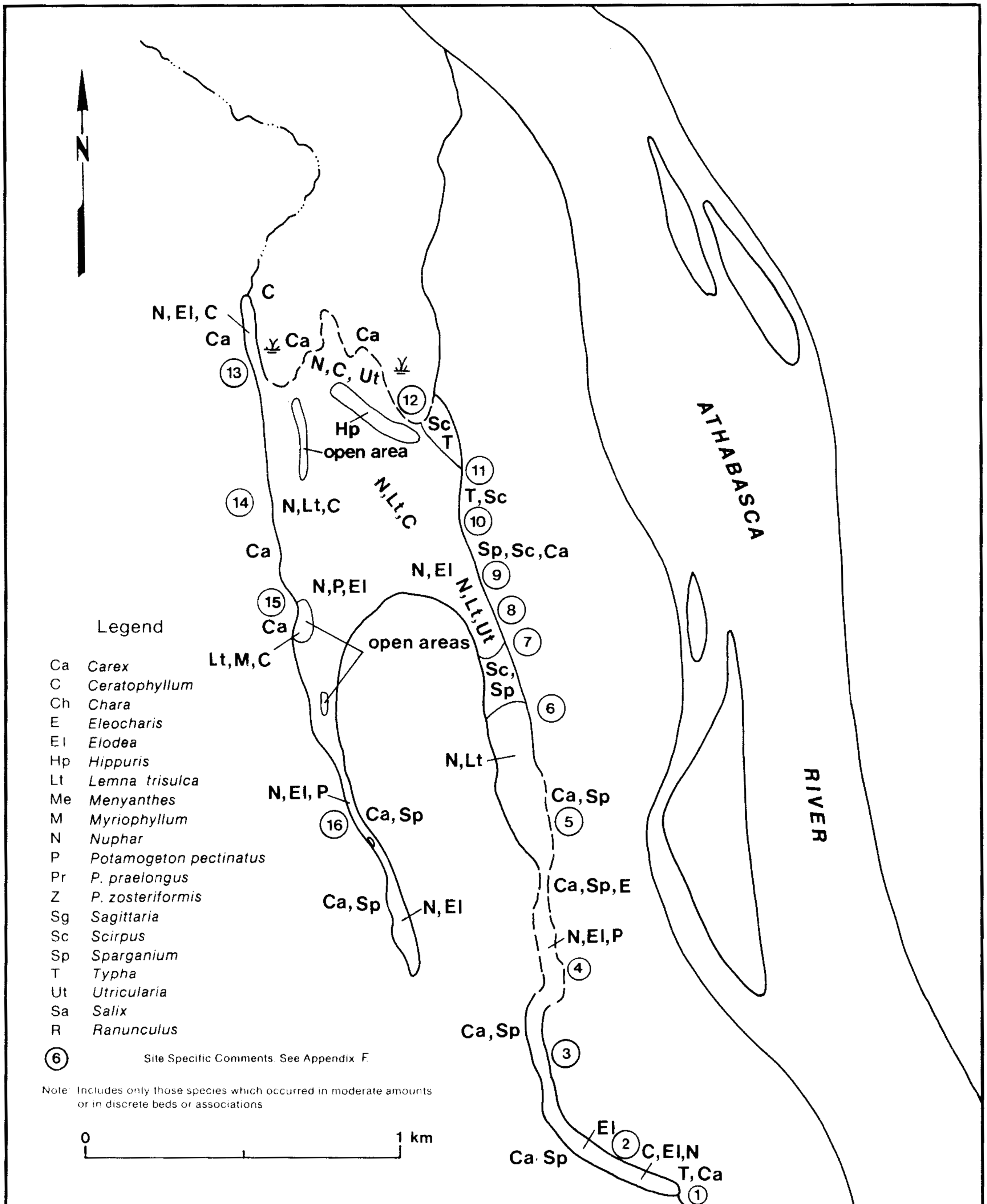

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Figure 6.1

HORSESHOE LAKE
Macrophyte Distribution
1984

Table 6.1 Distribution pattern and relative abundance of macrophytes found in Horseshoe Lake, July 1984.

Species	Distribution Pattern
	Submersed
Ceratophyllum demersum	Common
Chara spp.	Rare
Drepanocladus spp.	Abundant[a]
Elodea longivaginata	Abundant
Lemna trisulca	Abundant
Myriophyllum demersum	Common
Potamogeton pectinatus	Common
Potamogeton praelongus	Present
Potamogenton pusillus	Present
Potamogeton zosteriformis	Present
Utricularia vulgaris	Common
	Floating-Leafed
Nuphar variegatum	Abundant
Lemna minor	Present
	Emergent
Carex spp.	Common
Eleocharis spp.	Common
Hippuris vulgaris	Common
Sagittaria spp.	Common
Scirpus validus	Common
Sparganium spp.	Common
Typha latifolia	Common

[a]Locally abundant but not widespread.

Table 6.2. Summary of water quality data for Horseshoe Lake, 1984.

Site/Date Parameter	HL-W 21 June 0.5 m	 27 July 0.5 m	 24 Sept. 0.5 m
Temperature ^{O}C	18.5s;17.0b	22.0s;20.0b	5.0s;5.0b
pH	7.6s;7.6b	7.2s;6.9b	7.9s;7.9b
Specific Conductance $\mu S{\cdot}cm^{-1}$	440s;440b	560s;625b	500s;500b
Dissolved Oxygen	12.5s;12.7b	8.3s;7.3b	10.8s;9.5b
Oxygen % Saturation	131s;129b	95s;80b	84s;74b
Turbidity N.T.U.	7.3	3.0	3.0
Calcium	25.60	25.00	46.50
Magnesium	12.70	15.60	15.70
Sodium	53.00	70.00	54.50
Potassium	0.82	2.35	3.05
Chloride	41.90	57.00	37.00
Sulphate	12.0	9.3	9.3
PP. Alkalinity as $CaCO_3$	L0.1	L0.1	2.0
Alkalinity, T. as $CaCO_3$	159.0	206.0	234.0
Bicarbonate	194.0	251.0	280.5
Carbonate	0	0	2.5
Hardness, T. as $CaCO_3$	116.0	127.0	181.0
Silica (Reactive)	0.40	0.90	1.41
Total Filterable Residue	260	315	311
Total Non-Filterable Residue	12.0	3.2	22.4
Chemical Oxygen Demand	68	63	49
Oil & Grease	1.0	3.3	1.1
Nitrogen, T. as N	1.05	1.34	0.90
Nitrate + Nitrite Nitrogen as N	0.006	0.004	0.003
Kjeldahl Nitrogen, T. as N	1.04	1.34	0.90
Ammonia Nitrogen, T. as N	0.05	0.04	L0.01
Phosphorus, T. as P	0.068	0.060	0.050
Ortho-Phosophorus as P	0.024	0.032	0.009
Total Organic Carbon	17.3	24.0	20.3
Total Inorganic Carbon	34.0	47.0	47.0
Phenol	0.008	0.007	0.005
Arsenic, T.	0.0005	0.0003	0.0005
Selenium, T.	L0.0002	L0.0002	0.0006
Boron, T.	0.08	0.09	0.03
Cadmium, T.	L0.001	L0.001	L0.001
Copper, T.	L0.001	L0.001	L0.001
Iron, T.	0.86	0.68	0.25
Chromium, T.	L0.001	0.002	L0.001
Manganese, T.	0.030	0.090	L0.010
Zinc, T.	0.001	0.002	0.003
Lead, T.	L0.002	L0.002	L0.002
Vanadium, T.	L0.001	L0.001	L0.001
Nickel, T.	L0.001	L0.001	L0.001
Mercury, T.	L0.0001	L0.0001	L0.0001
Cyanide, T.	0.003	0.004	0.005
Tannin & Lignin	1.2	1.6	1.3
Ion Balance	1.01	0.95	1.01

Notes: All values are reported as $mg{\cdot}L^{-1}$ unless otherwise stated.
L - Less Than; T. - Total; N - Nitrogen; P - Phorphorus;
s - Surface; b - Bottom.

ranged from 7.3 $mg \cdot L^{-1}$ at the bottom in July to 12.5 at the surface in June. Oxygen was supersaturated (131%) in June then declined in July reaching a low of 74% at the bottom in September. Speculatively, the high level of primary productivity, exemplified by the supersaturated oxygen condition, contributed high oxygen demand during late summer resulting in notably lower oxygen saturation, particularly at the bottom.

The total non-filterable residue ranged from 3.2 $mg \cdot L^{-1}$ (July) to 22.4 $mg \cdot L^{-1}$ (September). The source of the high values in September cannot be ascertained. Bottom ooze disturbed inadvertently may have been a source. The Secchi disc visibilities recorded during July and September were 1.0 m and 0.7 m, respectively.

6.2.2 MAJOR IONS

The water in Horseshoe Lake was of the sodium bicarbonate type. In June the ionic dominance was $HCO_3^- > Na^+ > Ca^{++} > Cl^- > Mg^{++} > SO_4^=$ $> K^+$ (Figure 5.4). In July, the concentrations of most parameters increased except for calcium and sulphate, resulting in chloride becoming the second most dominant anion. Subsequent decreases in sodium, chloride and increases in calcium concentrations resulted in the water becoming a sodium/calcium bicarbonate type in September. The considerable increase in concentrations of potassium from June to September was unique as compared to those described for the other systems; the cause of of such behaviour is unclear. The ionic character of the surface and exceeded the ASWQO of 0.005 $mg{\cdot}L^{-1}$ in June and July. Oil and grease concentrations ranged from 1.0 to 3.3 $mg{\cdot}L^{-1}$.

6.3 FISH

Horseshoe Lake was sampled during summer and fall 1984 (Table 2.1). On both occasions sampling was conducted from a canoe using a backpack electrofisher (Figure 2.5). Fish were not captured during either sampling event; however, one juvenile northern pike was observed by study personnel during the aquatic macrophyte survey in July, and two juveniles also were recorded by individuals conducting avifauna studies (J. Smith, LGL Ltd., pers. comm.). It is apparent that Horseshoe Lake is used to a limited extent for summer rearing. The degree of spawning in the lake, however, is unknown. An abundance of suitable spawning habitat for northern pike is available in Horseshoe Lake although it may not be accessible in all years. The accessibility of Horseshoe Lake to fish populations (i.e., northern pike) from the Athabasca River likely is controlled by flow stage in the Athabasca River (i.e., sufficient to cause back-flooding into Horseshoe Lake). In years of high spring flows, northern pike could migrate into the system to spawn. Northern pike spawning has been observed in Saline Lake (located across the Athabasca River), a waterbody similar in many respects to Horseshoe Lake (O'Neil, personal observation). The shallow nature of Horseshoe Lake, with abundant growth of macrophytes and the absence of a defined inlet, is expected to produce unsuitable overwinter conditions for fish. Therefore, if spawning does occur in Horseshoe Lake, the adults and offspring would be required to vacate the waterbody prior to freeze-up.

bottom waters was similar as indicated by the specific conductance and total filterable residue concentrations.

6.2.3 NUTRIENTS

Total nitrogen concentrations (ranging from 0.90 to 1.34 mg $N \cdot L^{-1}$) slightly exceeded the ASWQO of 1.0 mg $N \cdot L^{-1}$. Nitrite + nitrate concentrations were low ranging from 0.003 mg $N \cdot L^{-1}$ (September) to 0.006 mg $N \cdot L^{-1}$ (June). Total phosphorus concentrations ranged from 0.050 mg $P \cdot L^{-1}$ (September) to 0.068 mg $P \cdot L^{-1}$ (June). The values slightly exceeded the ASWQO of 0.05 mg $P \cdot L^{-1}$ and more notably the Environment Canada guideline of 0.025 mg $P \cdot L^{-1}$. The ortho-phosphorus concentrations ranged from 0.009 to 0.032 mg $P \cdot L^{-1}$ in September and July, respectively, and showed no relationship with the total phosphorus seasonal fluctuation. Reactive silica levels (0.40 to 1.41 $mg \cdot L^{-1}$) were low, showing increased concentrations from June to September. Total organic carbon levels ranged from 17.3 to 24.0 $mg \cdot L^{-1}$ in June and July, respectively.

6.2.4 TRACE METALS AND OTHER SUBSTANCES

The concentrations of most trace metals and elements in Horseshoe Lake were below detection limits and showed no trend among sampling periods. Iron concentrations in June (0.86 $mg \cdot L^{-1}$) and July (0.68 $mg \cdot L^{-1}$), and the manganese concentration (0.090 $mg \cdot L^{-1}$), exceeded their respective ASWQO of 0.30 and 0.050 $mg \cdot L^{-1}$. With respect to other parameters, phenol levels (ranging from 0.005 to 0.008 $mg \cdot L^{-1}$) slightly

Table 7.1. Summary of water quality data for the Athabasca River, 1984.

Site/Date	AR-W8			AR-W7			AR-W6			AR-W5		
Parameter	26 May	28 July	27 Sept.	26 May	28 July	27 Sept.	26 May	28 July	27 Sept.	26 May	28 July	27 Sept.
Temperature °C	12.0	24.0	5.0	12.0	24.0	5.0	12.0	23.5	5.2	12.0	24.0	6.0
pH	7.9	8.6	7.6	7.9	8.7	8.0	7.6	8.7	7.7	7.8	8.6	7.9
Specific Conductance $\mu S\cdot cm^{-1}$	240	200	200	300	350	200	225	200	190	230	200	190
Dissolved Oxygen	9.2	8.9	12.8	9.2	8.9	11.6	9.2	9.0	12.7	9.1	8.7	12.6
Oxygen % Saturation	84	105	99	84	105	90	84	103	98	83	102	100
Turbidity N.T.U.	110	19	180	68	43	140	98	45	200	98	48	160
Calcium	26.90	28.60	30.00	24.90	27.40	30.30	27.80	26.00	30.00	25.30	26.60	31.20
Magnesium	6.85	8.00	8.10	7.71	8.40	8.40	6.70	7.00	8.00	6.75	7.00	8.40
Sodium	7.70	4.10	4.00	19.80	19.00	5.80	7.40	4.00	3.80	7.70	5.20	4.20
Potassium	1.00	0.76	0.77	1.00	1.15	0.80	1.00	0.75	0.80	1.00	0.74	0.75
Chloride	2.30	1.30	1.40	9.50	10.70	2.80	2.00	1.50	1.10	2.90	2.90	1.60
Sulphate	17.2	18.9	21.5	19.1	20.0	21.7	17.6	18.4	20.7	17.1	18.3	22.9
Sulphide	L0.01		0.05	L0.01		0.08	L0.01		0.05	0.10		0.05
PP. Alkalinity, as $CaCO_3$	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1
Alkalinity, T. as $CaCO_3$	90.8	90.7	95.1	108.0	111.0	97.2	96.0	87.8	92.9	93.0	86.3	97.0
Bicarbonate	111.0	111.0	116.0	132.0	135.5	118.5	117.0	107.0	113.0	113.5	105.0	118.0
Hardness, T. as $CaCO_3$	95.5	104.5	108.5	94.0	103.0	110.0	97.0	94.0	108.0	91.0	95.0	112.5
Fluoride	0.06		0.04	0.07		0.04	0.06		0.04	0.06		0.04
Silica (Reactive)	5.20	2.77	3.60	4.12	2.54	3.64	5.20	2.96	3.64	5.30	3.20	3.70
Threshold Odour Number	2		2	2		4	2		2	2		2
Colour	100		200	100		200	100		200	100		200
Total Filterable Residue		120			160			110			125	
Total Non-Filterable Residue	293.0	76.4	254.0	185.0	52.0	198.0	250.0	85.2	281.0	331.0	81.6	249.0
Nitrate + Nitrite Nitrogen as N	0.043	0.004	0.063	0.032	0.016	0.065	0.034	0.003	0.052	0.030	0.003	0.053
Ammonia Nitrogen, T. as N	0.03	0.05	L0.01	0.03	0.20	0.03	L0.01	0.15	L0.01	L0.01	0.55	L0.01
Kjeldahl Nitrogen, T. as N	0.76	0.76	0.54	0.80	1.10	0.52	0.94	0.68	0.60	0.68	0.62	0.56
Nitrogen, T. as N	0.76	0.76	0.60	0.80	1.12	0.58	0.94	0.68	0.65	0.68	0.62	0.61
Total Organic Carbon		5.3			11.5			5.5			6.2	
Total Inorganic Carbon		19.0			26.0			20.0			19.0	
Phosphorus, T. as P	0.250	0.057	0.159	0.176	0.051	0.151	0.285	0.069	0.178	0.191	0.056	0.150
Ortho-Phosphorus as P	0.011	0.027	0.011	0.011	0.029	0.013	0.015	0.026	0.009	0.016	0.023	0.010
Phenol	0.003	L0.001	L0.001	0.006	0.003	L0.001	0.012	L0.001	L0.001	0.009	0.003	L0.001
Surfactants	0.12		0.06	0.15		0.09	0.14		0.06	0.11		0.05
Oil & Grease	0.6	1.7	1.1	1.1		1.1	1.5	1.4	1.6	1.2	0.1	1.0
Carbon Chloroform Extraction	1.1		1.4	2.9		1.2	1.9		1.6	1.4		1.4
Chemical Oxygen Demand	55	20	15	60	64	25	66	20	25	58	15	15
Biochemical Oxygen Demand	3.1		2.2	2.6		1.7	3.1		1.5	2.8		1.8
Cyanide,T.	0.002	0.001	0.004	0.003	0.002	0.003	0.003	0.001	0.003	0.002	0.003	0.003
Cadmium, T.	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001
Chromium, T.	0.001	0.002	0.002	0.001	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002
Copper, T.	0.008	0.002	0.003	0.005	0.002	0.003	0.008	0.002	0.004	0.008	0.002	0.003
Iron, T.	2.70	0.89	2.40	1.60	0.87	2.41	2.80	1.08	3.02	2.60	0.92	2.37
Lead, T.	L0.002	L0.002	0.003	L0.002	L0.002	0.003	0.003	L0.002	0.003	0.002	L0.002	0.002
Manganese, T.	0.233	0.060	0.190	0.177	0.070	0.170	0.232	0.060	0.220	0.141	0.070	0.180
Silver, T.	L0.001		L0.001	L0.001		L0.001	L0.001		L0.001	L0.001		L0.001
Zinc, T.	0.016	0.002	0.006	0.011	0.001	0.007	0.018	0.002	0.008	0.016	0.006	0.009
Vanadium, T.	0.009	L0.001	0.003	0.009	L0.001	0.002	0.009	L0.001	0.002	0.011	L0.001	0.002
Selenium, T.	L0.0002	L0.0002	0.0009	L0.0002	L0.0002	0.0007	L0.0002	L0.0002	0.0003	L0.0002	L0.0002	0.0009
Mercury, T.	L0.0001	L0.0001	L0.0001	0.0001	L0.0001	L0.0001	0.0001	L0.0001	L0.0001	L0.0001	L0.0001	L0.0001
Arsenic, T.	0.0011	0.0017	0.0010	0.0009	0.0010	0.0009	0.0010	0.0008	0.0011	0.0011	0.0006	0.0009
Nickel, T.	0.004	0.002	L0.001	L0.001	0.002	L0.001	0.004	0.002	0.003	0.003	0.002	L0.001
Aluminum, T.	0.90		0.77	0.72		0.73	0.85		0.85	1.03		0.70
Cobalt, T.	0.002		0.001	L0.001		0.002	0.002		0.002	0.002		0.002
Boron, T.	0.11	0.02	0.03	0.15	0.08	0.04	0.12	0.02	0.03	0.12	0.02	0.03
Titanium, T.	L0.010		L0.010	L0.010		L0.010	L0.010		L0.010	L0.010		L0.010
Barium, T.	0.11		0.08	0.08		0.08	0.10		0.08	0.12		0.08
Methyl Mercaptan	L0.1		L0.1	L0.1		L0.1	L0.1		L0.1	L0.1		L0.1
Sodium as % of Cations	15		7.4	32		10.2	14		71	16		7.5
Tannin & Lignin	1.2	0.5	1.2	1.3	1.1	1.3	1.4	0.5	1.5	1.4	0.6	1.1
Ion Balance	1.0	1.09	0.98	0.98	0.99	1.00	0.98	0.95	1.01	0.95	0.98	0.99

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Notes: All values are reported in $mg\cdot L^{-1}$ unless otherwise noted.
L - Less Than; T. - Total; N - Nitrogen; P - Phosphorus

SECTION 7.0

ATHABASCA RIVER

7.1 WATER QUALITY

7.1.1 PHYSICAL PARAMETERS

At stations AR-W1 to AR-W8, the water temperatures in the Athabasca River during May, July, and September ranged from 4.0°C (September) to 24.0°C (July) (Table 7.1). In July 1975, the maximum temperature was 20.0°C while in September the mean value was 12.3°C (McCart et al. 1977). The pH was alkaline, ranging from 7.6 to 8.7. Trends among sampling periods or among stations were not apparent, except that the highest pH generally occurred in July while the lowest pH was recorded in May. A similar pattern was identified in 1974/75 study by McCart et al. (1977). The levels of total non-filterable residue and turbidity were high, particularly those recorded in May and September. The non-filterable residue values ranged from 32.4 to 340.0 $mg \cdot L^{-1}$. The values were considerably higher in May and September than in July, which was similar to the pattern exhibited by the discharge rates in the river. The turbidity levels ranged from 14 to 200 N.T.U. with the lowest and highest values generally occurring in July and September, respectively. Between May and September 1975, total non-filterable residue and turbidity levels ranged from approximately 25 to 225 $mg \cdot L^{-1}$ and 15 to 50 N.T.U., respectively (McCart et al. 1977). The colour of the Athabasca River water ranged from 100 to 200 (true colour) units in May and September, respectively.

Table 7.1. Continued

Site/Date	AR-W4			AR-W3			AR-W2			AR-W1		
Parameter	26 May	28 July	27 Sept.	26 May	28 July	27 Sept.	26 May	28 July	27 Sept.	26 May	28 July	27 Sept.
Temperature °C	12.0	24.0	6.0	12.0	23.0	6.0	12.0	23.0	4.0	12.0	23.0	6.0
pH	7.8	8.0	7.9	7.8	8.3	8.0	7.9	8.0	8.0	7.8	7.8	8.1
Specific Conductance $\mu S \cdot cm^{-1}$	210	210	240	240	200	230	230	200	245	210	200	215
Dissolved Oxygen	9.1	8.7	11.9	9.1	8.4	11.7	9.1	8.5	11.7	9.1	8.8	10.8
Oxygen % Saturation	83	101	95	83	96	93	84	97	88	83	100	86
Turbidity N.T.U.	74	14	140	100	28	120	46	29	42	96	45	140
Calcium	22.50	25.00	28.90	25.30	26.50	32.80	23.00	26.00	30.20	26.20	26.00	33.10
Magnesium	5.69	6.50	7.90	6.78	7.00	9.10	6.76	7.60	9.70	6.50	7.40	8.90
Sodium	9.20	8.50	6.60	8.10	5.50	5.00	11.50	7.50	15.00	8.00	5.70	5.10
Potassium	1.00	0.71	0.75	1.00	0.75	0.78	1.00	0.76	0.77	1.00	0.76	0.76
Chloride	6.60	7.80	5.20	3.00	3.30	2.20	2.80	2.90	3.10	3.60	3.90	2.50
Sulphate	13.9	15.6	21.0	17.5	18.5	26.0	21.9	18.7	21.0	16.3	17.6	25.1
Sulphide	0.10		0.08	0.10		0.05	L0.01		0.06	0.10		0.07
PP. Alkalinity as $CaCO_3$	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1	L0.1
Alkalinity, T. as $CaCO_3$	80.0	83.3	99.6	94.0	88.6	101.0	88.0	91.6	116.0	91.0	87.6	99.0
Bicarbonate	98.0	102.0	121.5	115.0	108.0	123.0	107.5	112.0	141.5	111.0	107.0	121.0
Hardness, T. as $CaCO_3$	80.0	89.0	105.0	91.0	95.0	119.5	85.5	96.0	115.5	92.0	95.5	119.5
Fluoride	0.06		0.05	0.06		0.05	0.07		0.05	0.07		0.05
Silica (Reactive)	5.50	3.92	4.00	5.39	3.20	3.85	4.35	3.80	3.81	5.40	3.30	3.92
Threshold Odour Number	2		2	2		2	2		2	2		2
Colour	100		200	100		200	100		200	100		200
Total Filterable Residue		125			125			130			120	
Total Non-Filterable Residue	271.0	64.0	231.0	340.0	32.4	199.0	171.0	39.6	62.8	335.0	84.4	222.0
Nitrite + Nitrate Nitrogen as N	0.036	0.003	0.041	0.042	0.003	0.041	0.024	0.005	0.012	0.044	0.003	0.045
Ammonia Nitrogen, T. as N	L0.01	0.02	L0.01	L0.01	L0.01	L0.01	L0.01	0.04	0.02	L0.01	L0.01	0.28
Kjeldahl Nitrogen, T. as N	0.78	0.66	0.46	0.74	0.56	0.42	0.76	1.04	0.88	0.78	0.62	0.50
Nitrogen, T. as N	0.78	0.66	0.50	0.74	0.56	0.46	0.76	1.05	0.89	0.78	0.62	0.55
Total Organic Carbon		8.2			6.3			16.5			6.5	
Total Inorganic Carbon		17.0			19.0			18.0			18.0	
Phosphorus, T. as P	0.265	0.025	0.138	0.225	0.042	0.130	0.160	0.091	0.072	0.280	0.064	0.133
Ortho-Phosphorus as P	0.014	0.022	0.011	0.014	0.021	0.009	0.016	0.035	0.026	0.014	0.026	0.008
Phenol	0.006	0.002	L0.001	0.008	0.002	L0.001	0.012	0.004	0.005	0.003	L0.001	L0.001
Surfactants	0.12		0.07	0.11		0.08	0.15		0.19	0.11		0.09
Oil & Grease	0.6	0.3	0.8	0.4	0.2	1.4	0.6	0.3	2.7	0.5	0.1	1.0
Carbon Chloroform Extraction	2.5		1.2	0.5		1.6	1.6		2.5	0.4		1.2
Chemical Oxygen Demand	59	20	39	51	4	20	68	59	64	47	24	20
Biochemical Oxygen Demand	2.8		1.9	2.8		1.4	3.4		1.8	2.6		1.8
Cyanide, T.	0.003	0.002	0.003	0.003	0.001	0.003	0.004	0.021	0.007	0.008	0.001	0.005
Cadmium, T.	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001
Chromium, T.	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.001	0.002	0.002	0.002
Copper, T.	0.007	0.001	0.004	0.009	0.001	0.001	0.003	0.001	L0.001	0.008	0.002	0.004
Iron, T.	3.30	0.96	2.60	2.90	0.46	1.32	1.90	1.01	1.17	2.90	1.03	2.40
Lead, T.	0.002	L0.002	0.002	0.003	L0.002	L0.002	L0.002	L0.002	L0.002	0.002	L0.002	0.002
Manganese, T.	0.140	0.070	0.190	0.174	0.040	0.130	0.117	0.050	0.030	0.145	0.060	0.150
Silver, T.	L0.001		L0.001	L0.001		L0.001	L0.001		L0.001	L0.001		L0.001
Zinc, T.	0.019	0.001	0.008	0.021	0.007	0.003	0.021	0.001	0.003	0.020	0.003	0.008
Vanadium, T.	0.008	L0.001	0.002	0.009	L0.001	0.003	0.008	L0.001	0.001	0.010	L0.001	L0.001
Selenium, T.	L0.0002	L0.0002	L0.0002	L0.0002	L0.0002	L0.0002	L0.0002	L0.0002	L0.0002	L0.0002	L0.0002	0.0002
Mercury, T.	L0.0001	L0.0001	L0.0001	L0.0001	L0.0001	L0.0001	L0.0001	L0.0001	L0.0001	L0.0001	L0.0001	L0.0001
Arsenic, T.	0.0011	0.0006	0.0010	0.0014	0.0004	0.0010	0.0010	0.0007	0.0008	0.0012	0.0007	0.0010
Nickel, T.	0.003	0.002	L0.001	0.004	L0.001	L0.001	L0.001	L0.001	L0.001	0.004	0.002	L0.001
Aluminum, T.	0.84		0.72	1.00		0.17	0.68		0.14	0.82		0.65
Cobalt, T.	0.002		0.002	0.002		L0.001	L0.001		L0.001	0.002		0.002
Boron, T.	0.12	0.03	0.03	0.12	0.02	0.02	0.14	0.06	0.10	0.11	0.02	0.04
Titanium, T.	L0.010		L0.010	L0.010		L0.010	L0.010		L0.010	L0.010		L0.010
Barium, T.	0.08		0.07	0.13		0.05	0.07		0.03	0.11		0.07
Methyl Mercaptan	L0.1		L0.1	L0.1		L0.1	L0.1		L0.1	L0.1		L0.1
Sodium as % of Cations	20		12.0	16		8.3	23		21.9	16		8.5
Tannin & Lignin	1.3		1.1	1.7	0.6	1.0	1.1	1.8	2.4	1.1	0.6	1.7
Ion Balance	0.97	0.98	0.98	0.94	0.96	1.00	0.97	0.98	1.04	0.98	0.97	1.02

Notes: All values are reported in $mg \cdot L^{-1}$ unless otherwise noted.
L - Less Than; T. - Total; N - Nitrogen; P - Phosphorus.

The dissolved oxygen concentrations (ranging from 8.4 to 12.8 $mg \cdot L^{-1}$) were lowest in July and highest in September. The oxygen saturation levels, however, were lowest in May (83%) and highest in July (105%). Trends among stations were not evident. During the same sampling periods in 1975, oxygen saturation exceeded 80% (McCart et al. 1977).

7.1.2 MAJOR IONS

The water in the Athabasca River was of the calcium bicarbonate type, generally with an ionic dominance of $HCO_3^- > Ca^{++} > Mg^{++} > SO_4^=$ $> Na^+ > Cl^- > K^+$ (Figure 7.1). The ionic character of the water was similar among the stations, showing no trends as indicated by the specific conductance levels. Sodium and chloride ions, however, exhibited an erratic behaviour at AR-W7; this perhaps resulted from influence by the Poplar Creek Reservoir water. Sodium and chloride concentrations in Poplar Creek were considerably higher (approximately three times) than those recorded at AR-W8. At AR-W7 samples were obtained at the demarcation between the Athabasca River water, which was silty in colour, and the brown coloured Poplar Creek water. Similarly, at AR-W2 the behaviour of sodium may have resulted from the MacKay River influence where the sodium concentrations were approximately two to three times greater. The sampling approach used at AR-W2 was similar to that described for AR-W7.

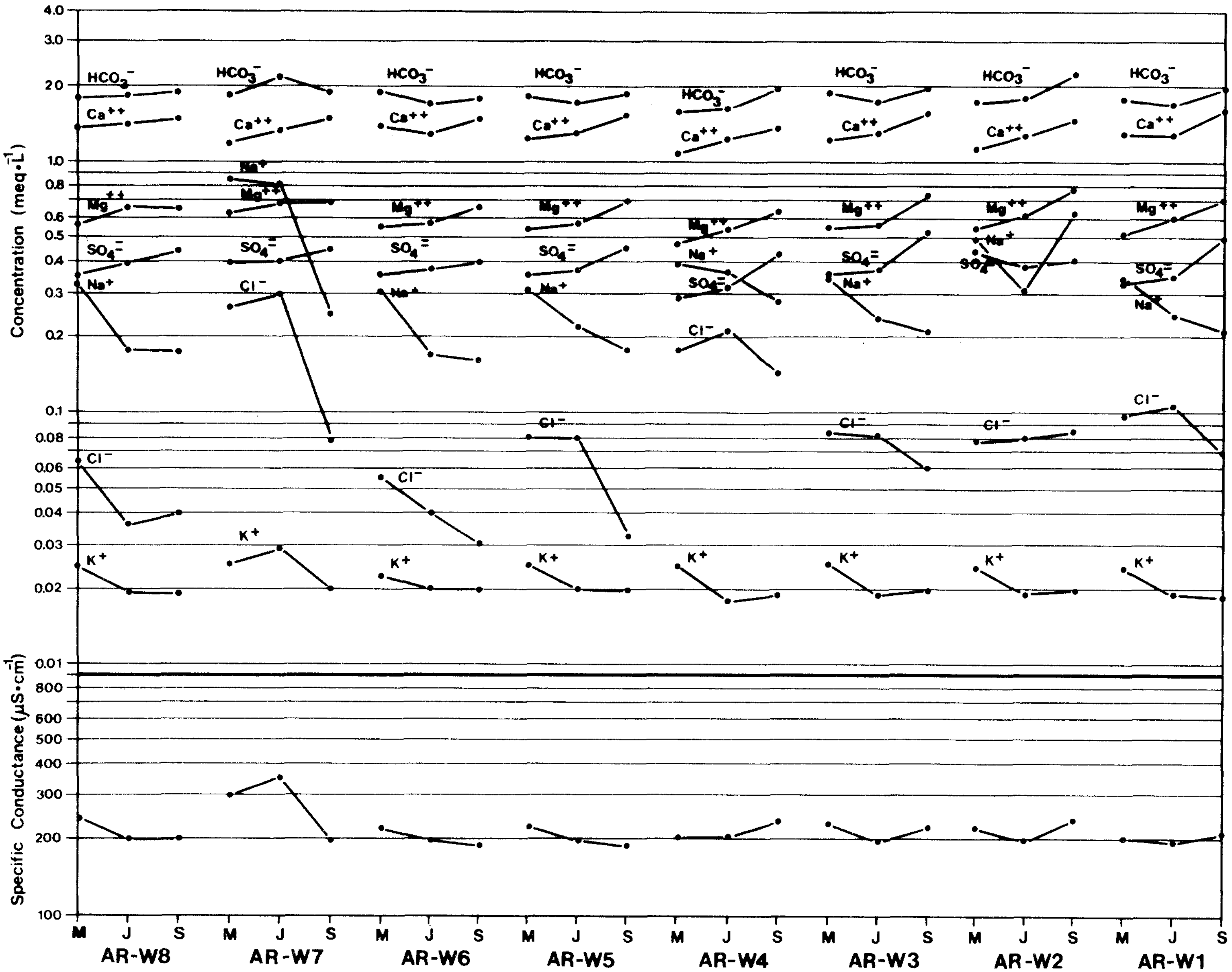

Figure 7.1 Ionic dominance of the major ions, and specific conductance profiles, for the Athabasca River in May, July and September, 1984.

7.1.3 NUTRIENTS

Total nitrogen concentrations ranged from 0.46 to 1.12 mg $N \cdot L^{-1}$ and generally were below the ASWQO of 1.0 mg $N \cdot L^{-1}$. The values, which generally were highest in May and lowest in September, showed no trend among the stations. Nitrate + nitrite concentrations ranged from 0.003 to 0.065 mg $N \cdot L^{-1}$. Although a trend among stations was not apparent, the values generally were highest in September and lowest in July.

Total phosphorus concentrations (ranging from 0.025 to 0.285 mg $P \cdot L^{-1}$) frequently exceeded the ASWQO of 0.05 mg $P \cdot L^{-1}$ but showed no trends among stations. The values generally were highest in May, declined sharply in July, and increased in September. This pattern closely paralleled the fluctuations of the non-filterable residue concentrations. The behaviour of ortho-phosphorus, however, was distinctly different, with the highest values occurring in July. In 1975, the concentrations of the total dissolved phosphorus, which ranged from approximately 0.030 to 0.020 mg $P \cdot L^{-1}$, showed the same behaviour with highest levels recorded during June and July (McCart et al. 1977). As with total nitrogen, there was no trend apparent among stations.

Reactive silica concentrations ranged from 2.54 to 5.50 $mg \cdot L^{-1}$. Although no trends among stations were apparent, the lowest and highest concentrations generally occurred in July and May, respectively.

Total organic carbon levels ranged from 5.3 to 16.5 $mg \cdot L^{-1}$. These concentrations were similar to those found in 1975 when concentrations between 11.0 to 15.0 $mg \cdot L^{-1}$ were reported immediately downstream of the SUNCOR pumphouse (McCart et al. 1977). In addition, they indicated that values along transects were similar with no consistent difference between the east and west bank.

7.1.4 TRACE METALS AND OTHER SUBSTANCES

Most trace metals and elements exhibited concentrations below the detection limits. Most parameters showed no distinct trends among stations or sampling periods. Concentrations of heavy metals adsorbed to particulate matter (mainly clay and organics) generally fluctuate in direct relationship with concentrations of total non-filterable residue. This was exemplified by the concentrations of total copper, zinc, vanadium, aluminum, nickel, iron, and manganese which generally exhibited the highest levels in May. Iron concentrations (ranging from 0.046 to 3.30 $mg \cdot L^{-1}$) frequently exceeded the ASWQO of 0.30 $mg \cdot L^{-1}$. All manganese levels (ranging from 0.040 to 2.33 $mg \cdot L^{-1}$) exceeded the ASWQO of 0.05 $mg \cdot L^{-1}$ except on two occasions. A single cyanide concentration (0.021 $mg \cdot L^{-1}$) slightly exceeded the ASWQO of 0.01 $mg \cdot L^{-1}$. Although the unusually high cyanide level is considered natural, it should be checked in future studies.

All aluminum levels (ranging from 0.14 to 1.03 $mg \cdot L^{-1}$) exceeded the tentative guideline of 0.100 $mg \cdot L^{-1}$ proposed by the International Joint Commission to Environment Canada. The source of the aluminum is probably associated with the suspended clay particles. Copper concentrations (ranging from 0.001 to 0.008 $mg \cdot L^{-1}$) occasionally exceeded the Environment Canada guideline of 0.005 $mg \cdot L^{-1}$. With respect to other parameters, phenol levels ranged from less than 0.001 to 0.012 $mg \cdot L^{-1}$ and occasionally exceeded the ASWQO of 0.005 $mg \cdot L^{-1}$. All carbon chloroform extraction values (ranging from 0.4 to 2.9 $mg \cdot L^{-1}$) exceeded the ASWQO of 0.2 $mg \cdot L^{-1}$. Oil and grease concentrations ranging from 0.1 to 2.7 $mg \cdot L^{-1}$ were recorded.

SECTION 8.0

DISCUSSION

8.1 WATER QUALITY

Water quality has an important role in determining the character of aquatic life in aquatic systems.

Lotic systems, including the MacKay River and tributaries, West Interception Ditch and tributaries, Bridge Creek, Lower Beaver Creek, Creek B-1, Upper Beaver Creek, Poplar Creek, and Athabasca River, were indicative of typical natural systems and revealed no characteristics that were considered deleterious or seriously inhibitory to the existing aquatic life. Except for the Athabasca River, the water was brown in colour due to the dissolved organics. Temperatures as high as 24.5°C were reached in July. The water quality parameters generally were within the Alberta Surface Water Quality Objectives (Alberta Environment 1977) and the Environment Canada-Water Quality Sourcebook (McNeely et al. 1979). The concentrations of trace metals and elements were below the detection limits except for iron and manganese. The source of phenol likely was natural, originating mainly from oil sands outcroppings and decaying vegetation. The waters generally were alkaline and of the calcium bicarbonate type, although sodium bicarbonate waters frequently were present. Even though the streams exhibited changes in ionic dominance, the level of salinity did not increase notably. Except for some tributaries associated with the West Interception Ditch, the dissolved oxygen conditions were within the acceptable limits for fish. Although the concentrations of nutrients (total nitrogen and total phosphorus) generally exceeded the water quality objectives, the concentrations of nitrate + nitrite and the ortho-phosphorus fractions frequently were low.

The water quality in lentic systems, including Beaver Creek Reservoir, Ruth Lake, Poplar Creek Reservoir, and Horseshoe Lake, were similar. The waters had a pH ranging from slightly acidic to alkaline and were of the sodium bicarbonate type with high levels of sodium and chloride ions. Concentrations of trace metals and elements generally were below detection limits except for iron and manganese which frequently exceeded the water quality objectives. These conditions are typical of shallow boreal lakes rich in organic matter. In Beaver Creek Reservoir stratification was poorly developed in June and July; an isothermal condition was reached in September. Temperatures as high as 22.0°C were reached at the surface in July. During stratification dissolved oxygen levels in the hypolimnion decreased to below 5.0 $mg \cdot L^{-1}$, a minimum limit for fish. A supersaturated oxygen condition was present in the epilimnion in July. Specific conductance levels were considerably higher in the hypolimnion than in the epilimnion. Total nitrogen concentrations were low and only slightly exceeded the water quality objective. The concentrations of nitrate + nitrite also were considered low. The concentrations of total phosphorus frequently exceeded the water quality objective; some concentrations of the ortho-phosphorus fraction also exceeded the objective.

Water quality in Ruth Lake was similar to that in the Beaver Creek Reservoir. Although Ruth Lake showed no stratification, slight temperature, pH, dissolved oxygen, and specific conductance gradients between the surface and the bottom were observed. Total nitrogen concentrations were similar to that in Beaver Creek Reservoir while total phosphorus levels were lower in Ruth Lake.

Poplar Creek Reservoir revealed a typical stratification pattern during June, July, and September; an isothermal condition was reached in October 1984. Anaerobic conditions were present in the hypolimnion in June and July, and the presence of hydrogen sulphide gas was apparent. The concentrations of most major ions were higher in Poplar Creek Reservoir than Ruth Lake. In Poplar Creek Reservoir specific conductance, total nitrogen, total phosphorus, and reactive silica levels were higher in the hypolimnion than in the epilimnion. Total nitrogen concentrations generally were higher than those in Ruth Lake based on results from composite samples. The concentrations of trace metals and elements were similar to those described for Ruth Lake; cyanide concentrations exceeded the water quality objectives.

During the study, Horseshoe Lake was aerobic and exhibited supersaturation in June. Water temperatures reached 22.0^{o}C in July. Total nitrogen and total phosphorus concentrations exceeded the water quality objectives. Concentrations of trace metals and elements were below the detection limits except for iron and manganese which exceeded the water quality objectives. Phenol levels also exceeded the objectives.

8.2 PHYTOPLANKTON

For Beaver Creek Reservoir, Ruth Lake, and Poplar Creek Reservoir, a comparison of mean phytoplankton standing crop estimates on a cell volume basis revealed that Beaver Creek Reservoir was the most productive and Poplar Creek Reservoir the least productive (Table 8.1). On an areal basis, however, which considers production for the total water column expressed on a surface area basis, Ruth Lake exhibited the lowest standing crop and Poplar Creek Reservoir the highest. High algal production levels in the epilimnion of Poplar Creek Reservoir also is indicated by the higher surface oxygen levels during both mid-June and late July sampling periods, in comparison to Ruth Lake and Beaver Creek Reservoir. The higher production level in Poplar Creek Reservoir is attributed mainly to a bloom of Cyanophyta, primarily **Aphanizomenon flos-aquae**, in the epilimnion. Although a similar increase in blue-green algae occurred in both Ruth Lake and Beaver Creek Reservoir, the biovolume was greater and the bloom persisted longer in Poplar Creek Reservoir.

The dominance by blue-green algae in the two reservoirs indicates that this group was able to take advantage of existing conditions and substantially increase its population. Blue-green algae can regulate their buoyancy (Reynolds 1975), and thus can better maintain themselves near the surface where incident light is greatest. This is a particular advantage in turbid systems such as Beaver Creek Reservoir where the trophogenic zone is shallow (Noton and Chymko 1978). Vertical mixing in

Table 8.1 Phytoplankton standing crop estimates based on the mean of three seasonal samples.

Waterbody	Volumetric Basis		Areal Basis	
	Cell Number ($Cells \cdot mL^{-1}$)	**Cell Volume** ($x10^3 \mu m^3 \cdot mL^{-1}$)	**Cell Number** ($x10^9 \cdot m^{-2}$)	**Cell Volume** ($x10^{12} \mu m^3 \cdot m^{-2}$)
Beaver Creek Reservoir	9 848	1 696	45.3	8.39
Ruth Lake	20 807	1 234	41.6	2.47
Poplar Creek Reservoir	17 294	1 135	27.4	17.9

a weakly stratified waterbody such as this, can circulate algae unable to regulate their buoyancy into deeper waters and out of the trophogenic zone, thereby suppressing production. Many species of blue-green algae exhibit rapid population increases when conditions are suitable. Hoogenhout and Amez (1964) reported that some species of **Anabaena** are capable of doubling their populations one to four times per day. Large concentrations of algae near the surface also can effectively shade other algae in the deeper waters (Fogg 1966), thereby inhibiting production of those species that cannot regulate their buoyancy and move toward the surface.

Blue-green algae can also fix atmospheric nitrogen, thereby fluorishing during periods when concentrations of available dissolved nitrogen are low (Dugdale and Dugdale 1962). Water quality results from the present study indicate that nitrate + nitrite nitrogen levels were generally low throughout the three waterbodies in all three of the seasons sampled. The low available nitrogen levels may be a limiting factor for populations of non blue-green algae.

The extensive macrophyte growth might explain the low phytoplankton production in Ruth Lake. The extensive growths of **Nuphar** likely shade a substantial portion of the waterbody, thereby inhibiting algal growth in the underlying waters. Macrophytes and algae also compete for the available macronutrients. The extent to which these factors affect algal production is unknown.

8.3 ZOOPLANKTON

In this study, zooplankton samples obtained from Beaver Creek Reservoir, Ruth Lake, and Poplar Creek Reservoir, revealed no uncommon or rare species among the rotifers, crustaceans, and Chaoboridae. The zooplankton communities of these three waters showed little differentiation and were similar in many respects to the communities of many other small lakes in central and northern Alberta (R.S. Anderson 1974 and unpublished data). On a wide scale, the communities were not unlike those of many small meso- and eutrophic lakes in the Great Plains area of central North America (e.g., those described by Teraguchi et al. 1983; Baker 1979).

The dominance of the cladoceran plankton by **Daphnia parvula** appears to be uncommon for this part of North America, although it is frequently encountered farther east (e.g., Ohio: Teraguchi et al. 1983). **D. parvula** was reported only infrequently prior to the 1960's (Brooks 1975), but has been recorded with increasing frequency in recent years. This could be due to any or all of the following reasons:

a) the species could have been missed, especially when scarce, because of its small size;
b) prior to the 1970's, there was a paucity of detailed studies in the large numbers of small lakes in western Canada;
c) increase in fish or other plankton predators could have shifted the size structure in favour of smaller species; and

d) the species may be still in the process of range expansion, a process that could have been hastened by the previous point.

The continuation of the dominance by **D. parvula** is not assured. The alteration of dominance between **D. parvula** one year and one or more other **Daphnia** spp. in another year has been noted for Field Lake, a small, elongate and shallow lake near Lac la Biche (R.S. Anderson, unpubl. data). Such occurrences elsewhere in northeastern Alberta can be expected.

It is noteworthy that the zooplankton communities of all three waterbodies under study were comprised of relatively small species in 1984, although large species had been common in 1974-1977. In the presence of sufficient food and the absence of zooplankton-feeding predators, the tendency is towards large species (e.g., Lynch 1977a, and others), although the species of certain genera such as **Daphnia** (large) and **Bosmina** (small) may coexist in the absence of predators by partitioning an adequately diverse food source (Kerfoot and DeMott 1980). Many investigators have shown that the shift from large to small species is related to the presence of abundant fish or other vertebrate predators, or large invertebrate predators (Brooks and Dodson 1965; Hrbacek and Novotna - Dvorakova 1965; Anderson and Raasveldt 1974; and Anderson 1980). Conversely, the decline or removal of fish may promote a return to large zooplankton species (Shapiro and Wright 1984). However, certain other studies have shown that the type and concentration of food available (Weglenska 1971) or combinations of a number of environmental factors in addition to food and/or predators may determine the size structure of zooplankton communities (Lynch 1977b, 1980).

Although the presence of large numbers of zooplankton - feeding fish (especially fathead minnows) is the most obvious explanation for the apparent shift from large to small body size in the crustacean plankters from the three waterbodies between 1977 and 1984, other causes are possible. Large year-to-year fluctuations do occur in many small lake zooplankton communities, and it would be necessary to gather fish, zooplankton, and other limnological data consistently over a period of several years to be able to determine the exact causes of community structure changes and to ascertain the permanent or cyclical nature of these changes. For example, high flushing rates in small water bodies are known to have an impact on community structure and abundance. In the waterbodies of this study, flushing may have reduced overall abundance, but does not seem to have affected composition, as species gone from any one waterbody are gone from all three. Furthermore, there is no evidence of "downstream" accumulation of either numbers or biomass. With respect to water quality, there is some evidence of higher total dissolved solids (TDS) and lower dissolved oxygen levels at greater depths in Poplar Creek Reservoir, but it is unlikely that any of the species present now or in 1977 would be eliminated by present levels of TDS. If species have been excluded from the deeper waters of this reservoir, it likely is due to low oxygen levels. The combination of higher TDS at greater depth, especially in Poplar Creek Reservoir, and the establishment of a pronounced thermocline would prevent complete mixing and could produce a zone of stagnation characterized by anoxic conditions. Such conditions reduce the lake volume occupied by zooplankters.

If zooplankton-feeding fish are a major factor in influencing the zooplankton community structure, a major change in fish species could, in future, see a return of some or all of the zooplankton species. These species are probably still present in very low numbers in the plankton, near shore in shallow areas, or in isolated shoreline ponds. If the large species should reappear, for whatever reasons, their reappearance could very well be accompanied by reductions in numbers of some of the small species dominating the 1984 plankton.

Due to the elongated and relatively narrow nature of the three waterbodies of this study, winds likely influence the distribution of zooplankton, with some species affected more than others (see Teraguchi et al. 1983). This wind factor may explain the considerable differences in abundance of certain species between different stations in the same reservoir on the same day in previous studies (Noton and Chymko 1977). To ascertain the effect of wind on zooplankton distribution sampling at several stations during a period of several days of moderate to strong wind action would be required. Conversely, to obviate the problem of uneven distribution due to wind action, composite samples from a minimum of ten stations should be taken in order to provide a representative assessment of total lake zooplankton.

8.4 ZOOBENTHOS

The composition of benthic communities within the study area is typical for the boreal region of northeastern Alberta. Differences in composition, richness, and abundance of zoobenthos could largely be ascribed to physical and energetic characterstics among stations. Multivariate analyses (Appendix H) detected compositionally distinct groupings of stations that reflected the differing physical nature of running water habitats in spring and summer. Stations dominated by mayflies and Simuliidae, such as upstream MacKay River and lower Poplar Creek stations, were characterized by moderate to rapid flow, hard, relatively unsilted substrate, and were located on wide streams that received abundant solar radiation. This stimulates periphytic development and provides a food supply conducive to development of grazing and filter-feeding organisms. Stations with equivalent flow and substrate conditions that received little sunlight harboured fewer individuals of these taxa and contained proportionately more organisms that feed on dead organic matter. Stations typical of this included some Lower Beaver Creek drainage stations, and smaller tributaries of the MacKay River. Stations with silted substrates and/or reduced velocity typically were dominated by Chironomidae and Oligochaeta (e.g., upstream W.I.D. and tributary stations).

There was little evidence that alteration of stream habitats resulted in taxonomically distinct communities. Principal components analysis consistently grouped stations subjected to modification with unperturbed stations having equivalent structural and energetic characteristics. In particular, the communities of Poplar Creek stations downstream of the inflow of Poplar Creek Reservoir were similar to erosional stations on the MacKay River. Changes in community composition, abundance, and biomass from earlier studies (e.g., Tsui et al. 1977; Noton and Chymko 1978) indicate recovery from perturbation effects and convergence to community characteristics typical for this portion of the province.

The zoobenthos of lentic sites was dominated by Oligochaeta, Chironomidae, and in some cases **Chaoborus**. The community in deeper regions of Beaver Creek Reservoir appeared to be increasingly dominated by Oligochaeta. This implies that the substrate in such areas is accumulating organic material, and reflects a natural increase in productivity of the reservoir as it matures. The dipteran, **Chaoborus**, has become more prevalent in hypolimnetic regions of Poplar Creek Reservoir, suggesting continued anoxic conditions in such areas. Again, this appears to be a natural consequence of eutrophication of a newly formed reservoir.

8.5 FISH

The assemblage of fish species recorded in the MacKay River was similar to that noted during previous investigations on this system (Griffiths 1973; RRCS 1975; McCart et al. 1978; Machniak et al. 1980). Differences in species composition were limited to forage species. Earlier studies identified 21 species as compared to 19 species encountered in 1984.

Variations in the relative abundance of sportfish between 1978 and the present were, for most species, attributed to differences in sampling techniques and effort. An exception was the large number of goldeye captured in 1984 in comparison to 1978. In 1984, goldeye was the most abundant sportfish species encountered in the MacKay River, with both adults and juveniles present. In 1978, goldeye was the fourth most abundant sport fish species (after walleye, northern pike, and Arctic grayling). All of the catch was comprised of juveniles. Goldeye also was the most abundant sport species encountered during 1976 and 1977 studies on the Athabasca River within the Mildred Lake area (Bond 1980). Similarly, most (99%) of goldeye recorded in this area were juveniles. The presence of numerous adult goldeye in the MacKay River in 1984 may indicate a more intensive use of this system than originally surmised. Evidence of goldeye spawning in the MacKay River in 1984 was not obtained; however, it is evident that the system provides important feeding habitat.

The limited sampling conducted on the MacKay River in 1984 did not provide sufficient data for an accurate assessment of sportfish movements or use patterns in the system. Machniak et al. (1980) indicated sport fish species in the MacKay River originated from Athabasca River populations and returned to this system before freeze-up. An exception was a resident population of northern pike reported in the upper reaches of the MacKay River. Walleye and northern pike movements into the MacKay River were described as post-spawning feeding migrations. Arctic grayling adults in spawning condition moved upstream in the MacKay River in early spring although spawning areas of these individuals were not recorded. The presence of a few young-of-the-year Arctic grayling in the MacKay River upstream of Lease 17 suggests some spawning use may be made of the upper reaches of the mainstem river or in tributaries to the system. The apparent absence (for extended rearing and adult feeding) of Arctic grayling from the middle and lower reaches of the MacKay River may be related to the high summer water temperatures (Sec. 3.2.1). Other factors (e.g., water chemistry, flow characteristics) also may be contributing factors. A similar small number of burbot, lake whitefish, and mountain whitefish were observed in the MacKay River during both 1978 and 1984 studies, and probably only indicates short distance/duration foraging movements by fish from the Athabasca River.

The late initiation of the spring study period in 1984 precluded the direct identification of spawning use of the MacKay River by spring spawning species (e.g., walleye, northern pike, yellow perch, sucker species). Indirect evidence (i.e., presence of spent adults and young-of-the-year fish) support the conclusion that both white sucker and longnose sucker spawning occurs in the MacKay River. White suckers were the most abundant coarse fish encountered. Machniak et al. (1980) reported a white sucker spawning migration into the MacKay River in early May 1978. A spawning migration of lesser magnitude was recorded for longnose suckers. Results for both study years indicate the presence of important spawning and rearing habitat for these species in the MacKay River.

Three species of fish were captured in the West Interception Ditch System and Bridge Creek including the fathead minnow, brook stickleback, and lake chub. The former two species were widespread in both systems. A similar distribution pattern was reported by Tsui et al. (1977). Lake chub were encountered in the ditch and in Bridge Creek, but only sporadically. The earlier investigators did not encounter lake chub in the upper part of the system (i.e., above North Starter Dike). It now appears that there is either a resident population of lake chub in the upper system or a periodic invasion of individuals from Creek B1 (i.e., overtopping of dam).

The 1984 sampling results indicate that the section of Lower Beaver Creek from the North Starter Dike to the Highway 63 crossing is devoid of fish. In 1977, lake chub, white suckers, and longnose suckers were present in this reach. It is apparent that the former upstream spawning movements into this reach no longer occur; this is likely due to severe habitat limitations and access restrictions (i.e., at culverts).

In 1984, the fish fauna of the Beaver Creek Diversion system (excluding Poplar Creek) consisted of resident populations of white suckers, fathead minnows, brook stickleback, and lake chub. Each of these species was recorded in Beaver Creek Reservoir and tributaries (i.e., Upper Beaver Creek and Creek B1) to the reservoir. Lake chub were absent from Ruth Lake and Poplar Creek Reservoir. Fathead minnow and brook stickleback were substantially more abundant in Ruth Lake than elsewhere in the diversion system. Densities of these species declined substantially at all lentic sample stations compared to densities reported in 1981. The reason for this population decrease is unclear, although it may be related to declining levels of productivity in the reservoir. The high densities recorded in 1978 and 1981 may have reflected an initial increase in productivity after impoundment. The decline in status of forage species also may have been due to competition for food and space by white suckers. White suckers, although present in low abundance in seine haul captures, exhibited similar gill net capture rates in 1981 compared to 1984. The presence of suitable spawning habitat for this species in Creek B1 may account for the apparent maintenance of white sucker population levels. The presence of diverse and densely populated invertebrate fauna in Creek B1 (Sec. 5.2.3) suggests that feeding conditions for young-of-the-year white suckers and lake chub are very suitable. In Ruth Lake, a substantial increase in gill net capture rates for white sucker was recorded in 1984 compared to 1981. This increase may be related to the presence of suitable rearing and feeding habitat since the catch in Ruth Lake consisted of juveniles and to a lesser extent, young adults.

As was noted in previous studies, the white sucker population in Poplar Creek Reservoir was characterized by relatively low abundance and the absence of annual recruitment (i.e., no y-o-y captured). The following features appear to limit the habitat suitability of this waterbody in comparison to Beaver Creek Reservoir: anoxic conditions in hypolimnetic strata during summer, which likely reduces the availability and quality of feeding areas; anoxic conditions throughout the majority of the water column during winter, which may reduce overwintering success (particularly for the larger individuals); and absence of suitable spawning habitat within, and in proximity to, the reservoir proper. It appears that the white sucker population in Poplar Creek Reservoir is supported by migrants from the upper part of the diversion system (Beaver Creek Reservoir).

Fish species composition in the Beaver Creek Diversion system (excluding Poplar Creek) has apparently stabilized since the development of the diversion system (Table 8.2). In Beaver Creek Reservoir, Poplar Creek Reservoir, Ruth Lake, and Upper Beaver Creek, species composition in 1981 was identical to that recorded in 1984. Differences in composition and abundance between 1981 and 1984 in Poplar Creek likely reflect differences in the extent of seasonal use (e.g., feeding related) by fish from the Athabasca River. The presence of Arctic grayling in particular appears to be dependent on flow rates in Poplar Creek.

Table 8.2. Post-development fish species composition in the Beaver Creek Diversion Study area recorded by previous investigators (1977[a], 1978[b], and 1981[c]), and during the present study (1984).

Species	Beaver Creek Reservoir				Ruth Lake				Poplar Creek Reservoir				Upper Beaver Creek				Poplar Creek			
	77	78	81	84	77	78	81	84	77	78	81	84	77	78	81	84	77	78	81	84
Lake whitefish																	+			
Mountain whitefish																	+			
Arctic grayling													+				+	+		+
Northern pike	+[d]																+	+		+
Yellow walleye																	+			
Yellow perch																	+	+		
Burbot																	+	+	+	+
Longnose sucker	+	+			+	+							+	+			+	+	+	+
White sucker	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Fathead minnow	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Lake chub	+	+	+	+		+				+			+	+	+	+	+	+	+	+
Spottail shiner																	+			
Finescale dace																	+			
Northern redbelly dace																				+
Spoonhead sculpin														+						
Brook stickleback	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Trout-perch																	+	+		
Total species (17)	6	5	4	4	4	5	3	3	3	4	3	3	6	6	4	4	15	10	6	9

[a]Noton and Chymko (1978).
[b]O'Neil (1979).
[c]O'Neil (1982).
[d]+ indicates species present.

SECTION 9.0

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PHOTOGRAPHIC PLATES

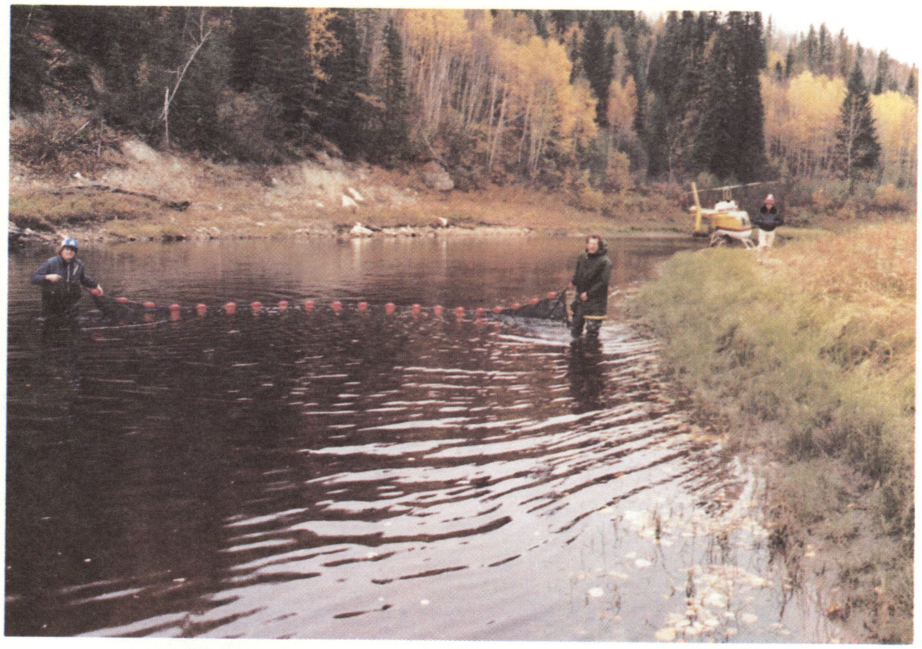

Plate 1. MacKay River (km 2.7). Sampling by beach seine at station MR-SIB in the vicinity of habitat station MR-H2. The plate illustrates typical Flat habitat in association with inundated riparian vegetation. These areas were utilized for rearing (i.e., by young-of-the-year yellow perch, sucker sp. and forage sp.) and feeding (i.e., by adult forage sp.) during the fall period, 26 September 1984.

Plate 2. Dover River (km 32). Aerial view (upstream) of the Dover River (at lower right), and a tributary (at centre), illustrating the low relief of the drainage basin. This results in the low gradient, beaver controlled stream character typical of Reaches 3 and 4, 24 September 1984.

Plate 3. Creek M4 at water quality station M4-W. The plate illustrates the high channel gradient and coarse angular substrate typically encountered within Reach 1 of the majority of sampled MacKay River tributaries, 20 June 1984.

Plate 4. West Interception Ditch showing the extensive growth of emergent and submergent aquatic vegetation that was typical of Reach 3 in the summer and fall. Area shown is at WID-H3 and WID-EF3, 27 September 1984.

Plate 5. Creek W3 at water quality station W3-W. Upstream view from confluence with W.I.D. (foreground) illustrates typical beaver controlled character of W.I.D. tributaries. Water quality samples were taken from within the beaver pond, 25 July 1984.

Plate 6. Lower Beaver Creek viewed downstream through electrofishing station LBC-EF2, taken at high spring flows. Brook stickleback was the only species recorded from this area, 25 May 1984.

Plate 7. Creek B1 (formerly Creek No. 4) viewed downstream from the road crossing to Beaver Creek Reservoir (in background). The plate shows stations B1-B, B1-EF1, and B1-H2 (transect T1 located at standpipe on left bank). In May, this area was the primary spawning section for white sucker and lake chub; 25 July 1984.

Plate 8. Beaver Creek Reservoir viewed from south end of the reservoir at the mouth of Upper Beaver Creek (lower left) toward the mine site. Fisheries station UBC-ES was situated within this section of Upper Beaver Creek, 25 September 1984.

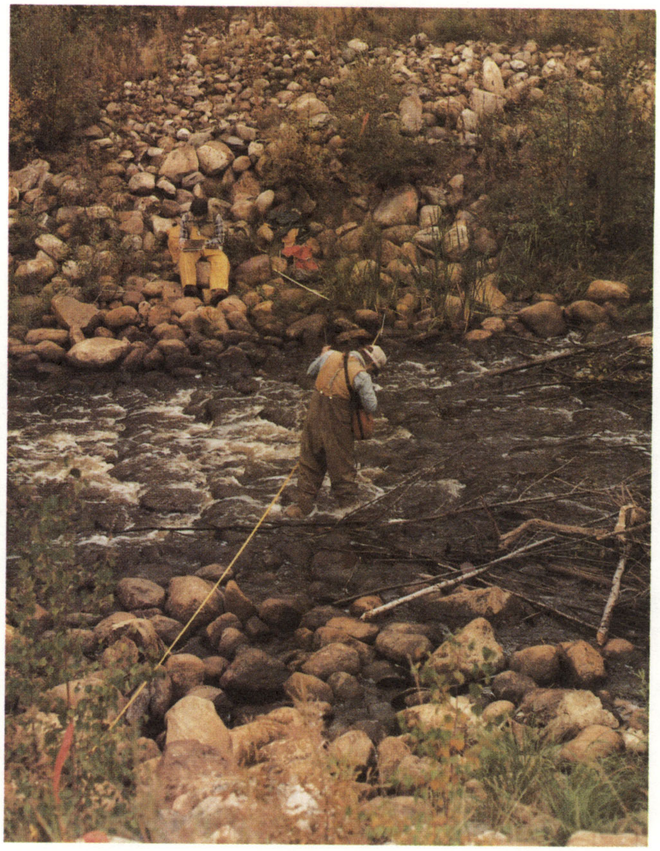

Plate 9. Poplar Creek illustrating habitat sampling procedures at PC-H1-T5. Note the flagging and painted arrow on the boulder on the far shore that mark the transect location, 6 September 1984.

Plate 10. Horseshoe Lake at water quality station HL-W. The plate illustrates the extensive macrophyte growth that has developed in the lake by late July, 27 July 1984.

APPENDICES

APPENDIX A

LOCATION AND IDENTIFICATION OF 1984 SAMPLE STATIONS

Table A1. Summary of sample station locations in the Syncrude Study Area, 1984.

System	Study Component	Station Designation	Station Location/Description[a]
MacKay River (mainstem)	Habitat	MR-H1	Km 0.8; approx. 300 m upstream of bridge; orange slash and S.P. on 30 cm diam. poplar on RUB.
		MR-H2	Km 2.8; transect is 9 m downstream of large poplar (approx. 35 m from waters edge) on RUB and 18 m downstream of painted boulder on LUB; S.P. on poplar on RUB.
		MR-H3	Km 10.3; transect between 20 m high poplar on LUB and 25 m high poplar approx. 10 m back from top of RUB.
		MR-H4	Km 22.0; transect located 34 m downstream from large boulder in mid-channel; across from birch 5 m back from top of RUB and 5 m upstream of large birch (12 m high) on RUB; S.P. on birch on RUB.
		MR-H5	Km 29.3; transect between large poplar on RUB and large poplar on LUB; S.P. on poplar on LUB.
		MR-H6	Km 38.9; transect between poplar 15 m from waters edge on LUB and 6 m high spruce 4 m from edge of RUB.
		MR-H7	Km 45.2; transect between painted boulders on RUB and LUB; no S.P.
		MR-H8	Km 49.1; transect between alder 4 m from top of RUB and alder on LUB; S.P. on alder on RUB.
		MR-H9	Km 58.7; transect located 24 m upstream of large painted boulder on LUB and across from flagged alder on RUB; no S.P.
	Water Quality	MR-W1	Km 0.5; sampled off edge of bridge.
		MR-W2	Km 38.7; 40 m downstream of Creek M5 confluence.
		MR-W3	Km 60.8; approx. 2 km upstream of M11 confluence.
	Benthos	MR-B1	Km 0.7; 90 m upstream of bridge; flagging and paint on alders in shallow ditch along LUB.
		MR-B2	Km 14.0; along RUB.
		MR-B3	Km 29.3; 1.5 km upstream of Dover River confluence; site marked by two red rings on tree and painted rock on RUB.
		MR-B4	Km 40.2; 90 m upstream of Creek M6 confluence; site marked by red paint on saplings and painted rock on LUB.
	Fisheries	MR-ES1	Km 0.0 to Km 5.0; alternate banks.
		MR-ES2	Km 10.5 to Km 15.0; alternate banks.
		MR-ES3	Km 26.3 to 31.0; alternate banks.
		MR-EF1	Km 0.6; 60 m along LUB.
		MR-EF2	Km 2.7; 110 m along LUB.
		MR-EF3	Km 10.2; 110 m (alternate RUB and LUB).
		MR-EF4	Km 21.8; 100 m along RUB.
		MR-EF5	Km 29.8; 60 m along LUB.
		MR-EF6	Km 38.9; 70 m along RUB.
		MR-EF7	Km 49.1; 50 m along RUB.
		MR-EF8	Km 59.3; 110 m along LUB.
		MR-EF9	Km 75.9; 160 m along RUB.
		MR-S1	Km 1.6; 3 hauls along RUB.
		MR-S1A	Km 0.6; 1 haul along LUB; 2 hauls along RUB.
		MR-S1B	Km 2.7; 3 hauls along RUB.
		MR-S2	Km 7.8; 3 hauls along RUB.
		MR-S2A	Km 10.2; 3 hauls along RUB.
		MR-S3	Km 19.8; 3 hauls along RUB.
		MR-S3A	Km 21.8; 1 haul along RUB.
		MR-S4	Km 49.1; 1 haul along LUB.
		MR-S5	Km 75.9; 2 hauls along LUB.
MacKay River (tributaries)	Water Quality	M1-W	approx. 50 m upstream from mouth; flagged.
		M2-W	approx. 40 m upstream from mouth; flagged.
		M3-W	approx. 10 m upstream from mouth; flagged.
		M4-W	approx. 20 m upstream from mouth; flagged.
		M5-W	approx. 40 m upstream from mouth; flagged.
		M6-W	access by cutline at top of valley approx. 1.0 km upstream from mouth; approx. 20 m below beaverdam; flagged.
		M7-W	approx. 250 m upstream from mouth and 30 m below large beaverdam; flagged.
		M8-W	approx. 10 m upstream from mouth; flagged.
		M9-W	approx. 25 m upstream from mouth; flagged.
		M10-W	approx. 40 m upstream from mouth; flagged.
		M11-W	approx. 40 m upstream from mouth; flagged.
	Benthos	M2-B	approx. 40 m upstream from mouth; red paint on saplings on RUB.
		M6-B	approx. 600 m upstream from mouth; site marked by 2 red rings on tree on RUB.
Dover River (mainstem)	Habitat	DR-H1	Km 0.3; transect between large poplar on top of RUB and alder on LUB; S.P. on large poplar on RUB.
		DR-H2	Km 9.0; transect located 1.5 m upstream of 7 m high spruce on LUB and across from flagged alder 4 m back from channel on RUB; S.P. on spruce on LUB.
		DR-H3	Km 17.3; two transects: T1 located 2 m upstream of 10 m high alder on LUB (8 m from bank edge) and across from 3 m high alder on RUB; S.P. on alder on LUB: T2 (located approx. 100 m upstream of T1) situated between large aspen on edge of steep LUB and alder leaning out over water on RUB; S.P. on alder on LUB.
		DR-H4	Km 32.1; transect between alder 4 m inland from LUB and alder overhanging RUB; S.P. on alder on LUB.
	Water Quality	DR-W	Km 3.0; approx. 40 m upstream from confluence of Creek D1; discharge transect situated approx. 150 m upstream from confluence of Creek D1.
	Benthos	DR-B	100 m upstream from MacKay River confluence; marked by 2 red lines on boulder embedded in escarpment on RUB.
	Fisheries	DR-EF1	section extended from confluence with MacKay River upstream for 300 m.
		DR-EF2	Km 9.0; 90 m section along LUB above old meander scar on RUB.
		DR-EF3	Km 17.3; 110 m section; alternate banks.
		DR-EF4	Km 32.1; 130 m section; alternate banks.
		DR-S1	Km 9.0; 1 haul along LUB.
		DR-S2	Km 32.1; 1 haul along LUB.
Dover River (tributary)	Water Quality	D1-W	approx. 75 m upstream from mouth; flagged.
W.I.D.	Habitat	W.I.D.-H1	21 m (straightline distances) upstream of Bridge Creek confluence; Transect T1 across from willow clump on RUB; Transects T2 to T5 situated at 50 m intervals upstream from T1 (all flagged).
		WID-H2	at edge of cutline (E-W orientation); flagged wooden stake on LUB; Transect T2 (located 50 m downstream of T1) also marked on LUB with flagged wooden stake.
		WID-H3	Transect T1 located approx. 500 m downstream from dam at source; between flagged wooden stakes; S.P. on large black spruce (20 m back from channel) on RUB; T2 (50 m downstream of T1) between wooden stakes on LUB and willow on RUB; Transect T3 (30 m downstream of T1) between steel survey stake on LUB and wooden stake on RUB.
	Water Quality	WID-W1	at road crossing approx. 25 m downstream of culvert exit.
		WID-W2	approx. 800 m downstream from Creek W2 confluence.
	Benthos	WID-B1	12.2 km downstream of source; 50 m downstream of double culverts.
		WID-B2	4.2 km downstream of source; site marked by double red rings on 2 poplars on RUB; designated as Station 5 by Tsui, et. al (1977).

Continued . . .

Table A1. Continued.

System	Study Component	Station Designation	Station Location/Description[a]
W.I.D. (tributaries)	Water Quality	W3-W	below first beaverdam approx. 30 m upstream from mouth.
		W4-W	30 m upstream from W.I.D. confluence.
		W5-W	3 m upstream from W.I.D. confluence.
	Benthos	W3-B	30 m upstream from mouth and 25 m upstream of beaverdam; flagged on beaverdam; designated as Station 7 by Tsui et. al (1977).
	Fisheries	W2-EF	along southern edge of large beaverpond located approx. 200 m upstream from mouth
Bridge Creek	Habitat	BRC-H1	Transect T1 located 30 m upstream from culvert inlet at Hwy 63 crossing; S.P. on large (1.5 m) stump on RUB at T1; remaining 4 transects at 25 m intervals upstream of T1; (all transects flagged).
		BRC-H2	Transect T5 located 20 m downstream from W.I.D. confluence (flagging on poplar on LUB); Transects T5 to T2 located at 25 m intervals downstream of T5; T1 located 50 m downstream of T2. All transects flagged.
		BRC-H3	Transect T1 located 20 m upstream from W.I.D. confluence; Transects T2 to T5 at 25 m intervals upstream of T1 (all flagged).
	Water Quality	BRC-W1	200 m upstream from Hwy 63 crossing; site marked by 2 red paint rings on tree on LUB.
		BRC-W2	25 m upstream from W.I.D. confluence.
	Benthos	BRC-B	200 m upstream from Hwy 63 crossing; site marked by 2 red paint rings on tree on LUB.
	Fisheries	BRC-EF1	section starts from culvert outlet downstream of Hwy 63 to approx. 150 m downstream.
		BRC-EF2	150 m section upstream from culvert inlet at Hwy 63.
		BRC-EF3	200 m section downstream from W.I.D. confluence.
		BRC-EF4	150 m section upstream from W.I.D. confluence.
Lower Beaver Creek	Habitat	LBC-H1	Transect T1 located 20 m upstream from culvert inlet at Hwy 63 crossing; Transects T2 to T5 located at 50 m intervals upstream from T1 (all transects flagged); S.P. at T5 on 6 m alder on LUB.
	Water Quality	LBC-W1	approx. 100 m downstream from Bridge Creek confluence.
		LBC-W2	approx. 150 m upstream from Hwy 63 crossing.
	Benthos	LBC-B1	approx. 80 m downstream from Bridge Creek confluence; site marked by 2 red paint rings on tree on LUB.
		LBC-B2	approx. 200 m upstream from Hwy 63 crossing.
	Fisheries	LBC-EF1	from culvert at Hwy 63 crossing downstream for 150 m.
		LBC-EF2	from culvert at Hwy 63 crossing upstream for 150 m.
Creek B1	Habitat	B1-H1	T1 located 20 m downstream of large boulder on top of RUB (boulder located 800 m downstream of impoundment outlet when travelling by road); 2 additional transects located at 50 m intervals upstream from T1 (all transects flagged).
		B1-H2	Transect T1 located at metal standpipe approx. 80 m downstream from temporary road crossing (crossing situated approx. 400 m upstream from Beaver Creek Reservoir); 2 additional sites at 50 m intervls downstream from T1 (all transects flagged); Note: this station was added (after the establishment of B1-H1) to determine habitat characteristics in a white sucker spawning area and therefore does not follow the sequential station coding system.
	Water Quality	B1-W1	immediately downstream of culvert at road crossing in channelized section of Creek B1 (approx. 320 m downstream from the outlet of the impoundment.
		B1-W2	upstream end of the culvert at the road crossing of the natural stream channel.
	Benthos	B1-B	approx. 40 m downstream of the temporary road crossing situated 400 m upstream from Beaver Creek Reservoir.
	Fisheries	B1-EF1	same location as B1-H2.
		B1-EF2	same location as B1-H1.
Beaver Creek Reservoir	Water Quality	BCR-W	approx. 400 m from a perpendicular to the dam and approx. 400 m from west bank; at the BCR-1 station (Noton and Chymko 1978).
	Benthos	BCR-B1	near access point (boat launch site) approx. 20 m offshore; at 1-m depth contour; marked with yellow float.
		BCR-B2	at 3-m depth contour; marked with float.
		BCR-B3	at 5-m depth contour; marked with float.
		BCR-B4	at 1-m depth contour; marked with float.
		BCR-B5	at 3-m depth contour; marked with float.
		BCR-Z	same as BCR-W.
		BCR-P	same site BCR-W.
	Fisheries	BCR-ES1	diversion channel from Beaver Creek Reservoir to Ruth Lake; alternate banks.
		BCR-ES2	in vicinity of BCR-S3
		BCR-G1	perpendicular to shore adjacent to mine depressurization water discharge pipe; at same location as G1 established by O'Neil (1979).
		BCR-G2	parallel to island along 3-m depth contour; at same location as G2 established by O'Neil (1979).
		BCR-S3	on west shore at cutline crossing; same location as S3 established by O'Neil (1979).
Ruth Lake	Water Quality	RL-W	approximately 0.8 km SE and nearer the outlet than the RL-2 site established by Noton and Chymko (1978).
	Benthos	RL-B	located 1/8 the way down the north shore approx. 80 m off shore; aligned with cutline; marked with white float.
	Zooplankton	RL-Z	same as RL-W.
	Phytoplankton	RL-P	same as RL-W.
	Fisheries	RL-ES	from 100 m south-east of beaverlodge in a northwest direction to 300 m past beaverlodge.
		RL-GN	approx. 100 m offshore from beaverlodge.
		RL-S2	approx. 1/3 way down the north shore; approx. 200 m north-west of beaverlodge; near Station S2 established by O'Neil (1979).
Poplar Creek Reservoir	Water Quality	PCR-W	at south end of reservoir approx. 125 m off dam face on 18 m depth contour; situated approx. halfway between PCR-B5 PCR-B4; marked with float. Approximately the same location as PCR-1 established by Noton and Chymko (1978).
	Benthos	PCR-B1	at south end of reservoir on 1-m depth contour; site nearest to spillway canal; marked with float.
		PCR-B2	at south end of reservoir 100 m off dam face and SW of PCR-B1 on 3-m depth contour; marked with float.
		PCR-B3	at south end of reservoir 100 m off dam face in line with and to the SW of PCR-B2; on 5-m contour; marked with float.
		PCR-B4	at south end of reservoir, closest to west shore of reservoir 100 m off dam face; on 10-m contour; marked with float.
		PCR-B5	halfway between PCR-B3 and PCR-B4, approx. 100 m off dam face; marked with float. 5 m contour.
	Zooplankton	PCR-Z	same as PCR-W.
	Phytoplankton	PCR-P	same as PCR-W.
	Fisheries	PCR-G1	located approx. 50 m off point of west shore; north of causeway.
		PCR-G2	located approx. 40 m off west shore perpendicular to dam face; south of causeway.
		PCR-S3	along eastern shore, approx. 300 m south of causeway; same location as S3 established by O'Neil (1979).
Upper Beaver Creek	Habitat	UBC-H	one transect location approx. 40 m downstream of AOSTRA road crossing; flagging on overhanging alder on RUB; S.P. on 10 m high willow clump situated 12 m back from L.U.B.
	Water Quality	UBC-W	at Water Survey of Canada gauge site located approx. 100 m downstream from the AOSTRA road crossing.
	Benthos	UBC-B	approx. 20 m downstream of WSC gauge; paint and flagging on cluster of overhanging dead trees; at station established by Noton and Chymko (1978).
	Fisheries	UBC-ES	lower 1.0 km; alternate banks.
		UBC-EF	from AOSTRA road crossing downstream for approx. 400 m.
Poplar Creek	Habitat	PC-H1-T1	transect situated approx. mid-way between drop structures 5 and 6 (DS5 and 6) across from large white spruce (orange blaze and S.P.) located approx. 15 m from RUB edge: Note - labelled on S.P. as PC1(a)-T1.
		PC-H1-T2	transect located 20 m downstream from crest of DS5 (distance measured from top end of large boulder at crest of DS5).

Continued . . .

Table A1. Continued.

System	Study Component	Station Designation	Station Location/Description[a]
		PC-H1-T3	transect 1.6 m downstream from DS5; S.P. on large white spruce 20 m back from RUB: Note - labelled on S.P. as PC1(c)-T1.
		PC-H1-T4	transect 20.6 m downstream from crest of DS 11 across from flagged and painted birch tree on LUB: Note - labelled on flagging as PC1(b)-T2.
		PC-H1-T5	transect 3.6 m downstream from crest of DS 11; between painted small boulders on LUB and RUB; willows near both boulders flagged: Note - labelled on flagging as PC1(c)-T2.
		PC-H2	transect T1 situated approx. 28 m downstream from 1-m high beaverdam; between birch tree (flagging, paint and S.P.) on RUB and alder on LUB; 4 additional transects (T2 to T5) located at 50 m intervals (measured along RUB) upstream from T1 (all transects marked by flagged trees on both LUB and RUB).
		PC-H3	transect T1 situated 20 m upstream from Ruth Creek confluence; marked by flagged alder on RUB; 4 additional transects (T2 to T5) located upstream of T1 at 50 m intervals; S.P. on birch tree marking LUB at T3.
	Water Quality	PC-W1	approx. 500 m upstream Athabasca River confluence.
		PC-W2	approx. 600 m downstream of stilling basin; Station PC-2 (Noton and Chymko 1978).
		PC-W3	approx. 500 m upstream of stilling basin.
	Benthos	PC-B1	station approx. 25 m upstream of Hwy 63 bridge at yellow angle iron stake on LUB; at Syncrude benthic station PC1.
		PC-B2	approx. 70 m downstream of DS 9; marked by 2 red rings on jackpine; at Syncrude benthic station PC2.
		PC-B3	approx. 600 m upstream of spillway confluence; at Syncrude benthic station PC3.
		PC-B4	approx. 100 m upstream from Ruth Creek confluence; rebar in stream channel; at Syncrude benthic station PC4.
	Fisheries[b]	PC-EF1	section begins approx. 20 m upstream from Ruth Creek confluence and extends upstream for approx. 200 m.
		PC-EF2	section begins at approx. 200 m upstream from stilling basin confluence at PC-H1(T1) site and extends 150 m upstream.
		PC-EF3	section begins below DS 10 and extends upstream to the stilling basin confluence.
		PC-EF5	section begins at crest of DS 4 and extends to the crest of DS 6.
		PC-EF6	section begins at large pool below DS 1 and extends to crest of DS 2.
Athabasca River	Water Quality	AR-W1	mid-channel and approx. 50 m upstream of MacKay River confluence.
		AR-W2	150 m downstream from MacKay River confluence and approx. 3 m from RUB.
		AR-W3	10 m upstream from MacKay River confluence and approx. 12 m from RUB.
		AR-W4	mid-channel and approx. 50 m upstream of pumphouse.
		AR-W5	75 m upstream from pumphouse and 6 m from RUB.
		AR-W6	mid-channel, approx. 50 m upstream from Poplar Creek confluence.
		AR-W7	5 m downstream from Poplar Creek confluence, approx. 3 m from RUB.
		AR-W8	10 m upstream from Poplar Creek confluence, and 10 m from RUB.
Horseshoe Lake	Water Quality	HL-W	off southern shore of main body of lake, midway between east and west arms.
	Fisheries	HL-EF1	sampled 400 m in lower portion of east arm.
		HL-EF2	sampled 500 m along southern shoreline of main lake from HL-W towards east arm.

[a] Abbreviations used in this column are: LUB and RUB = left and right banks viewed looking upstream; S.P. = metal survey plate; DS = drop structure.

[b] All Poplar Creek fisheries stations are the same as those established by O'Neil (1979).

Note: unless otherwise stated, all flagging and paint were blaze orange in color.

APPENDIX B

AQUATIC HABITAT

Table Bl. Stream Habitat - Survey Form

R.L. & L. ENVIRONMENTAL SERVICES LTD.

STREAM HABITAT SURVEY FORM

Stream ____________________ Reach ____ Date ______________

Station ____________ km ____________ Transect ______________

Orientation ___ UB to ___ UB H_2O Temp./Time ____________

Station/Transect Mark ______________________________

____

____

Width (m) Rooted ________ Wetted ________ Gradient (%) ______

Turbidity ________ Visibility ________

BANK FEATURES

Condition (RUB) ____ (LUB) ____ Stability (RUB) ____ (LUB) ______

Undercut (RUB) ____ (LUB) ____ Slope (Deg.) (RUB) ____ (LUB) ______

Cover (RUB) ____ (LUB) ____ Overhang (RUB) ____ (LUB) ______

Bankdepth (RUB) ____ (LUB) ____

DEPTH/VELOCITY

Location ( )																
Depth ( )																
Velocity ( ) 0.6 d																
0.2 d/0.8 d																

COVER TYPES

Interval ( )	Riffle	Run	Flat	Pool	In-Stream Cover	
				1 2 3 4 5	Veg Rating	Algae Rating

Dominant Substrate (mm)

Interval ( )	Fines		Gravels					Larges				D90 (18)	Embed. (19)
	Silt	Sand	VFG (2-4)	FG (4-8)	MG (8-16)	CG (16-32)	VCG (32-64)	SC (64-128)	LC (128-256)	SB (256-512)	LB (512+)		

Comments: (Photos, Habitat Description, etc.)

Crew ______________________

Table B2. Drainage description for fluvial systems in the study area.

System	Drainage Area (km^2)	Stream Order[a]	Dominant Terrain Type
MacKay River (at Athabasca R.)	5550.0	-	Muskeg
Dover River (at MacKay R. confl.)	963.0	-	Muskeg
D1	27.6	2	Muskeg
M1	11.1	2	Highland
M2	72.4	3	Muskeg
M3	5.2	1	Muskeg
M4	4.4	1	Muskeg
M5	6.4	1	Muskeg
M6	52.4	3	Muskeg
M7	28.1	2	Muskeg
M8	3.6	1	Muskeg
M9	2.1	1	Muskeg
M10	18.0	2	Muskeg
M11	3.2	1	Muskeg
West Interception Ditch (above Bridge Creek)	72.6	3	Muskeg
W1	16.1	_[b]	Muskeg
W2	1.8	1	Muskeg
W3	26.0	2	Muskeg
W4	10.4	1	Muskeg
W5	18.3	2	Muskeg
Bridge Creek (not incl. W.I.D)	13.7	1	Muskeg
Bridge Creek (incl. W.I.D)	86.3	3	Muskeg
Lower Beaver Creek (not incl. Bridge Creek)	3.8	2	Highland
Lower Beaver Creek (incl. Bridge Creek)	90.1	3	Muskeg
Upper Beaver Creek	165.0	3	Highland
Cache Creek	-	2	Muskeg
Creek B2	63.6	2	Highland
Creek B1 (at Beaver Cr. Res.)	47.8	2	Highland
Poplar Creek (at Athabasca R. confl.)	151.0	3	Highland

[a] According to Strahler (1957), not determined for larger systems.

_[b]Undefined drainage.

Table B3. Discharges calculated from measurements recorded during the 1984 study and from Water Survey of Canada (WSC) gauging stations on the MacKay River, Poplar Creek, and Upper Beaver Creek (1984 preliminary data).

System	Site	Spring		Summer		Fall	
		Date	$Q(m^3 \cdot s^{-1})$	Date	$Q(m^3 \cdot s^{-1})$	Date	$Q(m^3 \cdot s^{-1})$
MacKay River	WSC[a]	19 June	31.10	30 July	10.40	21 Sept.	6.38
	M1-W	19 June	0.08	28 July	L0.01[d]	22 Sept.	L0.01
	M2-W	19 June	0.17	30 July	L0.01	21 Sept.	0.05
	M3-W	19 June	0.06	30 July	L0.01	21 Sept.	L0.01
	M4-W	19 June	0.02	30 July	L0.01	21 Sept.	L0.01
	M5-W	19 June	0.02	30 July	L0.01	21 Sept.	L0.01
	M6-W	20 June	0.02	30 July	L0.01	21 Sept.	L0.01
	M7-W	20 June	0.10	30 July	L0.01	21 Sept.	0.01
	M8-W	20 June	L0.01	30 July	L0.01	21 Sept.	0
	M9-W	20 June	L0.01	30 July	0	21 Sept.	0
	M10-W	20 June	0.05	30 July	0	21 Sept.	0.01
	M11-W	20 June	0.02	30 July	L0.01	21 Sept.	0
Dover River	DR-W	19 June	1.33	30 July	1.64	21 Sept.	0.41
	D1-W	19 June	0.05	30 July	L0.01	21 Sept.	0.01
West Interception Ditch	WID-W1	17 June	0.10	25 July	0.02	26 Sept.	0.06
	W3-W	17 June	0.07	25 July	L0.01	25 Sept.	L0.01
	W4-W	17 June	0.02	25 July	L0.01	25 Sept.	L0.01
	W5-W	17 June	L0.01	25 July	L0.01	25 Sept.	L0.01
Lower Beaver Creek	LBC-W1	19 June	0.26	29 July	0.02	22 Sept.	0.02
	LBC-W2	19 June	0.01	29 July	L0.01	21 Sept.	0.01
Bridge Creek	BRC-W1	18 June	0.16	29 July	0.02	21 Sept.	0.01
	BRC-W2	17 June	0.04	25 July	L0.01	25 Sept.	L0.01
Poplar Creek	PC-W2[b]	18 June	4.18	26 July	1.47	23 Sept.	0.22
	PC-W3	18 June	0.69	26 July	0.30	23 Sept.	0.07
Upper Beaver Creek	UBC-W[c]	15 June	0.44	30 July	0.17	21 Sept.	0.18
Creek B1	B1-W2	15 June	0.21	30 July	0.06	21 Sept.	0.02

[a] WSC Stn. 07DB001.
[b] WSC Stn. 07DA007.
[c] WSC Stn. 07DA018.
[d] L=Less than.

Table B4. A comparison of discharge and drainage areas of fluvial water bodies in the 1984 Syncrude Study Area to the discharge and drainage area of the MacKay River, 1984.

SYSTEM	SEASONAL COMPARISON TO MACKAY RIVER DISCHARGE[a]							
	Drainage Area		SPRING		SUMMER		FALL	
	(km^2)	%[b]	Date	%	Date	%	Date	%
Creek M1	11.06	0.20	19 June	0.27	28 July	0.03	22 Sept.	0.05
Creek M2	72.35	1.30	19 June	0.53	30 July	0.05	21 Sept.	0.80
Creek M3	5.24	0.09	19 June	0.19	30 July	0.01	21 Sept.	0.10
Creek M4	4.38	0.08	19 June	0.06	30 July	L0.01[c]	21 Sept.	0.08
Creek M5	6.40	0.12	19 June	0.05	30 July	L0.01	21 Sept.	0.12
Creek M6	52.36	0.94	20 June	0.08	30 July	0.05	21 Sept.	0.08
Creek M7	28.06	0.51	20 June	0.32	30 July	L0.01	21 Sept.	0.09
Creek M8	3.57	0.06	20 June	L0.01	30 July	L0.01	21 Sept.	0
Creek M9	2.06	0.04	20 June	0.01	30 July	0	21 Sept.	0
Creek M10	18.04	0.32	20 June	0.17	30 July	0	21 Sept.	0.13
Creek M11	3.18	0.06	20 June	0.08	30 July	L0.01	21 Sept.	0
Dover River	963.00	17.35	19 June	4.29	30 July	15.79	21 Sept.	6.49
Creek D1	27.58	0.50	19 June	0.15	30 July	0.04	21 Sept.	0.19
W.I.D.	N/A[d]	N/A	17 June	0.26	25 July	0.10	25 Sept.	0.16
Creek W3	26.03	0.47	17 June	0.17	25 July	L0.01	25 Sept.	L0.01
Creek W4	10.37	0.19	17 June	0.04	25 July	L0.01	25 Sept.	0.05
Creek W5	18.30	0.33	17 June	L0.01	25 July	L0.01	25 Sept.	L0.01
L. Beaver Cr.	3.78	0.07	19 June	0.82	29 July	0.18	22 Sept.	0.34
Bridge Cr.	13.70	0.25	17 June	0.44	29 July	0.18	21 Sept.	0.17
U.Beaver Cr.	165.00	2.97	15 June	0.86	30 July	1.67	21 Sept.	2.88
Creek B1	47.44	0.85	15 June	0.40	30 July	0.54	21 Sept.	0.36
Poplar Cr.	427.06[e]	7.69	18 June	11.58	26 July	7.24	23 Sept.	3.40

[a] Calculated by the division of the discharge for each system on a particular date by the discharge recorded in the MacKay River on that date (from Water Survey of Canada, preliminary 1984 data)

[b] Percent of MacKay River drainage area (5550 km^2 - Water Survey of Canada 1983)

[c] L - Less than

[d] Drainage area not calculated

[e] Includes drainage area of Poplar Creek proper (151 km^2), Upper Beaver Creek (165 km^2), Creek B1 (47.44 km^2) and Creek B2 (63.62 km^2); does not include mine or reservoir drainage areas.

APPENDIX C

ZOOPLANKTON

Table C1. Mean body length and individual aliquot counts of zooplankton from Beaver Creek Reservoir (station BCR Z), 1984.

	15 June 1984					24 July 1984					23 September 1984				
	Mean Body Length[a] (mm)	Count in Aliquot No.[b]			Calculated Sample Total	Mean Body Length (mm)	Count in Aliquot No.			Calculated Sample Total	Mean Body Length (mm)	Count in Aliquot No.			Calculated Sample Total
		1	2	3			1	2	3			1	2	3	
COPEPODA															
CALANOIDA															
Diaptomus oregonensis	0.842	34	29	24	464	1.007	101	88	82	1 445	1.190	166	154	167	2 597
diaptomid nauplii		284	-	-	4 544		244	-	-	3 904		12	-	-	192
CYCLOPOIDA															
Acanthocyclops vernalis A+ adv.C	0.826 (n=14)	14	-	-	224	0.750 (n=8)	8	-	-	128	0.707 (n=16)	16	-	-	256
Diacyclops thomasi A+ adv.C		0	-	-	0	0.769 (n=8)	8	-	-	128	0.799 (n=18)	18	-	-	288
Mesocyclops edax	0.750 (n=2)	2	-	-	32	0.732 (n=4)	4	-	-	64	0.750 (n=7)	7	-	-	112
cyclopoid copepodids, immature C	0.441	75	-	-	1200	0.459	140	-	-	2 240	0.512	204	-	-	3 264
cyclopoid nauplii		264	-	-	4 224		152	-	-	2 432		540	-	-	8 640
CLADOCERA															
Bosmina longirostris	0.352	59	45	57	859	0.314	324	-	-	5 184	0.324	106	-	-	1 696
Ceriodaphnia lacustris		0	-	-	0	0.503 (n=2)	2	-	-	32		0	-	-	0
Macrothrix hirsuticornis	0.403 (n=1)	1	-	-	16		0	-	-	0		0	-	-	0
Daphnia parvula	0.663 (n=18)	11	7	9	144	0.525	92	-	-	1 472	0.744 (n=11)	3	8	4	80
Diaphanosoma leuchtenbergianum		0	0	2	11	0.631	241	-	-	3 856	0.737 (n=7)	7	2	2	59
Alona guttata		0	0	1	5		1	-	-	16		0	0	1	5
Chydorus sphaericus	0.220 (n=2)	0	1	1	11		2	2	3	37	0.236 (n=8)	8	3	1	64
ROTIFERA															
Keratella cochlearis		308	-	-	4 928		42	-	-	672		4 051	-	-	64 816
Keratella earlinae		2 146	-	-	34 336		756	-	-	12 096		560	-	-	8 960
Keratella quadrata		616	-	-	9 856		0	-	-	0		19	-	-	304
Keratella hiemalis		28	-	-	448		0	-	-	0		0	-	-	0
Notholca acuminata		8	-	-	128		0	-	-	0		0		-	0
Euchlanis dilatata		0	-	-	0		56	-	-	896		0	-	-	0
Brachionus calyciflorис		38	-	-	6 096		0	-	-	0		0	-	-	0
Brachionus quadridentatus		0	1	-	8		0	-	-	0		4	-	-	64
Asplanchna priodonta		2	-	-	32		4		-	64		8	-	-	128
Synchaeta pectinata (?)		0	-	-	0		0	-	-	0		672	-	-	10 752
Synchaeta oblonga (?)		0	-	-	0		0	-	-	0		261	-	-	4 176
Synchaeta sp.		20	-	-	320		0	-	-	0		0	-	-	0
Gastropus (?) sp.		18			288		0	-	-	0		0	-	-	0
Polyarthra vulgaris		0	-	-	0		8	-	-	128		0	-	-	0
Filinia longiseta		46	-	-	736		8	-	-	128		37	-	-	592
Polyarthra dolichoptera		2 212	-	-	35 392		0	-	-	0		0	-	-	0
Rotaria neptunia		0	1	-	8		0	-	-	0		0	-	-	0
unidentified rotifers		0	-	-	0		0	-	-	0		93	-	-	1 488
OTHER TAXA															
Ostracoda, immature		4	2	5	59		0	-	-	0		0	-	-	0

[a] Mean body length based on measurements of 30 individuals except where noted in brackets. Mean length not determined for Rotifera or immatures.

[b] Counts in aliquots 2 and 3 are for selected mature forms only, to allow assessment of replicability. Dash indicates species or life stage not counted in second or third aliquot. Depth sampled and total volume sampled were 0 - 5.5 m and 461 L on 15 June, 0 - 3.5 m and 294 L on 24 July, and 0 - 4.5 m and 377 L on 23 September. Volume of aliquot is 1/16 of preserved sample volume.

[c] A = adult; C = copepodid, usually I to III; adv. C = advanced copepodids, usually IV and V.

Table C2. Mean body length and individual aliquot counts of zooplankton from Ruth Lake (station RL-Z), 1984.

	16 June 1984					26 July 1984					24 September 1984					
	Mean Body Length[a] (mm)	Count in Aliquot No.[b] 1	2	3	Calculated Sample Total	Mean Body Length (mm)	Count in Aliquot no. 1	2	3	Calculated Sample Total	Mean Body Length (mm)	Count in Aliquot No. 1	2	3	13/16	Calculated Sample Total
COPEPODA																
CALANOIDA																
Diaptomus oregonensis	0.654	46	74	44	875	0.612 (n=7)	2	2	3	17	1.217 (n=4)	2	1	1	39	43
diaptomid nauplii		168	-	-	2 688		33	33	35	539		11	11	9	-	165
CYCLOPOIDIA																
Acanthoyclops vernalis A+ adv.C	0.666 (n=4)	4	1	0	27		0	-	-	0		0	0	0	0	0
Diacyclops thomasi A+ adv.C.	1.025 (n=1)	1	0	0	5		0	-	-	0	0.842 (n=3)	0	0	1	4	5
Mesocylops edax	0.798 (n=6)	2	3	1	32		0	-	-	0	0.824 (n=3)	0	1	1	3	5
Microcyclops varicans rubellus A	0.494 (n=4)	0	2	2	21											
cyclopoid copepodids, immature C	0.429	61	61	58	960	0.395	23	24	21	385	0.419 (n=9)	2	3	4	-	48
cyclopoid nauplii		208	-	-	3 328		101	81	85	1 424		66	77	68	-	1 125
CLADOCERA																
Bosmina longirostris	0.298 (n=14)	37	35	28	533	0.227 (n=5)	2	2	1	17	0.329 (n=2)	1	1	0	-	11
Ceriodaphnia lacustris		0	-	-	0		0	0	1	2		0	-	-	-	0
Daphnia parvula	0.711 (n=7)	1	2	4	37	-	0	0	0	1	0.915 (n=1)	0	1	0	0	1
Diaphanosoma leuchtenbergianum	0.714 (n=4)	0	3	1	21	0.519 (n=11)	3	5	3	51		0		-	-	0
Acroperus harpae	-	0	2	0	11											
Chydorus sphaericus	0.265 (n=4)	4	7	4	80	0.311 (n=2)	0	0	0	3		0	-	-	-	0
ROTIFERA																
Keratella cochlearis		182	-	-	2 912		174	-	-	2 784		145	-	-	-	2 320
Keratella earlinae		1 260	-	-	20 160		74	-	-	1 184		10	-	-	-	160
Keratella quadrata		168	-	-	2 688		11	-	-	176		2	1	-	-	24
Notholca acuminata		0	-	-	0		1	-	-	16		1	-	-	-	16
Trichotria pocillum		14	-	-	224		0	-	-	0		0	-	-	-	0
Euchlanis dilata		0	-	-	0		0	2	1	16		0	-	-	-	0
Brachnionus quadridentatus		0	-	-	0		2	1	0	16		0	1	0	-	5
Synchaeta pectinata		0	-	-	0		0	-	-	0		4	-	-	-	64
Synchaeta oblonga		0	-	-	0		8	-	-	128		8	-	-	-	128
Filinia longiseta		14	-	-	224		3	-	-	48		2	4	-	-	48
Polyarthra dolichoptera		392	-	-	6 272		6	-	-	96		10	-	-	-	160
Polyarthra vulgaris		14	-	-	224		14	-	-	224		4	-	-	-	64
Conochilus unicornis		0	-	-	0		3	-	-	48		0	-	-	-	0
Lecane (Monostyle) bulla		0	-	-	0		4	-	-	64		0	-	-	-	0
Lecane luna		0	-	-	0		0	-	-	0		0	1	0	-	5
unidentified rotifers		28	-	-	448		0	-	-	0		10	-	-	-	160
OTHER TAXA																
DIPTERA																
CERATOPOGONIDAE (larvae)		1	-	-	5		0	-	-	0		0	-	-	-	0
OSTRACODA, immature		3	0	0	16	-	0	0	0	1		0	-	-	-	0

[a] Mean body length based on measurements of 30 individuals except where noted in brackets. *Mean length not determined for Rotifera or immatures.*

[b] Counts in aliquots 2 and 3 are for selected mature forms only, to allow assessment of replicability. Dash indicates species or life stage not counted in second or third aliquot. Depth sampled and total volume sampled were 0 - 1.5 m and 126 L, respectively, on all three sampling dates. Volume of aliquot is 1/16 of preserved sample volume.

[c] A = adult; C = copepodid, usually I to III; adv. C = advanced copepodids, usually IV and V.

Table C3. Mean body length and individual aliquot counts of zooplankton from Poplar Creek Reservoir (Station PCR-Z), 1984.

	16 June 1984					26 July 1984					24 September 1984				
	Mean Body Length[a] (mm)	Count in Aliquot No.[b] 1	2	3	Calculated Sample Total	Mean Body Length (mm)	Count in Aliquot No. 1	2	3	Calculated Sample Total	Mean Body Length (mm)	Count in Aliquot No. 1	2	3	Calculated Sample Total
COPEPODA															
CALANOIDA															
Diaptomus oregonensis	0.779	100	104	102	1 632	1.296 (n=14)	14	15	10	208	1.174	377	302	391	5 707
diaptomid nauplii		93	-	-	1 488		196	-	-	3 136		5	-	-	80
CYCLOPOIDA															
Acanthocyclops vernalis A+ adv.C	0.659	39	-	-	624	0.875 (n=18)	48	-	-	768	0.622 (n=13)	13	-	-	208
Diacyclops thomasi A+ adv.C	0.865 (n=8)	8	-	-	128	0.966	64	-	-	1 024	0.820	70	-	-	1 120
Mesocyclops edax	0.846 (n=14)	77	-	-	1 232	1.043 (n=11)	33	-	-	528	1.162 (n=8)	13	-	-	208
cyclopoid copepodids, immature C	0.418	257	-	-	4 112	0.551	1 080	-	-	17 280	0.490	216	-	-	3 456
cyclopoid nauplii		327	-	-	5 232		196	-	-	3 136		149	-	-	2 384
CLADOCERA															
Bosmina longirostris	0.272	147	-	-	2 352	0 271	1 582	-	-	25 312	0.311	365	-	-	5 840
Ceriodaphnia lacustris		0	-	-	0	0.454 (n=11)	11	-	-	176		0	-	-	0
Ceriodaphnia quadrangula		0	-	-	0	0.531 (n=4)	4	-	-	64		0	-	-	0
Macrothrix hirsuticornis	0.256 (n=1)	0	0	1	5		0	-	-	0		0	-	-	0
Daphnia parvula	0.741 (n=14)	14	8	10	171	0.592	803	-	-	12 848	0 746	186	201	190	3 077
Diaphanosoma leuchtenbergianum	0.564 (n=14)	14	6	8	149	0.620 (n=24)	79	-	-	1 264	0.695 (n=4)	4	7	8	101
Alona guttata	0.300 (n=1)	1	0	0	5		0	-	-	0		0	-	-	0
Chydorus sphaericus	0.420 (n=1)	1	1	1	16	0.256 (n=2)	2	-	-	32		0	-	-	0
ROTIFERA															
Keratella cochlearis		1 614	-	-	25 824		6	-	-	96		10 416	-	-	166 656
Keratella earlinae		3 220	-	-	51 520		77	-	-	1 232		168	-	-	2 688
Keratella quadrata		486	-	-	7 776		8	-	-	128		172	-	-	2 752
Notholca acuminata		9	-	-	144		0	-	-	0		0	-	-	0
Euchlanis dilatata		3	-	-	48		6	-	-	96		0	-	-	0
Euchlanis mikropous		0	-	-	0		9	-	-	144		0	-	-	0
Trichocerca multicrinis		0	-	-	0		14	-	-	224		0	-	-	0
Brachionus calycifloris		65	-	-	1 040		0	-	-	0		0	-	-	0
Brachionus quadridentatus		28	-	-	448		0	-	-	0		28	-	-	448
Asplanchna priodonta		50	-	-	864		8	-	-	128		128	-	-	2 048
Synchaeta pectinate (?)		284	-	-	4 544		0	-	-	0		336	-	-	5 376
Synchaeta oblonga (?)		0	-	-	0		0	-	-	0		84	-	-	1 344
Gastrpus (?) sp.		0	-	-	0		8	-	-	128		0	-	-	0
Filinia longiseta		14	-	-	224		0	-	-	0		514	-	-	8 224
Polyarthra dolichoptera		66	-	-	1 056		9	-	-	144		172	-	-	2 752
Polyarthra vulgaris		1 624	-	-	25 984		0	-	-	0		0	-	-	0
Conochilus unicornis		0	-	-	0		0	-	-	0		112	-	-	1 792
DIPTERA															
CHAOBORIDAE															
Chaoborus flavicans		4	3	3	53		3	1	2	32		0	1	0	5
Chaoborus punctipennis		2	6	4	64		2	0		0		11	0	0	1
Chaoborus instar 1 (unident.)		0	-	-	0		2	1	4	32		0	-	-	0
OTHER TAXA															
Small fish		1	-	-	1		0	-	-	0		0	-	-	0

[a] Mean body length based on measurements of 30 individuals except where noted in brackets. Mean length not determined for Rotifera or immatures.

[b] Counts in aliquots 2 and 3 are for selected mature forms only, to allow assessment of replicability. Dash indicates species or life stage not counted in second or third aliquot. Depth sampled and total volume sampled were 0 - 14 m and 1174 L, respectively, on 16 June and 26 July, and 0 - 16 m and 1340 L on 24 September. Volume of aliquot was 1/16 of preserved sample volume.

[c] A = adult; C = copepodid, usually I to III; adv. C = advanced copepodids, usually IV and V.

APPENDIX D

ZOOBENTHOS

Table D1. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station MR-B1 on the MacKay River. 1984.

SYNCRUDE Code		Taxa	Spring (19 June)					Summer (28 July)					Fall (22 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**								4	1.3						
	15	NEMATODA											2		1	1.0	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae						5		1	2.0		1		2	1.0	
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**						1			0.3						
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**															
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta	8	12	9	9.7		18	22	29	23.0	P	75	68	76	73.0	
		ARTHROPODA															
		Arachnida															
	13	Acari											19	22	52	31.0	
		Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**			1	0.3											P
		Metretopodidae															
	76	**Metretopus**															
		Baetidae							1		0.3		5	10	20	11.7	
	1	**Baetis**	3		1	1.3		1	2	3	2.0	A	4	14		6.0	P
		Callibaetis															
	77	**Centroptilum**															
	44	**Pseudocloeon**	1			0.3							9			3.0	
		Heptageniidae								2	0.7		1		2	1.0	
	2	**Heptagenia**							1		0.3	P			2	0.7	
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															A
	30	**Paraleptophlebia**															
		Ephemerellidae															
	19	**Ephemerella**	1	2	3	2.0	A						18	25	8	17.0	
		Tricorythidae															
	43	**Tricorythodes**						2	3	12	5.7	P		7	2	3.0	P
		Caenidae															
	45	**Caenis**										P			1	0.3	P
		Baetiscidae															
	81	**Baetisca**											1	3	3	2.3	A
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**					P					P					
	85	**Ischnura**															

Continued ...

Table D1. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (19 June) 1	2	3	x̄	Dip	Summer (28 July) 1	2	3	x̄	Dip	Fall (22 September) 1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**										P		3	1	1.3	P
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**															
	88	Libellulidae															
2		Plecoptera											5			1.7	
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**											2		2	1.3	
		Nemouridae											1			0.3	
	59	**Malenka**															
	34	**Nemoura**															
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**											10	7	6	7.7	P
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															
		Gerridae															
	95	**Gerris**															
3		Trichoptera															
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**											1			0.3	
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**															
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae					P					P					
		Haliplidae															
	111	**Haliplus**					P										
	47	Dytiscidae															
	6	Elmidae															
6		Diptera												5		1.7	
		pupae		1		0.3		1			0.3						
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	2			0.7		1	2		1.0	P					
		pupae															
	37	Ceratopogonidae		1		0.3											
	8	Chironomidae	7	9	5	7.0		25	9	8	14.0		99	36	140	91.7	A
	38	Tabanidae															
	46	Empididae											4		5	3.0	
		COLUMN TOTALS	**22**	**25**	**19**	**21.9**		**54**	**40**	**59**	**50.9**		**256**	**202**	**322**	**260.0**	
		TAXA		**12**			**4**		**16**			**9**		**23**			**9**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D2. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station MR-B2 on the MacKay River, 1984.

SYNCRUDE Code		Taxa	Spring (19 June)					Summer (30 July)					Fall (21 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**															
	15	NEMATODA															
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae						2			0.7						
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**															
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta		3		1.0		39	21	14	24.7		2	6	7	5.0	
		ARTHROPODA															
		Arachnida															
	13	Acari						2	2	4	2.7						P
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae						15	2		5.7		6	3	3	4.0	
	1	**Baetis**			1	0.3	P	21	26	10	19.0	A					P
		Callibaetis															
	77	**Centroptilum**															
	44	**Pseudocloeon**			1	0.3				3	1.0				2	0.7	
		Heptageniidae						2			0.7				1	0.3	
	2	**Heptagenia**					P					P			2	0.7	P
	78	**Rhithrogena**												1		0.3	P
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															P
	30	**Paraleptophlebia**															
		Ephemerellidae															
	19	**Ephemerella**					P							1		0.3	
		Tricorythidae															
	43	**Tricorythodes**						3		2	1.7	A					P
		Caenidae															
	45	**Caenis**							1		0.3						P
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D2.   Continued.

SYNCRUDE Code		Taxa	Spring (19 June)					Summer (30 July)					Fall (21 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**					P		4		1.3	A					
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**															
	88	Libellulidae															
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**											1			0.3	
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**															
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**											1		2	1.0	P
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															
		Gerridae															
	95	**Gerris**															
3		Trichoptera															
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**							1		0.3						
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**															
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae															
	6	Elmidae															
6		Diptera															
		pupae															
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae		1	4	1.7	P	91	160	110	120.3						
		pupae															
	37	Ceratopogonidae															P
	8	Chironomidae	1	3	1	1.7		16	18	10	14.7				1	0.3	
	38	Tabanidae															
	46	Empididae															
		COLUMN TOTALS	**1**	**7**	**7**	**5.0**		**191**	**235**	**153**	**193.1**		**10**	**11**	**18**	**12.9**	
		TAXA		**8**			**5**		**14**			**4**		**16**			**9**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D3. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station MR-B3 on the MacKay River, 1984.

SYNCRUDE Code		Taxa	Spring (19 June)					Summer (30 July)					Fall (21 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**															
	15	NEMATODA							1		0.3				1	0.3	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae						4	7		3.7			1		0.3	
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**															
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**							1		0.3		1			0.3	
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta	18	13	12	14.3		34	40	4	26.0		4	66	9	26.3	P
		ARTHROPODA															
		Arachnida															
	13	Acari								1	0.3	P	1	1	10	4.0	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola							1		0.3						
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae						3	14		5.7		1	20	4	8.3	
1		**Baetis**	10	5	7	7.3	P	6	11	6	7.7	A		1		0.3	
		Callibaetis															
	77	**Centroptilum**										P					
	44	**Pseudocloeon**	3	8	1	4.0									1	0.3	
		Heptageniidae						4	6		3.3		1	1	1	1.0	
	2	**Heptagenia**	1		1	0.7	P	4			1.3	P	1	1		0.7	P
	78	**Rhithrogena**						1			0.3			1		0.3	
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															A
	30	**Paraleptophlebia**															
		Ephemerellidae															
	19	**Ephemerella**	1			0.3	P										
		Tricorythidae															
	43	**Tricorythodes**						13	13	1	9.0	P	3		4	2.3	A
		Caenidae															
	45	**Caenis**						1	2		1.0						
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D3. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (19 June) 1	2	3	x̄	Dip	Summer (30 July) 1	2	3	x̄	Dip	Fall (21 September) 1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**					P					P					P
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**															
	88	Libellulidae															
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**													1	0.3	
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**												1		0.3	
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															A
		Gerridae															
	95	**Gerris**															
3		Trichoptera															
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**							1		0.3						
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**															
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae															P
	6	Elmidae															
6		Diptera															
		pupae													1	0.3	
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	27	56	46	43.0	P	60	258	74	130.7	P					
		pupae															
	37	Ceratopogonidae															
	8	Chironomidae	5	4		3.0		3	9	2	4.7			1	11	4.0	
	38	Tabanidae															
	46	Empididae		1	1	0.7											
		COLUMN TOTALS	**65**	**87**	**68**	**73.3**		**133**	**364**	**88**	**194.9**		**12**	**94**	**43**	**49.3**	
		TAXA			**9**		**5**			**18**		**7**			**20**		**7**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D4. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station MR-B4 on the MacKay River, 1984.

SYNCRUDE Code		Taxa	Spring (19 June)					Summer (30 July)					Fall (21 September)				
MTC	MTG		1	2	3	$\bar{x}$	Dip	1	2	3	$\bar{x}$	Dip	1	2	3	$\bar{x}$	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**															
	15	NEMATODA	2			0.7				2	0.7				4	1.3	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae	2		1	1.0	P		2		0.7		5	5	1	2.7	
	65	Unionidae					P							1		0.3	
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**							1		0.3						
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**												1	1	0.7	
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**			1	0.3											
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta	2	33	4	13.0		3	22	16	13.7		138	59	198	131.7	
		ARTHROPODA															
		Arachnida															
	13	Acari		4		1.3			3	10	4.3		48	40	8	32.0	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**												1	1	0.7	
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae							3		1.0		104	32	125	87.0	
	1	**Baetis**	3	5	5	4.3	A	6	11	21	12.7	P	3	1	1	1.7	P
		Callibaetis															
	77	**Centroptilum**															
	44	**Pseudocloeon**		2	3	1.7							6		1	2.3	
		Heptageniidae							5		1.7						
	2	**Heptagenia**			1	0.3		5	2	6	4.3	P					
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**											5			1.7	A
	30	**Paraleptophlebia**										P	2			0.7	
		Ephemerellidae															
	19	**Ephemerella**					P			2	0.7						
		Tricorythidae															
	43	**Tricorythodes**						1	8	5	4.7	P	63	15	216	98.0	P
		Caenidae															
	45	**Caenis**	1			0.3		2	2	1	1.7	P		6	5	3.7	
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D4. Continued.

SYNCRUDE Code		Taxa	Spring (19 June) 1	2	3	x̄	Dip	Summer (30 July) 1	2	3	x̄	Dip	Fall (21 September) 1	2	3	x̄	Dip
MTC	MTG																
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															P
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**															
	88	Libellulidae															
2		Plecoptera													8	2.7	
		Pteronarcyidae															
	3	**Pteronarcys**										P					
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**															
		Perlidae															
	90	**Acroneuria**											1		1	0 7	
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															P
		Gerridae															
	95	**Gerris**															
3		Trichoptera															
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**															
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**															
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															P
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae															
	6	Elmidae															
6		Diptera															
		pupae			1	0.3			1		0 3				4	1.3	
	35	Tipulidae													1	0 3	
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	398	313	196	302.3	A	45	30	21	32.0						
		pupae	1			0.3		1			0.3						
	37	Ceratopogonidae												4		1.3	
	8	Chironomidae	2	9	7	6.0		6	14	4	8.0	P	394	228	206	276.0	P
	38	Tabanidae															
	46	Empididae															
		COLUMN TOTALS	**411**	**366**	**219**	**331.8**		**69**	**104**	**88**	**87.1**		**769**	**393**	**781**	**646.8**	
		TAXA			**15**		**5**			**18**		**7**			**23**		**7**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D5. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station M2-B on Creek M2, 1984.

SYNCRUDE Code		Taxa	Spring (19 June)					Summer (30 July)					Fall (21 September)				
MTC	MTG		1	2	3	$\bar{x}$	Dip	1	2	3	$\bar{x}$	Dip	1	2	3	$\bar{x}$	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**															
	15	NEMATODA															
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae															
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															
		Planorbidae											1			0.3	
	67	**Armiger**															
	11	**Gyraulus**															
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea								1	0.3						
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta		2		0.7		4	2		2.0		5	3		2.7	
		ARTHROPODA															
		Arachnida															
	13	Acari													2	0.7	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Emphemeroptera							3		1.0						
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae											8	3	2	4.3	
	1	**Baetis**	19	20	18	19.0	A	12	9	18	13.0	P	5	10	1	5.3	P
		Callibaetis															
	77	**Centroptilum**															
	44	**Pseudocloeon**		1	1	0.7								3		1.0	A
		Heptageniidae															
	2	**Heptagenia**															
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae												7		2.3	
	80	**Leptophlebia**															P
	30	**Paraleptophlebia**								1	0.3	P					
		Ephemerellidae															
	19	**Ephemerella**															
		Tricorythidae															
	43	**Tricorythodes**															
		Caenidae															
	45	**Caenis**															
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D5. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (19 June) 1	2	3	x̄	Dip	Summer (30 July) 1	2	3	x̄	Dip	Fall (21 September) 1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**								2	0.7	A					
	88	Libellulidae															
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**			1	0.3											
	34	**Nemoura**											9	41	6	18.7	
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															
		Gerridae															
	95	**Gerris**										P					
3		Trichoptera															
		pupae						1			0.3						
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**															
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**															
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae								1	0.3						
	6	Elmidae															
6		Diptera															
		pupae							2	3	1.7		1	2	1	1.3	
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	27	17	20	21.3			1	5	2.0	P	4	8	4	5.3	
		pupae								2	0.7						
	37	Ceratopogonidae															
	8	Chironomidae	2	5	9	5.3		11	9	20	13.3	P	13	59	24	32.0	P
	38	Tabanidae								1	0.3						
	46	Empididae															
		COLUMN TOTALS	**48**	**45**	**49**	**47.3**		**28**	**26**	**54**	**35.9**		**46**	**136**	**40**	**73.9**	
		TAXA			**6**		**1**			**14**		**6**			**12**		**4**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D6. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from Station DR B on Dover River 1984.

SYNCRUDE Code		Taxa	Spring (19 June)					Summer (30 July)					Fall (21 September)				
			1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
MTC	MTG																
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**												1	1	0.7	
	15	NEMATODA								2	0 7			1		0 3	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae	1	1		0.7			3		1.0			1		0.3	
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															
		Planorbidae											1	8		3.0	
	67	**Armiger**															
	11	**Gyraulus**	1	1		0.7		3			1.0						
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**											2	8		3.3	
9		ANNELIDA															
	23	Hirudinea												1		0.3	
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta	3	3	4	3.3		11	16	14	13.7		15	161	37	71.0	
		ARTHROPODA															
		Arachnida															
	13	Acari	4	4		2.7		2	3	4	3.0		7		8	5.0	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae						9	7	16	10.7		49	13	51	37.7	
	1	**Baetis**	25	22	11	19.3	A	54	28	36	39.3	A		1	4	1.7	P
		Callibaetis															
	77	**Centroptilum**										P					
	44	**Pseudocloeon**											2			0.7	
		Heptageniidae						4			1.3				1	0.3	
	2	**Heptagenia**						3		1	1.3	P			1	0.3	P
	78	**Rhithrogena**															
	79	**Stenonema**												3		1.0	
		Leptophlebiidae															
	80	**Leptophlebia**												1	1	0 7	
	30	**Paraleptophlebia**															
		Ephemerellidae															
	19	**Ephemerella**	4			1.3	A	1			0 3		2		3	1.7	
		Tricorythidae															
	43	**Tricorythodes**						7	1	1	3.0	P		1		0.3	
		Caenidae															
	45	**Caenis**	1			0.3	P										
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D6. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (19 June) 1	2	3	x̄	Dip	Summer (30 July) 1	2	3	x̄	Dip	Fall (21 September) 1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**	1			0.3		1	1		0.7	P					P
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**															
	88	Libellulidae															
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**				-	P										
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**								1	0.3						
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**											1			0.3	
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**											2	5	1	2.7	P
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															
		Gerridae															
	95	**Gerris**															
3		Trichoptera															
		pupae															
		Philopotamidae															
	17	**Wormaldia**							2	1	1.0						
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**						1	1	1	1.0	P					
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**															
		Hydroptilidae	1			0.3											
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**					P										
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae															
	6	Elmidae		1		0.3		2			0.7			1		0.3	
6		Diptera															
		pupae		1	3	1.3		2	1		1.0				1	0.3	
	35	Tipulidae											1			0.3	
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	16	31	29	25.3	A	10	85	97	64.0	P					
		pupae						3			1 0						
	37	Ceratopogonidae											1			0 3	
	8	Chironomidae	3	21	6	10.0		25	3	9	12.3		6	8	4	6.0	P
	38	Tabanidae															
	46	Empididae		1		0.3							1		1	0.7	
		COLUMN TOTALS	**60**	**86**	**53**	**66.1**		**138**	**151**	**183**	**157.3**		**90**	**214**	**114**	**139.2**	
		TAXA		**16**			**6**		**21**			**7**		**26**			**5**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D7. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station M6-B on Creek M6, 1984.

SYNCRUDE Code		Taxa	Spring (19 June)					Summer (30 July)					Fall (21 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**															
	15	NEMATODA		5		1.7		5	2	3	3.3			4	4	2.7	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae		2	1	1.0			9	17	8.7		12	39	5	18.7	
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**							1		0.3						
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**															
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea						2			0.7		1	3	1	1.7	
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**												2		0.7	
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta	8	6	19	11.0		104	34	45	61.0		85	590	366	347.0	
		ARTHROPODA															
		Arachnida															
	13	Acari			2	0.7		2			0.7		8			2.7	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Ephemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae													1	0.3	
	1	**Baetis**	8	33	14	18.3	P						1			0.3	A
		Callibaetis															
	77	**Centroptilum**															
	44	**Pseudocloeon**															
		Heptageniidae															
	2	**Heptagenia**	1		1	0.7											
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															
	30	**Paraleptophlebia**						1			0.3						
		Ephemerellidae															
	19	**Ephemerella**															
		Tricorythidae															
	43	**Tricorythodes**															
		Caenidae															
	45	**Caenis**															
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D7. Continued.

SYNCRUDE Code		Taxa	Spring (19 June) 1	2	3	$\bar{x}$	Dip	Summer (30 July) 1	2	3	$\bar{x}$	Dip	Fall (21 September) 1	2	3	$\bar{x}$	Dip
MTC	MTG																
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**															
	88	Libellulidae															
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**		8	5	4.3											
	34	**Nemoura**															
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															
		Gerridae															
	95	**Gerris**										P					
3		Trichoptera							1		0.3						
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**															
		Rhyacophilidae															
	51	**Rhyacophila**		1	2	1.0											
		Glossosomatidae															
	5	**Glossosoma**						1			0.3						
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**		2		0.7											
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**											3			1.0	
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae															
	6	Elmidae			1	0.3							1			0.3	
6		Diptera															
		pupae	1		1	0.7				1	0.3						
	35	Tipulidae											1	3		1.3	
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	21	10	4	11.7		1			0.3			2		0.7	
		pupae															
	37	Ceratopogonidae												2		0.7	
	8	Chironomidae	5	49	47	33.7		30	19	20	23.0	P	1731	515	2368	1538.0	A
	38	Tabanidae											3		7	3.3	
	46	Empididae															
		COLUMN TOTALS	**44**	**116**	**97**	**85.8**		**146**	**66**	**86**	**99.2**		**1846**	**1160**	**2752**	**1919.4**	
		TAXA			**13**		**1**			**13**		**2**			**15**		**2**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present; Neill sampler: area = 0.1 m^2, mesh size = *0.210 mm; Dipnet: mesh size = 0.250 mm.*

Table D8. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station WID-B1 on the West Interception Ditch, 1984.

SYNCRUDE Code		Taxa	Spring (17 June)					Summer (28 July)					Fall (26 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**						5			1.7			7	9	5.3	P
	15	NEMATODA			8	2.7		3		8	3.7		5	3	5	4.3	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae						3			1.0						
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**		4		1.3	P						1			0.3	
		Physidae															
	10	**Physa**															
		Planorbidae											13	13	6	10.3	
	67	**Armiger**															
	11	**Gyraulus**		16		5.3		10	2		4.0	P					
	50	**Helisoma**								16	5.3						
	68	**Promenetus**		1		0.3			1		0.3						
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta		5	66	23.7	P	7	1	18	8.7		1	6	2	3.0	
		ARTHROPODA															
		Arachnida															
	13	Acari			3	1.0							2		3	1.7	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**					P		1		0.3		1		1	0.7	
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**					P										
		Metretopodidae															
	76	**Metretopus**															
		Baetidae											54	13	14	27.0	A
	1	**Baetis**	4	6	8	6.0	A		8	7	5.0	P	9		19	9.3	P
		Callibaetis															
	77	**Centroptilum**															
	44	**Pseudocloeon**															
		Heptageniidae		4	2	2.0							1			0.3	
	2	**Heptagenia**		1		0.3	A										
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															
	30	**Paraleptophlebia**					A										
		Ephemerellidae															
	19	**Ephemerella**															
		Tricorythidae															
	43	**Tricorythodes**								1	0.3	P	5	13	1	6.3	
		Caenidae															
	45	**Caenis**															
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**											10	8	3	7.0	P

Continued ...

Table D8. Continued.

SYNCRUDE Code		Taxa	Spring (17 June)					Summer (28 July)					Fall (26 September)				
			1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
MTC	MTG																
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**											1			0 3	
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															P
		Corduliidae															
	39	**Somatochlora**															
	88	Libellulidae								1	0.3	P	1	3		1.3	
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**											1			0.3	
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**															
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae										P		1		0.3	
		Gerridae															
	95	**Gerris**															
3		Trichoptera											1			0.3	
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**											1			0.3	
	97	**Polycentropus**					A										
		Hydropsychidae											1			0.3	
	98	**Cheumatopsyche**															
	4	**Hydropsyche**											1			0 3	
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**															
		Hydroptilidae															
	41	Hydroptila											3	1		1.3	
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**											1			0.3	
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**						1			0.3		1		1	0.7	
	109	**Oecetis**											1			0.3	
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**							1		0 3	P		2		0 7	
	47	Dytiscidae					P										
	6	Elmidae															
6		Diptera															
		pupae			4	1.3	P		2	12	4.7		1	1		0.7	
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	1	19	16	12.0	A	6	36	47	29.7	P	9	1	9	6.3	
		pupae	1			0.3											
	37	Ceratopogonidae								2	0.7		2	3	4	3.0	
	8	Chironomidae	3	14	127	48.0	A	140	78	238	152.0	P	3166	2323	1528	2339.0	A
	38	Tabanidae															
	46	Empididae															
		COLUMN TOTALS	**9**	**70**	**234**	**104.2**		**175**	**130**	**350**	**218.3**		**3293**	**2398**	**1602**	**2430.5**	
		TAXA			**18**		**12**			**19**		**8**			**29**		**6**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals). P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D9. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples and dipnet samples from station W3-B on Creek W3, 1984.

SYNCRUDE Code		Taxa	Spring (17 June)					Summer (28 July)					Fall (26 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**								2	0.7						
	15	NEMATODA		2		0.7		4		2	2.0		14	4		6.0	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae													4	1.3	
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															P
		Planorbidae															P
	67	**Armiger**															
	11	**Gyraulus**										P					
	50	**Helisoma**															
	68	**Promenetus**					P										P
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**								1	0.3						
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta	3		4	2.3		31	24	45	33.3		8		36	14.7	P
		ARTHROPODA															
		Arachnida															
	13	Acari								1	0.3						P
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**	1			0.3											
	73	**Hyalella azteca**					P	4	4	1	3.0	A					P
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**					P										
		Metretopodidae															
	76	**Metretopus**															
		Baetidae															
	1	**Baetis**															
		Callibaetis															
	77	**Centroptilum**															
	44	**Pseudocloeon**															
		Heptageniidae															
	2	**Heptagenia**															
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															
	30	**Paraleptophlebia**															
		Ephemerellidae															
	19	**Ephemerella**															
		Tricorythidae															
	43	**Tricorythodes**													4	1.3	
		Caenidae															
	45	**Caenis**											2			0.7	
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**					P										
		Coenagrionidae					P										
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D9. Continued.

SYNCRUDE Code		Taxa	Spring (17 June)					Summer (28 July)					Fall (26 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**										P					P
		Corduliidae															
	39	**Somatochlora**															
	88	Libellulidae															P
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**															
		Perlidae															
	90	**Aeroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae					P					P					P
	94	Corixidae					A					P					
		Gerridae															
	95	**Gerris**															
3		Trichoptera															
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**															
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**															
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															P
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**															P
	47	Dytiscidae					A										
	6	Elmidae															
6		Diptera															
		pupae	1			0.3	P										
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**					P						8			2.7	
	7	Simuliidae															
		pupae															
	37	Ceratopogonidae								1	0.3		24			8.0	
	8	Chironomidae		1	5	2.0	P	14	14	60	29.3		52	20	84	52.0	
	38	Tabanidae															
	46	Empididae															
		COLUMN TOTALS	5	3	9	5.6		53	42	113	69.2		108	24	128	86.7	
		TAXA			14		11			12		5			18		11

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals). P = present; Ekman grab sampler: area = 0 023 m^2, sieve mesh size = 0.250 mm; Dipnet: mesh size = 0.250 mm.

Table D10. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station WID-B2 on the West Interception Ditch, 1984.

SYNCRUDE Code		Taxa	Spring (17 June)					Summer (28 July)					Fall (26 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**											4			1.3	
	15	NEMATODA	1	1		0.7		2	40	12	18.0		2	20		7.3	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae													4	1.3	
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**					P					P	2			0.7	
		Physidae															
	10	**Physa**										P					P
		Planorbidae											34			11.3	
	67	**Armiger**															
	11	**Gyraulus**							1	2	1.0	P					
	50	**Helisoma**															
	68	**Promenetus**			1	0.3											
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta	38	10	1	16.3	P	1	22	55	26.0		174	31	92	99.0	
		ARTHROPODA															
		Arachnida															
	13	Acari	1	1		0.7	P							4		1.3	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**					A										
		Metretopodidae															
	76	**Metretopus**															
		Baetidae															
	1	**Baetis**					P										
		Callibaetis															
	77	**Centroptilum**															
	44	**Pseudocloeon**															
		Heptageniidae															
	2	**Heptagenia**															
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															
	30	**Paraleptophlebia**					P										
		Ephemerellidae															
	19	**Ephemerella**															
		Tricorythidae															
	43	**Tricorythodes**															
		Caenidae															
	45	**Caenis**															
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**					P										
		Coenagrionidae					P										
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D10. Continued.

SYNCRUDE Code		Taxa	Spring (17 June)					Summer (28 July)					Fall (26 September)				
			1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
MTC	MTG																
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**					P										
	88	Libellulidae															
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**															
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae					P					P					P
		Gerridae															
	95	**Gerris**															
3		Trichoptera															
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**		1		0.3											
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**															
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**															
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae								1	0.3						
	111	**Haliplus**					P										
	47	Dytiscidae			1	0.3	P					P		1		0.3	
	6	Elmidae			1	0.3								4	4	2.7	
6		Diptera															
		pupae	1	1		0.7	P		1		0.3			4	8	4.0	
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	5	1		2.0	P	1			0.3						
		pupae											2			0.7	
	37	Ceratopogonidae													4	1.3	
	8	Chironomidae	4	3	24	10.3	A	84	16	41	47.0	A	548	420	412	460.0	A
	38	Tabanidae															
	46	Empididae															
		COLUMN TOTALS	**50**	**18**	**28**	**31.9**		**88**	**80**	**111**	**92.9**		**766**	**484**	**524**	**591.2**	
		TAXA			**19**		**15**			**11**		**6**			**14**		**3**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals). P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D11. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station BRC-B on Bridge Creek, 1984.

SYNCRUDE Code		Taxa	Spring (18 June)					Summer (29 July)					Fall (21 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**															P
	15	NEMATODA	4	1		1.7		2			0.7			1		0.3	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae															
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**															
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea													2	0.7	
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta	7	1		2.7		11	2	16	9.7		7	4	9	6.7	
		ARTHROPODA															
		Arachnida															
	13	Acari	1			0.3											
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Ephemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**					P										
		Baetidae															
	1	**Baetis**	1	4	2	2.3	P	1	5	6	4.0	P					
		Callibaetis															
	77	**Centroptilum**															
	44	**Pseudocloeon**															
		Heptageniidae															
	2	**Heptagenia**															
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															
	30	**Paraleptophlebia**										P					
		Ephemerellidae															
	19	**Ephemerella**															
		Tricorythidae															
	43	**Tricorythodes**															
		Caenidae															
	45	**Caenis**					P										
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D11. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (18 June) 1	2	3	x̄	Dip	Summer (29 July) 1	2	3	x̄	Dip	Fall (21 September) 1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**					P										
	88	Libellulidae															
2		Plecoptera						5	3	14	7.3						
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taenioptery x**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**															
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															
		Gerridae															
	95	**Gerris**															
3		Trichoptera															
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**															
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**										P	1			0.3	
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**						1	1	1	1.0						
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															P
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae					P					P					
	6	Elmidae	2			0.7											
6		Diptera															
		pupae															
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	7	1	3	3.7	A	3	2	2	2.3						
		pupae															
	37	Ceratopogonidae	1			0.3											
	8	Chironomidae	7		2	3.0		10	2	7	6.3		1			0.3	A
	38	Tabanidae															
	46	Empididae	2			0.7											
		COLUMN TOTALS	**32**	**7**	**7**	**15.4**		**33**	**15**	**46**	**31.3**		**9**	**5**	**11**	**8.3**	
		TAXA			**13**		**6**			**10**		**4**			**7**		**3**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals). P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D12. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station LBC-B1 on Lower Beaver Creek, 1984.

SYNCRUDE Code		Taxa	Spring (19 June)					Summer (29 July)					Fall (22 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**															
	15	NEMATODA							5	1	2.0		4	4	2	3.3	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae															
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**											1			0.3	
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**															
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**	1	1		0.7											
	22	Oligochaeta	1	26	53	26.7		28	13	19	20.0		66	63	2	43.7	
		ARTHROPODA															
		Arachnida															
	13	Acari						2			0.7		4	1		1.7	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae											1	1	1	1.0	
	1	**Baetis**	1	2		1.0	A	136	68	81	95.0		5	7		4.0	
		Callibaetis															
	77	**Centroptilum**					P										
	44	**Pseudocloeon**															
		Heptageniidae							1		0.3						
	2	**Heptagenia**						1			0.3						
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															P
	30	**Paraleptophlebia**															
		Ephemerellidae															
	19	**Ephemerella**															
		Tricorythidae															
	43	**Tricorythodes**								1	0.3						
		Caenidae															
	45	**Caenis**						1			0.3						
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D12. Continued.

SYNCRUDE Code MTC	SYNCRUDE Code MTG	Taxa	Spring (19 June) 1	2	3	x̄	Dip	Summer (29 July) 1	2	3	x̄	Dip	Fall (22 September) 1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**					P	1			0.3						
	88	Libellulidae															
2		Plecoptera											2		1	1 0	P
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**											33	46	8	29.0	
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**											5	1		2.0	
	92	Chloroperlidae												6		2.0	
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															
		Gerridae															
	95	**Gerris**															
3		Trichoptera															
		pupae					P										
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**											10	8	1	6.3	P
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**											8	2	1	3.7	
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															P
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**					P										
	47	Dytiscidae							1		0.3	P					
	6	Elmidae															
6		Diptera															
		pupae							2	2	1.3		3			1.0	
	35	Tipulidae							1		0.3						
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae		1		0.3		1			0.3						
		pupae															
	37	Ceratopogonidae															
	8	Chironomidae	3	4	12	6.3		38	9	31	26.0	A	168	188	37	131	
	38	Tabanidae	1			0.3		1			0.3		1	2	1	1.3	
	46	Empididae											1			0.3	
		COLUMN TOTALS	**7**	**34**	**65**	**35.3**		**209**	**100**	**135**	**147.7**		**312**	**329**	**54**	**231.6**	
		TAXA			**10**		**5**			**15**		**2**			**18**		**4**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals). P = present: Neill sampler: area = 0.1 m^2. mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D13. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station LBC-B2 on Lower Beaver Creek, 1984.

SYNCRUDE Code		Taxa	Spring (19 June)					Summer (29 July)					Fall (21 September)				
			1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
MTC	MTG																
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**						1	12	1	4.7		4	12		5.3	
	15	NEMATODA			1	0.3		1			0.3						
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae		4	11	5.0		520	12	6	179.3		2	34	18	18.0	
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**			3	1.0											
		Physidae															
	10	**Physa**								4	1.3	P					P
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**						1			0.3						
	50	**Helisoma**															
	68	**Promenetus**						6			2.0						
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea		6	12	6.0			6	22	9.3		8	5	3	5.3	
		Glossiphoniidae															
	69	**Glossiphonia complanata**		6	7	4.3	P	11	2		4.3			3		1.0	
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**						3			1.0						
		Erpobdellidae															
	72	**Nephelopsis obscura**	2			0.7	P	2			0.7						
	22	Oligochaeta	12	122	172	102.0	P	306	148	165	206.3		218	222	194	211.3	
		ARTHROPODA															
		Arachnida															
	13	Acari		4	1	1.7		2		9	3.7		4		4	2.7	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae															
	1	**Baetis**	10		1	3.7	A	4		2	2.0	A			2	0.7	
		Callibaetis															
	77	**Centroptilum**										P					
	44	**Pseudocloeon**					P										
		Heptageniidae															
	2	**Heptagenia**										P					
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae												4		1.3	
	80	**Leptophlebia**											1			0.3	
	30	**Paraleptophlebia**											1			0.3	
		Ephemerellidae															
	19	**Ephemerella**						1			0.3						
		Tricorythidae															
	43	**Tricorythodes**											1			0.3	
		Caenidae															
	45	**Caenis**						1			0.3						
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D13. Continued.

SYNCRUDE Code		Taxa	Spring (19 June)					Summer (29 July)					Fall (21 September)				
MTC	MTG		1	2	3	$\bar{x}$	Dip	1	2	3	$\bar{x}$	Dip	1	2	3	$\bar{x}$	Dip
		Gomphidae															
	28	**Gomphus**						1			0.3						
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**															
	88	Libellulidae															
2		Plecoptera						2			0.7						
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**															
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae						1	14		5.0						P
		Gerridae															
	95	**Gerris**								1	0.3						
3		Trichoptera															
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**	1			0.3											
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**												2		0.7	
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**						8		26	11.3						
		Phryganeidae															
	101	**Agrypnia**											1			0.3	
	102	**Ptilostomis**															P
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**											1			0.3	P
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															P
		Haliplidae						2			0.7						
	111	**Haliplus**			1	0.3	P			1	0.3	P		2		0.7	P
	47	Dytiscidae	10		7	5.7	A	4		7	3.7	P					P
	6	Elmidae						1		3	1.3						
6		Diptera		1		0.3			1		0.3						
		pupae	2	3	3	2.7		38	32	17	29.0						
	35	Tipulidae								1	0.3						
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae		1	1	0.7											
		pupae															
	37	Ceratopogonidae		3	2	1.7											
	8	Chironomidae	22	116	87	75.0	A	598	271	674	514.3	P	112	112	78	100.7	
	38	Tabanidae	2	8	12	7.3			1	3	1.3		5	1	7	4.3	
	46	Empididae															
		COLUMN TOTALS	**61**	**274**	**321**	**218.7**		**1514**	**499**	**942**	**984.6**		**358**	**397**	**306**	**353.5**	
		TAXA			**19**		**8**			**31**		**7**			**23**		**7**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D14. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples and dipnet samples from station UBC B on Upper Beaver Creek, 1984.

SYNCRUDE Code		Taxa	Spring (15 June)					Summer (30 July)					Fall (22 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**						2		8	3.3						
	15	NEMATODA															
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae							3	2	1.7				4	1.3	
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**															
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea						1	2		1.0						
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta		1		0.3	P	18	3	53	24.7		68	36	36	46.7	
		ARTHROPODA															
		Arachnida															
	13	Acari	4			1.3		5	1		2.0				8	2.7	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**										P					
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae															
	1	**Baetis**					A										
		Callibaetis															
	77	**Centroptilum**										P					
	44	**Pseudocloeon**															
		Heptageniidae							1		0.3						
	2	**Heptagenia**															
	78	**Rhithrogena**															
	79	**Stenonema**					P										
		Leptophlebiidae															
	80	**Leptophlebia**															P
	30	**Paraleptophlebia**															
		Ephemerellidae															
	19	**Ephemerella**															
		Tricorythidae															
	43	**Tricorythodes**															
		Caenidae															
	45	**Caenis**	45			15.0	A	1	28		9.7		20	36	4	20.0	
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**					P										
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**					P										
	85	**Ischnura**															

Continued ...

Table D14. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (15 June) 1	2	3	x̄	Dip	Summer (30 July) 1	2	3	x̄	Dip	Fall (22 September) 1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**										P					P
	87	**Anax**										P					
		Corduliidae															
	39	**Somatochlora**					P		2		0.7						
	88	Libellulidae															
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**															
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae					P					P					A
		Gerridae															
	95	**Gerris**															
3		Trichoptera															
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**															
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**															
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															P
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**							1		0.3						
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															P
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae					P										
	6	Elmidae							1		0.3						
6		Diptera															
		pupae	3			1.0		2	11		4.3						
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	1			0.3	A										
		pupae	2			0.7	P										
	37	Ceratopogonidae						9	4	1	4.7		12	12	8	10.7	
	8	Chironomidae	39	1		13.3	P	39	155	49	81.0	P	152	296	132	193.3	
	38	Tabanidae															
	46	Empididae															
		COLUMN TOTALS	**94**	**2**	**0**	**31.9**		**77**	**212**	**113**	**134.0**		**252**	**380**	**192**	**274.7**	
		TAXA		**14**			**12**		**18**			**6**		**11**			**5**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present: Ekman grab sampler: area = 0.023 m^2, sieve mesh size = 0.250 mm; Dipnet: mesh size = 0.250 mm.

Table D15. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station B1-B on Creek B1, 1984.

SYNCRUDE Code		Taxa	Spring (N/A)					Summer (28 July)					Fall (26 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA	NO SAMPLES WERE COLLECTED IN SPRING														
		Hydrozoa															
	12	**Hydra**											1	1		0.7	
	15	NEMATODA						1			0.3						
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae													1	0.3	
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**											2	1		1.0	
		Physidae															
	10	**Physa**											1			0.3	
		Planorbidae															
	67	**Armiger**											23		4	9.0	
	11	**Gyraulus**						2			0.7						
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta							1	2	1.0		9	4	12	8.3	
		ARTHROPODA															
		Arachnida															
	13	Acari						2			0.7		6		2	2.7	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola											9			3.0	
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**												1		0.3	
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae															
	1	**Baetis**						15	6	4	8.3	A	6		1	2.3	A
		Callibaetis															
	77	**Centroptilum**															
	44	**Pseudocloeon**															
		Heptageniidae															
	2	**Heptagenia**										P					
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**											11		1	4.0	P
	30	**Paraleptophlebia**											1		2	1.0	
		Ephemerellidae															
	19	**Ephemerella**															
		Tricorythidae															
	43	**Tricorythodes**						1	1	1	1.0		1		1	0.7	
		Caenidae															
	45	**Caenis**											3			1.0	
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D15. Continued.

SYNCRUDE Code		Taxa	Spring (N/A)					Summer (28 July)					Fall (26 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**										P	1			0.3	
	88	Libellulidae															
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**															
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															
		Gerridae															
	95	**Gerris**															
3		Trichoptera											1			0.3	
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**													2	0 7	
		Polycentropodidae															
	20	**Neureclipsis**											7			2.3	
	97	**Polycentropus**											1	2		1.0	
		Hydropsychidae															
	98	**Cheumatopsyche**							1		0.3						
	4	**Hydropsyche**											1			0.3	
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**						1			0.3		1			0.3	
		Hydroptilidae															
	41	Hydroptila												1		0.3	
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**											1			0.3	
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae															
	6	Elmidae						3	3		2.0		2		2	1.3	
6		Diptera															
		pupae						2	2		1.3		1			0.3	
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae						51	23		24.7	A	6	1		2 3	A
		pupae						1	3		1.3		1		5	2.0	
	37	Ceratopogonidae											2			0.7	
	8	Chironomidae						43	31	3	25.7	P	221	115	149	161.7	P
	38	Tabanidae															
	46	Empididae						1			0.3		1			0.3	
		COLUMN TOTALS						**123**	**. 71**	**10**	**67.9**		**320**	**126**	**182**	**209.0**	
		TAXA								**16**		**5**			**30**		**4**

Notes: MTC = major ta· nomic category; MTG = major taxonomic group; A = abundant (five or more individuals). P = present; Neill sampler: area = 0.1 m^2. mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D16. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples and dipnet samples from station BCR-B1 on Beaver Creek Reservoir, 1984.

SYNCRUDE Code		Taxa	Spring (15 June)				Summer (24 July)					Fall (23 September)				
MTC	MTG		1	2	3	$\bar{x}$	1	2	3	$\bar{x}$	Dip	1	2	3	$\bar{x}$	Dip
		COELENTERATA														
		Hydrozoa														
	12	**Hydra**														
	15	NEMATODA	1	2		1.0	1	1		0.7			4		1.3	
8		MOLLUSCA														
		Pelecypoda														
	29	Sphaeriidae		1		0.3										
	65	Unionidae														
		Gastropoda														
		Valvatidae														
	66	**Valvata**										2		4	2.0	
		Valvata sincera sincera														
		Valvata tricarinata														
		Lymnaeidae														
	32	**Lymnaea**							1	0.3	A					P
		Physidae														P
	10	**Physa**									A					
		Planorbidae	2			0.7						2	4	4	3.3	P
	67	**Armiger**														
	11	**Gyraulus**						2	2	1.3	P					
	50	**Helisoma**														
	68	**Promenetus**														
		Ancylidae														
	18	**Ferrissia**														
9		ANNELIDA														
	23	Hirudinea			1	0.3		1	2	1.0						
		Glossiphoniidae														
	69	**Glossiphonia complanata**														
	70	**Helobdella stagnalis**							4	1.3						
		Hirudinidae														
	71	**Haemopis grandis**														
		Erpobdellidae														
	72	**Nephelopsis obscura**							1	0.3						
	22	Oligochaeta	243	83	68	131.3	60	74	64	66.0		168	16	100	94.7	
		ARTHROPODA														
		Arachnida														
	13	Acari		1		0.3							16	4	6.7	
	10	Crustacea														
		Malacostraca														
		Amphipoda														
	24	**Gammarus lacustris**	1			0.3							4		1.3	
	73	**Hyalella azteca**	2			0.7					A		8		2.7	P
		Insecta														
	74	Collembola														
1		Ephemeroptera														
		Siphlonuridae														
	35	**Ameletus**														
	75	**Siphlonurus**														
		Metretopodidae														
	76	**Metretopus**														
		Baetidae														
	1	**Baetis**														
		Callibaetis														
	77	**Centroptilum**														
	44	**Pseudocloeon**														
		Heptageniidae														
	2	**Heptagenia**														
	78	**Rhithrogena**														
	79	**Stenonema**														
		Leptophlebiidae														
	80	**Leptophlebia**														
	30	**Paraleptophlebia**														
		Ephemerellidae														
	19	**Ephemerella**														
		Tricorythidae														
	43	**Tricorythodes**											4		1.3	
		Caenidae														
	45	**Caenis**	4	7		3.7			2	0.7		4			1.3	
		Baetiscidae														
	81	**Baetisca**														
5		Odonata														
		Calopterygidae														
	82	**Calopteryx**														
		Lestidae														
	83	**Lestes**									P					
		Coenagrionidae									P					A
	84	**Coenagrion**														
	85	**Ischnura**											4	4	2.7	

Continued ...

Table D16. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (15 June) 1	2	3	x̄	Summer (24 July) 1	2	3	x̄	Dip	Fall (23 September) 1	2	3	x̄	Dip
		Gomphidae														
	28	**Gomphus**														
	86	**Ophiogomphus**														
		Aeshnidae														
	42	**Aeshna**														
	87	**Anax**														P
		Corduliidae														
	39	**Somatochlora**														
	88	Libellulidae														
2		Plecoptera														
		Pteronarcyidae														
	3	**Pteronarcys**														
		Taeniopterygidae														
	89	**Taeniopteryx**														
		Nemouridae														
	59	**Malenka**														
	34	**Nemoura**														
		Perlidae														
	90	**Acroneuria**														
	91	**Claassenia**														
		Perlodidae														
	58	**Arcynopteryx**														
	48	**Isoperla**														
	92	Chloroperlidae														
		Hemiptera														
	93	Notonectidae									P					P
	94	Corixidae	1	1	2	1.3					A	2	4		2.0	P
		Gerridae														
	95	**Gerris**														
3		Trichoptera														
		pupae														
		Philopotamidae														
	17	**Wormaldia**														
		Psychomyiidae														
	96	**Psychomyia**														
		Polycentropodidae														
	20	**Neureclipsis**														
	97	**Polycentropus**														
		Hydropsychidae														
	98	**Cheumatopsyche**														
	4	**Hydropsyche**														
		Rhyacophilidae														
	51	**Rhyacophila**														
		Glossosomatidae														
	5	**Glossosoma**														
		Hydroptilidae														
	41	Hydroptila														
	99	**Ochrotrichia**														
		Phryganeidae														
	101	**Agrypnia**											4		1.3	
		Phryganea														
	102	**Ptilostomis**														
		Brachycentridae														
	27	**Brachycentrus**														
		Lepidostomatidae														
	103	**Lepidostoma**														
		Limnephilidae														
	104	**Clostoeca**														
	105	**Grammotaulius**														
	106	**Hesperophylax**														
	107	**Nemotaulius**														
		Helicopsychidae														
	108	**Helicopsyche**														
		Leptoceridae														
	9	**Ceraclea**														
	109	**Oecetis**														
4		Coleoptera														
	110	Gyrinidae														
		Haliplidae														
	111	**Haliplus**									P					P
	47	Dytiscidae									P					
	6	Elmidae														
6		Diptera														
		pupae	1	2	1	1.3										
	35	Tipulidae														
		Chaoboridae														
	112	**Chaoborus**														
	7	Simuliidae														
		pupae														
	37	Ceratopogonidae						1		0.3						
	8	Chironomidae	37	9	20	22.0	70	13	48	43.7		72	140	80	97.3	A
	38	Tabanidae														
	46	Empididae														
		COLUMN TOTALS	**292**	**106**	**92**	**163.2**	**131**	**92**	**124**	**115.3**		**250**	**208**	**196**	**217.9**	
		TAXA			**12**			**17**			**10**			**19**		**10**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals). P = present; Ekman grab sampler: area = 0.023 m^2. sieve mesh size = 0.250 mm; Dipnet: mesh size = 0.700 mm.

Table D17. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples from station BCR-B2 on Beaver Creek Reservoir, 1984.

SYNCRUDE Code		Taxa	Spring (15 June)				Summer (24 July)				Fall (23 September)			
			1	2	3	x̄	1	2	3	x̄	1	2	3	x̄
MTC	MTG													
		COELENTERATA												
		Hydrozoa												
	12	**Hydra**									16	4	4	8.0
	15	NEMATODA		1	2	1.0	2		1	1.0	20	20	20	20.0
8		MOLLUSCA												
		Pelecypoda												
	29	Sphaeriidae	1	2	2	1.7	1		4	1.7				
	65	Unionidae												
		Gastropoda												
		Valvatidae												
	66	**Valvata**		20	14	11.3	3	5	13	7.0	4	4	4	4.0
		Valvata sincera sincera												
		Valvata tricarinata												
		Lymnaeidae												
	32	**Lymnaea**												
		Physidae												
	10	**Physa**												
		Planorbidae												
	67	**Armiger**												
	11	**Gyraulus**												
	50	**Helisoma**												
	68	**Promenetus**												
		Ancylidae												
	18	**Ferrissia**												
9		ANNELIDA												
	23	Hirudinea												
		Glossiphoniidae												
	69	**Glossiphonia complanata**												
	70	**Helobdella stagnalis**			1	0.3								
		Hirudinidae												
	71	**Haemopis grandis**												
		Erpobdellidae												
	72	**Nephelopsis obscura**												
	22	Oligochaeta	7	6	26	13.0	21	9	44	24.7	136	56	44	78.7
		ARTHROPODA												
		Arachnida												
	13	Acari			1	0.3						8		2.7
	10	Crustacea												
		Malacostraca												
		Amphipoda												
	24	**Gammarus lacustris**												
	73	**Hyalella azteca**												
		Insecta												
	74	Collembola												
1		Emphemeroptera												
		Siphlonuridae												
	33	**Ameletus**												
	75	**Siphlonurus**												
		Metretopodidae												
	76	**Metretopus**												
		Baetidae									4			1.3
	1	**Baetis**												
		Callibaetis												
	77	**Centroptilum**												
	44	**Pseudocloeon**												
		Heptageniidae												
	2	**Heptagenia**												
	78	**Rhithrogena**												
	79	**Stenonema**												
		Leptophlebiidae												
	80	**Leptophlebia**												
	30	**Paraleptophlebia**												
		Ephemerellidae												
	19	**Ephemerella**												
		Tricorythidae												
	43	**Tricorythodes**									8			2.7
		Caenidae												
	45	**Caenis**												
		Baetiscidae												
	81	**Baetisca**												
5		Odonata												
		Calopterygidae												
	82	**Calopteryx**												
		Lestidae												
	83	**Lestes**												
		Coenagrionidae												
	84	**Coenagrion**												
	85	**Ischnura**												

Continued ...

Table D17. Continued.

SYNCRUDE Code		Taxa	Spring (15 June)				Summer (24 July)				Fall (23 September)			
MTC	MTG		1	2	3	x̄	1	2	3	x̄	1	2	3	x̄
		Gomphidae												
	28	**Gomphus**												
	86	**Ophiogomphus**												
		Aeshnidae												
	42	**Aeshna**												
	87	**Anax**												
		Corduliidae												
	39	**Somatochlora**												
	88	Libellulidae												
2		Plecoptera												
		Pteronarcyidae												
	3	**Pteronarcys**												
		Taeniopterygidae												
	89	**Taeniopteryx**												
		Nemouridae												
	59	**Malenka**												
	34	**Nemoura**												
		Perlidae												
	90	**Acroneuria**												
	91	**Claassenia**												
		Perlodidae												
	58	**Arcynopteryx**												
	48	**Isoperla**												
	92	Chloroperlidae												
		Hemiptera												
	93	Notonectidae												
	94	Corixidae												
		Gerridae												
	95	**Gerris**												
3		Trichoptera												
		pupae												
		Philopotamidae												
	17	**Wormaldia**												
		Psychomyiidae												
	96	**Psychomyia**												
		Polycentropodidae												
	20	**Neureclipsis**												
	97	**Polycentropus**												
		Hydropsychidae												
	98	**Cheumatopsyche**												
	4	**Hydropsyche**												
		Rhyacophilidae												
	51	**Rhyacophila**												
		Glossosomatidae												
	5	**Glossosoma**												
		Hydroptilidae												
	41	Hydroptila												
	99	**Ochrotrichia**												
		Phryganeidae												
	101	**Agrypnia**												
	102	**Ptilostomis**												
		Brachycentridae												
	27	**Brachycentrus**												
		Lepidostomatidae												
	103	**Lepidostoma**												
		Limnephilidae												
	104	**Clostoeca**												
	105	**Grammotaulius**												
	106	**Hesperophylax**												
	107	**Nemotaulius**												
		Helicopsychidae												
	108	**Helicopsyche**												
		Leptoceridae												
	9	**Ceraclea**												
	109	**Oecetis**												
4		Coleoptera												
	110	Gyrinidae												
		Haliplidae												
	111	**Haliplus**												
	47	Dytiscidae												
	6	Elmidae												
6		Diptera							2	0.7				
		pupae												
	35	Tipulidae												
		Chaoboridae												
	112	**Chaoborus**	1			0.3								
	7	Simuliidae												
		pupae												
	37	Ceratopogonidae												
	8	Chironomidae	7	9	14	10.0	2	12	16	10.0	76	32	44	50.7
	38	Tabanidae												
	46	Empididae												
		COLUMN TOTALS	**16**	**38**	**60**	**37.9**	**29**	**26**	**80**	**45.1**	**264**	**124**	**116**	**168.1**
		TAXA			**8**				**6**				**8**	

Notes: MTC = major taxonomic category; MTG = major taxonomic group; Ekman grab sampler: area = 0.023 m^2, sieve mesh size = 0.250 mm.

Table D18. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples from station BCR E3 on Beaver Creek Reservoir, 1984.

SYNCRUDE Code		Taxa	Spring (15 June)				Summer (24 July)				Fall (23 September)			
MTC	MTG		1	2	3	x̄	1	2	3	x̄	1	2	3	x̄
		COELENTERATA												
		Hydrozoa												
	12	**Hydra**									20	8		9.3
	15	NEMATODA	3	5		2.7		3	1	1.3	24	28	8	20.0
8		MOLLUSCA												
		Pelecypoda												
	29	Sphaeriidae			1	0.3								
	65	Unionidae									2			0.7
		Gastropoda												
		Valvatidae												
	66	**Valvata**	4	6	3	4.3			6	2.0	6	8		4.7
		Valvata sincera sincera												
		Valvata tricarinata												
		Lymnaeidae												
	32	**Lymnaea**												
		Physidae												
	10	**Physa**												
		Planorbidae												
	67	**Armiger**												
	11	**Gyraulus**												
	50	**Helisoma**												
	68	**Promenetus**												
		Ancylidae												
	18	**Ferrissia**												
9		ANNELIDA												
	23	Hirudinea												
		Glossiphoniidae												
	69	**Glossiphonia complanata**												
	70	**Helobdella stagnalis**												
		Hirudinidae												
	71	**Haemopis grandis**												
		Erpobdellidae												
	72	**Nephelopsis obscura**											16	5.3
	22	Oligochaeta	41	40	43	41.3	31	43	89	54.3	62	88	328	159.3
		ARTHROPODA												
		Arachnida												
	13	Acari												
	10	Crustacea												
		Malacostraca												
		Amphipoda												
	24	**Gammarus lacustris**												
	73	**Hyalella azteca**												
		Insecta												
	74	Collembola												
1		Emphemeroptera												
		Siphlonuridae												
	33	**Ameletus**												
	75	**Siphlonurus**												
		Metretopodidae												
	76	**Metretopus**												
		Baetidae												
	1	**Baetis**												
		Callibaetis												
	77	**Centroptilum**												
	44	**Pseudocloeon**												
		Heptageniidae												
	2	**Heptagenia**												
	78	**Rhithrogena**												
	79	**Stenonema**												
		Leptophlebiidae												
	80	**Leptophlebia**												
	30	**Paraleptophlebia**												
		Ephemerellidae												
	19	**Ephemerella**												
		Tricorythidae												
	43	**Tricorythodes**												
		Caenidae												
	45	**Caenis**											4	1.3
		Baetiscidae												
	81	**Baetisca**												
5		Odonata												
		Calopterygidae												
	82	**Calopteryx**												
		Lestidae												
	83	**Lestes**												
		Coenagrionidae												
	84	**Coenagrion**												
	85	**Ischnura**												

Continued ...

Table D18. Continued.

SYNCRUDE Code		Taxa	Spring (15 June)				Summer (24 July)				Fall (23 September)			
MTC	MTG		1	2	3	$\bar{x}$	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$
		Gomphidae												
	28	**Gomphus**												
	86	**Ophiogomphus**												
		Aeshnidae												
	42	**Aeshna**												
	87	**Anax**												
		Corduliidae												
	39	**Somatochlora**												
	88	Libellulidae												
2		Plecoptera												
		Pteronarcyidae												
	3	**Pteronarcys**												
		Taeniopterygidae												
	89	**Taeniopteryx**												
		Nemouridae												
	59	**Malenka**												
	34	**Nemoura**												
		Perlidae												
	90	**Acroneuria**												
	91	**Claassenia**												
		Perlodidae												
	58	**Arcynopteryx**												
	48	**Isoperla**												
	92	Chloroperlidae												
		Hemiptera												
	93	Notonectidae												
	94	Corixidae												
		Gerridae												
	95	**Gerris**												
3		Trichoptera												
		pupae												
		Philopotamidae												
	17	**Wormaldia**												
		Psychomyiidae												
	96	**Psychomyia**												
		Polycentropodidae												
	20	**Neureclipsis**												
	97	**Polycentropus**												
		Hydropsychidae												
	98	**Cheumatopsyche**												
	4	**Hydropsyche**												
		Rhyacophilidae												
	51	**Rhyacophila**												
		Glossosomatidae												
	5	**Glossosoma**												
		Hydroptilidae												
	41	Hydroptila												
	99	**Ochrotrichia**												
		Phryganeidae												
	101	**Agrypnia**												
	102	**Ptilostomis**												
		Brachycentridae												
	27	**Brachycentrus**												
		Lepidostomatidae												
	103	**Lepidostoma**												
		Limnephilidae												
	104	**Clostoeca**												
	105	**Grammotaulius**												
	106	**Hesperophylax**												
	107	**Nemotaulius**												
		Helicopsychidae												
	108	**Helicopsyche**												
		Leptoceridae												
	9	**Ceraclea**												
	109	**Oecetis**												
4		Coleoptera												
	110	Gyrinidae												
		Haliplidae												
	111	**Haliplus**												
	47	Dytiscidae												
	6	Elmidae												
6		Diptera												
		pupae												
	35	Tipulidae												
		Chaoboridae												
	112	**Chaoborus**	1		1	0.7								
	7	Simuliidae			1	0.3								
		pupae												
	37	Ceratopogonidae												
	8	Chironomidae	9	33	9	17.0		4	25	9.7	16	28	60	34.7
	38	Tabanidae												
	46	Empididae												
		COLUMN TOTALS	**58**	**84**	**58**	**66.6**	**31**	**50**	**121**	**67.3**	**130**	**160**	**416**	**235.3**
		TAXA			**7**				**4**				**8**	

Notes: MTC = major taxonomic category; MTG = major taxonomic group; Ekman grab sampler; area = 0.023 m^2, sieve mesh size = 0.250 mm.

Table D19. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples from station BCR B4 on Beaver Creek Reservoir, 1984.

SYNCRUDE Code		Taxa	Spring N/A				Summer (24 July)				Fall (23 September)			
MTC	MTG		1	2	3	x̄	1	2	3	x̄	1	2	3	x̄
		COELENTERATA	NO SAMPLES WERE											
		Hydrozoa	COLLECTED IN SPRING											
	12	**Hydra**										16	4	6.7
	15	NEMATODA									16	64	12	30.7
8		MOLLUSCA												
		Pelecypoda												
	29	Sphaeriidae					8	13	11	10.7	12	8	8	9.3
	65	Unionidae												
		Gastropoda												
		Valvatidae												
	66	**Valvata**					2		1	1.0			8	2.7
		Valvata sincera sincera												
		Valvata tricarinata												
		Lymnaeidae												
	32	**Lymnaea**												
		Physidae												
	10	**Physa**												
		Planorbidae									4	4	8	5.3
	67	**Armiger**												
	11	**Gyraulus**					2			0.7				
	50	**Helisoma**												
	68	**Promenetus**												
		Ancylidae												
	18	**Ferrissia**												
9		ANNELIDA												
	23	Hirudinea							1	0.3				
		Glossiphoniidae												
	69	**Glossiphonia complanata**												
	70	**Helobdella stagnalis**												
		Hirudinidae												
	71	**Haemopis grandis**												
		Erpobdellidae												
	72	**Nephelopsis obscura**												
	22	Oligochaeta					18	34	22	24.7	264	124	256	214.7
		ARTHROPODA												
		Arachnida												
	13	Acari						1		0.3	28	4	12	14.7
	10	Crustacea												
		Malacostraca												
		Amphipoda												
	24	**Gammarus lacustris**												
	73	**Hyalella azteca**												
		Insecta												
	74	Collembola												
1		Emphemeroptera												
		Siphlonuridae												
	33	**Ameletus**												
	75	**Siphlonurus**												
		Metretopodidae												
	76	**Metretopus**												
		Baetidae												
	1	**Baetis**												
		Callibaetis												
	77	**Centroptilum**												
	44	**Pseudocloeon**												
		Heptageniidae												
	2	**Heptagenia**												
	78	**Rhithrogena**												
	79	**Stenonema**												
		Leptophlebiidae												
	80	**Leptophlebia**												
	30	**Paraleptophlebia**												
		Ephemerellidae												
	19	**Ephemerella**												
		Tricorythidae									8			2.7
	43	**Tricorythodes**												
		Caenidae												
	45	**Caenis**						1	1	0 7				
		Baetiscidae												
	81	**Baetisca**												
5		Odonata												
		Calopterygidae												
	82	**Calopteryx**												
		Lestidae												
	83	**Lestes**												
		Coenagrionidae												
	84	**Coenagrion**												
	85	**Ischnura**												

Continued ...

Table D19. Continued.

SYNCRUDE Code		Taxa	Spring N/A				Summer (24 July)				Fall (23 September)			
MTC	MTG		1	2	3	x̄	1	2	3	x̄	1	2	3	x̄
		Gomphidae												
	28	**Gomphus**												
	86	**Ophiogomphus**												
		Aeshnidae												
	42	**Aeshna**												
	87	**Anax**												
		Corduliidae												
	39	**Somatochlora**												
	88	Libellulidae												
2		Plecoptera												
		Pteronarcyidae												
	3	**Pteronarcys**												
		Taeniopterygidae												
	89	**Taeniopteryx**												
		Nemouridae												
	59	**Malenka**												
	34	**Nemoura**												
		Perlidae												
	90	**Acroneuria**												
	91	**Claassenia**												
		Perlodidae												
	58	**Arcynopteryx**												
	48	**Isoperla**												
	92	Chloroperlidae												
		Hemiptera												
	93	Notonectidae												
	94	Corixidae					1			0.3				
		Gerridae												
	95	**Gerris**												
3		Trichoptera												
		pupae												
		Philopotamidae												
	17	**Wormaldia**												
		Psychomyiidae												
	96	**Psychomyia**												
		Polycentropodidae												
	20	**Neureclipsis**												
	97	**Polycentropus**												
		Hydropsychidae												
	98	**Cheumatopsyche**												
	4	**Hydropsyche**												
		Rhyacophilidae												
	51	**Rhyacophila**												
		Glossosomatidae												
	5	**Glossosoma**												
		Hydroptilidae												
	41	Hydroptila												
	99	**Ochrotrichia**												
		Phryganeidae												
	101	**Agrypnia**												
	102	**Ptilostomis**												
		Brachycentridae												
	27	**Brachycentrus**												
		Lepidostomatidae												
	103	**Lepidostoma**												
		Limnephilidae												
	104	**Clostoeca**												
	105	**Grammotaulius**												
	106	**Hesperophylax**												
	107	**Nemotaulius**												
		Helicopsychidae												
	108	**Helicopsyche**												
		Leptoceridae												
	9	**Ceraclea**												
	109	**Oecetis**												
4		Coleoptera												
	110	Gyrinidae												
		Haliplidae									12		4	5.3
	111	**Haliplus**												
	47	Dytiscidae												
	6	Elmidae												
6		Diptera												
		pupae					2	1	1	1.3				
	35	Tipulidae												
		Chaoboridae												
	112	**Chaoborus**										4		1.3
	7	Simuliidae												
		pupae												
	37	Ceratopogonidae					2	1		1.0	8		4	4.0
	8	Chironomidae					46	63	35	48.0	540	32	232	268.0
	36	Tabanidae									4			1.3
	46	Empididae												
		COLUMN TOTALS					**80**	**115**	**72**	**89.0**	**896**	**256**	**548**	**566.7**
		TAXA							**11**				**13**	

Notes: MTC = major taxonomic category; MTG = major taxonomic group; Ekman grab sampler: area = 0.023 m^2. sieve mesh size = 0.250 mm.

Table D20. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples from station BCR-B5 on Beaver Creek Reservoir, 1984.

SYNCRUDE Code		Taxa	Spring N/A				Summer (24 July)				Fall (23 September)			
MTC	MTG		1	2	3	x̄	1	2	3	x̄	1	2	3	x̄
		COELENTERATA	NO SAMPLES WERE											
		Hydrozoa	COLLECTED IN SPRING											
	12	**Hydra**										12	4	5.3
	15	NEMATODA									2		12	4.7
8		MOLLUSCA												
		Pelecypoda												
	29	Sphaeriidae					1			0.3			2	0.7
	65	Unionidae												
		Gastropoda												
		Valvatidae												
	66	**Valvata**					2	7	11	6.7				
		Valvata sincera sincera												
		Valvata tricarinata												
		Lymnaeidae												
	32	**Lymnaea**												
		Physidae												
	10	**Physa**												
		Planorbidae											2	0.7
	67	**Armiger**												
	11	**Gyraulus**						1		0.3				
	50	**Helisoma**												
	68	**Promenetus**												
		Ancylidae												
	18	**Ferrissia**												
9		ANNELIDA												
	23	Hirudinea						1	2	1.0				
		Glossiphoniidae												
	69	**Glossiphonia complanata**												
	70	**Helobdella stagnalis**												
		Hirudinidae												
	71	**Haemopis grandis**												
		Erpobdellidae												
	72	**Nephelopsis obscura**												
	22	Oligochaeta					7	95	24	42.0	32	44	74	50.0
		ARTHROPODA												
		Arachnida												
	13	Acari												
	10	Crustacea												
		Malacostraca												
		Amphipoda												
	24	**Gammarus lacustris**												
	73	**Hyalella azteca**							3	1.0				
		Insecta												
	74	Collembola												
1		Emphemeroptera												
		Siphlonuridae												
	33	**Ameletus**												
	75	**Siphlonurus**												
		Metretopodidae												
	76	**Metretopus**												
		Baetidae												
	1	**Baetis**												
		Callibaetis												
	77	**Centroptilum**												
	44	**Pseudocloeon**												
		Heptageniidae												
	2	**Heptagenia**												
	78	**Rhithrogena**												
	79	**Stenonema**												
		Leptophlebiidae												
	80	**Leptophlebia**												
	30	**Paraleptophlebia**												
		Ephemerellidae												
	19	**Ephemerella**												
		Tricorythidae												
	43	**Tricorythodes**												
		Caenidae												
	45	**Caenis**									2			0.7
		Baetiscidae												
	81	**Baetisca**												
5		Odonata												
		Calopterygidae												
	82	**Calopteryx**												
		Lestidae												
	83	**Lestes**												
		Coenagrionidae												
	84	**Coenagrion**												
	85	**Ischnura**												

Continued ...

Table D20. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring N/A 1	2	3	x̄	Summer (24 July) 1	2	3	x̄	Fall (23 September) 1	2	3	x̄
		Gomphidae												
	28	**Gomphus**												
	86	**Ophiogomphus**												
		Aeshnidae												
	42	**Aeshna**												
	87	**Anax**												
		Corduliidae												
	39	**Somatochlora**												
	88	Libellulidae												
2		Plecoptera												
		Pteronarcyidae												
	3	**Pteronarcys**												
		Taeniopterygidae												
	89	**Taeniopteryx**												
		Nemouridae												
	59	**Malenka**												
	34	**Nemoura**												
		Perlidae												
	90	**Acroneuria**												
	91	**Claassenia**												
		Perlodidae												
	58	**Arcynopteryx**												
	48	**Isoperla**												
	92	Chloroperlidae												
		Hemiptera												
	93	Notonectidae												
	94	Corixidae												
		Gerridae												
	95	**Gerris**												
3		Trichoptera												
		pupae												
		Philopotamidae												
	17	**Wormaldia**												
		Psychomyiidae												
	96	**Psychomyia**												
		Polycentropodidae												
	20	**Neureclipsis**												
	97	**Polycentropus**												
		Hydropsychidae												
	98	**Cheumatopsyche**												
	4	**Hydropsyche**												
		Rhyacophilidae												
	51	**Rhyacophila**												
		Glossosomatidae												
	5	**Glossosoma**												
		Hydroptilidae												
	41	Hydroptila												
	99	**Ochrotrichia**												
		Phryganeidae												
	101	**Agrypnia**												
	102	**Ptilostomis**												
		Brachycentridae												
	27	**Brachycentrus**												
		Lepidostomatidae												
	103	**Lepidostoma**												
		Limnephilidae												
	104	**Clostoeca**												
	105	**Grammotaulius**												
	106	**Hesperophylax**												
	107	**Nemotaulius**												
		Helicopsychidae												
	108	**Helicopsyche**												
		Leptoceridae												
	9	**Ceraclea**												
	109	**Oecetis**												
4		Coleoptera												
	110	Gyrinidae												
		Haliplidae												
	111	**Haliplus**												
	47	Dytiscidae												
	6	Elmidae												
6		Diptera												
		pupae												
	35	Tipulidae												
		Chaoboridae												
	112	**Chaoborus**												
	7	Simuliidae												
		pupae												
	37	Ceratopogonidae							1	0.3				
	8	Chironomidae					11	28	29	22.7	24	24	54	34.0
	38	Tabanidae												
	46	Empididae												
		COLUMN TOTALS					**20**	**133**	**70**	**74.3**	**60**	**80**	**148**	**96.1**
		TAXA							**8**				**7**	

Notes: MTC = major taxonomic category; MTG = major taxonomic group; Ekman grab sampler: area = 0.023 m^2, sieve mesh size = 0 250 mm.

Table D21. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples and dipnet samples from station RL-B on Ruth Lake, 1984.

SYNCRUDE Code		Taxa	Spring (16 June)				Summer (25 July)					Fall (24 September)				
MTC	MTG		1	2	3	x̄	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA														
		Hydrozoa														
	12	**Hydra**														
	15	NEMATODA		1		0.3								1	0.3	
8		MOLLUSCA														
		Pelecypoda														
	29	Sphaeriidae					1			0.3		2			0.7	
	65	Unionidae														
		Gastropoda														
		Valvatidae														
	66	**Valvata**														
		Valvata sincera sincera														
		Valvata tricarinata														
		Lymnaeidae														
	32	**Lymnaea**														
		Physidae														
	10	**Physa**									P					P
		Planorbidae														
	67	**Armiger**										40	20	28	29.3	
	11	**Gyraulus**									P	14		2	5.3	
	50	**Helisoma**														
	68	**Promenetus**											2		0.7	
		Ancylidae														
	18	**Ferrissia**														
9		ANNELIDA														
	23	Hirudinea														
		Glossiphoniidae														
	69	**Glossiphonia complanata**														
	70	**Helobdella stagnalis**														
		Hirudinidae														
	71	**Haemopis grandis**														
		Erpobdellidae														
	72	**Nephelopsis obscura**														
	22	Oligochaeta					4	4	7	5.0		4		3	2.3	
		ARTHROPODA														
		Arachnida														
	13	Acari														
	10	Crustacea										14	14	24	17.3	
		Malacostraca														
		Amphipoda														
	24	**Gammarus lacustris**									P			1	0.3	
	73	**Hyalella azteca**							1	0.3	A	2	14	14	10.0	P
		Insecta														
	74	Collembola														
1		Emphemeroptera														
		Siphlonuridae														
	33	**Ameletus**														
	75	**Siphlonurus**														
		Metretopodidae														
	76	**Metretopus**														
		Baetidae														
	1	**Baetis**														
		Callibaetis														
	77	**Centroptilum**														
	44	**Pseudocloeon**														
		Heptageniidae														
	2	**Heptagenia**														
	78	**Rhithrogena**														
	79	**Stenonema**														
		Leptophlebiidae														
	80	**Leptophlebia**														
	30	**Paraleptophlebia**														
		Ephemerellidae														
	19	**Ephemerella**														
		Tricorythidae														
	43	**Tricorythodes**										12			4.0	
		Caenidae														
	45	**Caenis**			1	0.3							26	16	14.0	
		Baetiscidae														
	81	**Baetisca**														
5		Odonata														
		Calopterygidae														
	82	**Calopteryx**														
		Lestidae														
	83	**Lestes**									P					
		Coenagrionidae														
	84	**Coenagrion**											4	2	2.0	P
	85	**Ischnura**										2			0.7	

Continued ...

Table D21. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (16 June) 1	2	3	x̄	Summer (25 July) 1	2	3	x̄	Dip	Fall (24 September) 1	2	3	x̄	Dip
		Gomphidae														
	28	**Gomphus**														
	86	**Ophiogomphus**														
		Aeshnidae														
	42	**Aeshna**														
	87	**Anax**									P					
		Corduliidae														
	39	**Somatochlora**														
	88	Libellulidae									P					
2		Plecoptera														
		Pteronarcyidae														
	3	**Pteronarcys**														
		Taeniopterygidae														
	89	**Taeniopteryx**														
		Nemouridae														
	59	**Malenka**														
	34	**Nemoura**														
		Perlidae														
	90	**Acroneuria**														
	91	**Claassenia**														
		Perlodidae														
	58	**Arcynopteryx**														
	48	**Isoperla**														
	92	Chloroperlidae														
		Hemiptera														
	93	Notonectidae									P					
	94	Corixidae									A					P
		Gerridae														
	95	**Gerris**														
3		Trichoptera														
		pupae														
		Philopotamidae														
	17	**Wormaldia**														
		Psychomyiidae														
	96	**Psychomyia**														
		Polycentropodidae														
	20	**Neureclipsis**														
	97	**Polycentropus**														
		Hydropsychidae														
	98	**Cheumatopsyche**														
	4	**Hydropsyche**														
		Rhyacophilidae														
	51	**Rhyacophila**														
		Glossosomatidae														
	5	**Glossosoma**														
		Hydroptilidae														
	41	Hydroptila														
	99	**Ochrotrichia**														
		Phryganeidae														
		Phryganea												1	0.3	
	101	**Agrypnia**														
	102	**Ptilostomis**														
		Brachycentridae														
	27	**Brachycentrus**														
		Lepidostomatidae														
	103	**Lepidostoma**														
		Limnephilidae														
	104	**Clostoeca**														
	105	**Grammotaulius**														
	106	**Hesperophylax**														
	107	**Nemotaulius**														
		Helicopsychidae														
	108	**Helicopsyche**														
		Leptoceridae														
	9	**Ceraclea**														
	109	**Oecetis**														
4		Coleoptera														
	110	Gyrinidae														
		Haliplidae										2			0.7	
	111	**Haliplus**									P					
	47	Dytiscidae														
	6	Elmidae														
6		Diptera														
		pupae										2			0.7	
	35	Tipulidae														
		Chaoboridae														
	112	**Chaoborus**										4		6	3.3	
	7	Simuliidae														
		pupae														
	37	Ceratopogonidae														
	8	Chironomidae	4	12	5	7.0	4	5	28	12.3	P	82	164	118	121.3	A
	38	Tabanidae														
	46	Empididae														
		COLUMN TOTALS	**4**	**14**	**5**	**7.6**	**9**	**9**	**36**	**17.9**		**180**	**244**	**216**	**213.2**	
		TAXA			**3**				**13**		**11**			**20**		**5**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present; Ekman grab sampler: area = 0.023 m^2 sieve mesh size = 0.250 mm; Dipnet: mesh size = 0.700 mm.

Table D22. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples and dipnet samples from station PCR-B1 on Poplar Creek Reservoir, 1984.

SYNCRUDE Code		Taxa	Spring (16 June)				Summer (26 July)					Fall (25 September)				
MTC	MTG		1	2	3	x̄	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA														
		Hydrozoa														
	12	**Hydra**						4		1.3		3	1		1.3	
	15	NEMATODA	1	2		1.0	1			0.3		5			1.6	
8		MOLLUSCA														
		Pelecypoda														
	29	Sphaeriidae					1		1	0.7		4	4	4	4.0	
	65	Unionidae														
		Gastropoda										1			0.3	
		Valvatidae														
	66	**Valvata**			2	0.7		1	2	1.0			3		1.0	
		Valvata sincera sincera														
		Valvata tricarinata														
		Lymnaeidae														
	32	**Lymnaea**									P					P
		Physidae														P
	10	**Physa**														
		Planorbidae										20	19	53	30.7	
	67	**Armiger**										1			0.3	
	11	**Gyraulus**					1	7		2.7	P					
	50	**Helisoma**														
	68	**Promenetus**														
		Ancylidae														
	18	**Ferrissia**														
9		ANNELIDA														
	23	Hirudinea							1	0.3			12		4.0	
		Glossiphoniidae														
	69	**Glossiphonia complanata**														
	70	**Helobdella stagnalis**														
		Hirudinidae														
	71	**Haemopis grandis**														
		Erpobdellidae														
	72	**Nephelopsis obscura**														
	22	Oligochaeta	15	24	23	20.7	44	54	162	86.7		1335	430	1543	1102.7	
		ARTHROPODA														
		Arachnida														
	13	Acari										4	9	2	5.0	
	10	Crustacea														
		Malacostraca														
		Amphipoda														
	24	**Gammarus lacustris**					4		3	2.3		9			3.0	P
	73	**Hyalella azteca**					12	1		4.3	P					
		Insecta														
	74	Collembola														
1		Emphemeroptera														
		Siphlonuridae														
	33	**Ameletus**														
	75	**Siphlonurus**														
		Metretopodidae														
	76	**Metretopus**														
		Baetidae														
	1	**Baetis**														
		Callibaetis														
	77	**Centroptilum**	1			0.3	1			0.3		2			0.7	
	44	**Pseudocloeon**														
		Heptageniidae														
	2	**Heptagenia**														
	78	**Rhithrogena**														
	79	**Stenonema**														
		Leptophlebiidae														
	80	**Leptophlebia**														
	30	**Paraleptophlebia**														
		Ephemerellidae														
	19	**Ephemerella**														
		Tricorythidae														
	43	**Tricorythodes**										37	30	7	24.7	
		Caenidae														
	45	**Caenis**					1			0.3						
		Baetiscidae														
	81	**Baetisca**														
5		Odonata											1		0.3	
		Calopterygidae														
	82	**Calopteryx**														
		Lestidae														
	83	**Lestes**														
		Coenagrionidae														A
	84	**Coenagrion**														
	85	**Ischnura**										10	6	3	6.3	

Continued ...

Table D22. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (16 June) 1	2	3	x̄	Summer (26 July) 1	2	3	x̄	Dip	Fall (25 September) 1	2	3	x̄	Dip
		Gomphidae														
	28	**Gomphus**														
	86	**Ophiogomphus**														
		Aeshnidae														
	42	**Aeshna**									P					
	87	**Anax**														
		Corduliidae														
	39	**Somatochlora**														
	88	Libellulidae														
2		Plecoptera														
		Pteronarcyidae														
	3	**Pteronarcys**														
		Taeniopterygidae														
	89	**Taeniopteryx**														
		Nemouridae														
	59	**Malenka**														
	34	**Nemoura**														
		Perlidae														
	90	**Acroneuria**														
	91	**Claassenia**														
		Perlodidae														
	58	**Arcynopteryx**														
	48	**Isoperla**														
	92	Chloroperlidae														
		Hemiptera														
	93	Notonectidae									P					P
	94	Corixidae									A	2			0.7	P
		Gerridae														
	95	**Gerris**														
3		Trichoptera										2			0.7	
		pupae														
		Philopotamidae														
	17	**Wormaldia**														
		Psychomyiidae														
	96	**Psychomyia**														
		Polycentropodidae														
	20	**Neureclipsis**														
	97	**Polycentropus**														
		Hydropsychidae														
	98	**Cheumatopsyche**														
	4	**Hydropsyche**														
		Rhyacophilidae														
	51	**Rhyacophila**														
		Glossosomatidae														
	5	**Glossosoma**														
		Hydroptilidae														
	41	Hydroptila														
	99	**Ochrotrichia**														
		Phryganeidae														
	101	**Agrypnia**														
	102	**Ptilostomis**														
		Brachycentridae														
	27	**Brachycentrus**														
		Lepidostomatidae														
	103	**Lepidostoma**														
		Limnephilidae														
	104	**Clostoeca**														
	105	**Grammotaulius**														
	106	**Hesperophylax**														
	107	**Nemotaulius**														
		Helicopsychidae														
	108	**Helicopsyche**														
		Leptoceridae														
	9	**Ceraclea**														
	109	**Oecetis**														
4		Coleoptera														
	110	Gyrinidae														
		Haliplidae												1	0.3	
	111	**Haliplus**														
	47	Dytiscidae									P					P
	6	Elmidae														
6		Diptera					7			2.3						
		pupae														
	35	Tipulidae														
		Chaoboridae														
	112	**Chaoborus**														P
	7	Simuliidae														
		pupae														
	37	Ceratopogonidae			1	0.3							2		0.7	
	8	Chironomidae	15	33	25	24.3	198	52	40	96.7		1598	974	2180	1584.0	P
	38	Tabanidae			1	0.3										
	46	Empididae														
		COLUMN TOTALS	**32**	**59**	**52**	**47.7**	**270**	**119**	**209**	**199.3**		**3033**	**1491**	**3793**	**2722.3**	
		TAXA			**7**				**18**		**7**			**26**		**9**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals). P = present; Ekman grab sampler: area = 0.023 m^2, sieve mesh size = 0.250 mm; Dipnet: mesh size = 0.700 mm.

Table D23. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples from station PCR-B2 on Poplar Creek Reservoir, 1984.

SYNCRUDE Code		Taxa	Spring (16 June)				Summer (26 July)				Fall (25 September)			
MTC	MTG		1	2	3	x̄	1	2	3	x̄	1	2	3	x̄
		COELENTERATA												
		Hydrozoa												
	12	**Hydra**												
	15	NEMATODA												
8		MOLLUSCA												
		Pelecypoda												
	29	Sphaeriidae												
	65	Unionidae												
		Gastropoda												
		Valvatidae												
	66	**Valvata**												
		Valvata sincera sincera												
		Valvata tricarinata												
		Lymnaeidae												
	32	**Lymnaea**												
		Physidae												
	10	**Physa**												
		Planorbidae												
	67	**Armiger**		1		0.3								
	11	**Gyraulus**												
	50	**Helisoma**												
	68	**Promenetus**												
		Ancylidae												
	18	**Ferrissia**												
9		ANNELIDA												
	23	Hirudinea												
		Glossiphoniidae												
	69	**Glossiphonia complanata**												
	70	**Helobdella stagnalis**												
		Hirudinidae												
	71	**Haemopis grandis**												
		Erpobdellidae												
	72	**Nephelopsis obscura**												
	22	Oligochaeta	5	9	3	5.7	32	15	59	35.3	13	30	9	17.3
		ARTHROPODA												
		Arachnida												
	13	Acari												
	10	Crustacea												
		Malacostraca												
		Amphipoda												
	24	**Gammarus lacustris**	2			0.7								
	73	**Hyalella azteca**												
		Insecta												
	74	Collembola		1		0.3								
1		Emphemeroptera												
		Siphlonuridae												
	33	**Ameletus**												
	75	**Siphlonurus**												
		Metretopodidae												
	76	**Metretopus**												
		Baetidae												
	1	**Baetis**												
		Callibaetis												
	77	**Centroptilum**												
	44	**Pseudocloeon**												
		Heptageniidae												
	2	**Heptagenia**												
	78	**Rhithrogena**												
	79	**Stenonema**												
		Leptophlebiidae												
	80	**Leptophlebia**												
	30	**Paraleptophlebia**												
		Ephemerellidae												
	19	**Ephemerella**												
		Tricorythidae												
	43	**Tricorythodes**												
		Caenidae												
	45	**Caenis**												
		Baetiscidae												
	81	**Baetisca**												
5		Odonata												
		Calopterygidae												
	82	**Calopteryx**												
		Lestidae												
	83	**Lestes**												
		Coenagrionidae												
	84	**Coenagrion**												
	85	**Ischnura**												

Continued ...

Table D23. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (16 June) 1	2	3	x̄	Summer (26 July) 1	2	3	x̄	Fall (25 September) 1	2	3	x̄
		Gomphidae												
	28	**Gomphus**												
	86	**Ophiogomphus**												
		Aeshnidae												
	42	**Aeshna**												
	87	**Anax**												
		Corduliidae												
	39	**Somatochlora**												
	88	Libellulidae												
2		Plecoptera												
		Pteronarcyidae												
	3	**Pteronarcys**												
		Taeniopterygidae												
	89	**Taeniopteryx**												
		Nemouridae												
	59	**Malenka**												
	34	**Nemoura**												
		Perlidae												
	90	**Acroneuria**												
	91	**Claassenia**												
		Perlodidae												
	58	**Arcynopteryx**												
	48	**Isoperla**												
	92	Chloroperlidae												
		Hemiptera												
	93	Notonectidae												
	94	Corixidae												
		Gerridae												
	95	**Gerris**												
3		Trichoptera												
		pupae												
		Philopotamidae												
	17	**Wormaldia**												
		Psychomyiidae												
	96	**Psychomyia**												
		Polycentropodidae												
	20	**Neureclipsis**												
	97	**Polycentropus**												
		Hydropsychidae												
	98	**Cheumatopsyche**												
	4	**Hydropsyche**												
		Rhyacophilidae												
	51	**Rhyacophila**												
		Glossosomatidae												
	5	**Glossosoma**												
		Hydroptilidae												
	41	Hydroptila												
	99	**Ochrotrichia**												
		Phryganeidae												
	101	**Agrypnia**												
	102	**Ptilostomis**												
		Brachycentridae												
	27	**Brachycentrus**												
		Lepidostomatidae												
	103	**Lepidostoma**												
		Limnephilidae												
	104	**Clostoeca**												
	105	**Grammotaulius**												
	106	**Hesperophylax**												
	107	**Nemotaulius**												
		Helicopsychidae												
	108	**Helicopsyche**												
		Leptoceridae												
	9	**Ceraclea**												
	109	**Oecetis**												
4		Coleoptera												
	110	Gyrinidae												
		Haliplidae												
	111	**Haliplus**												
	47	Dytiscidae												
	6	Elmidae												
6		Diptera												
		pupae		1		0.3	1		2	1.0				
	35	Tipulidae												
		Chaoboridae												
	112	**Chaoborus**	1		11	4.0	1		1	0.7				
	7	Simuliidae												
		pupae												
	37	Ceratopogonidae												
	8	Chironomidae	21	19	7	15.7	3	9	4	5.3	14	30	20	21.3
	38	Tabanidae												
	46	Empididae												
		COLUMN TOTALS	**29**	**31**	**21**	**27.0**	**37**	**24**	**66**	**42.3**	**27**	**60**	**29**	**38.6**
		TAXA		**7**				**4**				**2**		

Notes: MTC = major taxonomic category; MTG = major taxonomic group; Ekman grab sampler: area = 0.023 m^2, sieve mesh size = 0.250 mm.

Table D24. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples from station PCR-B3 on Poplar Creek Reservoir, 1984.

SYNCRUDE Code		Taxa	Spring (16 June)				Summer (26 July)				Fall (25 September)			
			1	2	3	$\bar{x}$	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$
MTC	MTG													
		COELENTERATA												
		Hydrozoa												
	12	**Hydra**												
	15	NEMATODA		1		0.3								
8		MOLLUSCA												
		Pelecypoda												
	29	Sphaeriidae												
	65	Unionidae												
		Gastropoda												
		Valvatidae												
	66	**Valvata**												
		Valvata sincera sincera												
		Valvata tricarinata												
		Lymnaeidae												
	32	**Lymnaea**												
		Physidae												
	10	**Physa**												
		Planorbidae												
	67	**Armiger**												
	11	**Gyraulus**						2		0.7				
	50	**Helisoma**												
	68	**Promenetus**												
		Ancylidae												
	18	**Ferrissia**												
9		ANNELIDA												
	23	Hirudinea												
		Glossiphoniidae												
	69	**Glossiphonia complanata**		1		0.3								
	70	**Helobdella stagnalis**												
		Hirudinidae												
	71	**Haemopis grandis**												
		Erpobdellidae												
	72	**Nephelopsis obscura**												
	22	Oligochaeta	2		1	1.0	2			0.7				
		ARTHROPODA												
		Arachnida												
	13	Acari												
	10	Crustacea												
		Malacostraca												
		Amphipoda												
	24	**Gammarus lacustris**												
	73	**Hyalella azteca**												
		Insecta												
	74	Collembola												
1		Emphemeroptera												
		Siphlonuridae												
	33	**Ameletus**												
	75	**Siphlonurus**												
		Metretopodidae												
	76	**Metretopus**												
		Baetidae												
	1	**Baetis**												
		Callibaetis												
	77	**Centroptilum**												
	44	**Pseudocloeon**												
		Heptageniidae												
	2	**Heptagenia**												
	78	**Rhithrogena**												
	79	**Stenonema**												
		Leptophlebiidae												
	80	**Leptophlebia**												
	30	**Paraleptophlebia**												
		Ephemerellidae												
	19	**Ephemerella**												
		Tricorythidae												
	43	**Tricorythodes**												
		Caenidae												
	45	**Caenis**												
		Baetiscidae												
	81	**Baetisca**												
5		Odonata												
		Calopterygidae												
	82	**Calopteryx**												
		Lestidae												
	83	**Lestes**												
		Coenagrionidae												
	84	**Coenagrion**												
	85	**Ischnura**												

Continued ...

Table D24. Continued.

SYNCRUDE Code		Taxa	Spring (16 June)				Summer (26 July)				Fall (25 September)			
			1	2	3	$\bar{x}$	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$
MTC	MTG													
		Gomphidae												
	28	**Gomphus**												
	86	**Ophiogomphus**												
		Aeshnidae												
	42	**Aeshna**												
	87	**Anax**												
		Corduliidae												
	39	**Somatochlora**												
	88	Libellulidae												
2		Plecoptera												
		Pteronarcyidae												
	3	**Pteronarcys**												
		Taeniopterygidae												
	89	**Taenioptery x**												
		Nemouridae												
	59	**Malenka**												
	34	**Nemoura**												
		Perlidae												
	90	**Acroneuria**												
	91	**Claassenia**												
		Perlodidae												
	58	**Arcynopteryx**												
	48	**Isoperla**												
	92	Chloroperlidae												
		Hemiptera												
	93	Notonectidae												
	94	Corixidae												
		Gerridae												
	95	**Gerris**												
3		Trichoptera												
		pupae												
		Philopotamidae												
	17	**Wormaldia**												
		Psychomyiidae												
	96	**Psychomyia**												
		Polycentropodidae												
	20	**Neureclipsis**												
	97	**Polycentropus**												
		Hydropsychidae												
	98	**Cheumatopsyche**												
	4	**Hydropsyche**												
		Rhyacophilidae												
	51	**Rhyacophila**												
		Glossosomatidae												
	5	**Glossosoma**												
		Hydroptilidae												
	41	Hydroptila												
	99	**Ochrotrichia**												
		Phryganeidae												
	101	**Agrypnia**												
	102	**Ptilostomis**												
		Brachycentridae												
	27	**Brachycentrus**												
		Lepidostomatidae												
	103	**Lepidostoma**												
		Limnephilidae												
	104	**Clostoeca**												
	105	**Grammotaulius**												
	106	**Hesperophylax**												
	107	**Nemotaulius**												
		Helicopsychidae												
	108	**Helicopsyche**												
		Leptoceridae												
	9	**Ceraclea**												
	109	**Oecetis**												
4		Coleoptera												
	110	Gyrinidae												
		Haliplidae												
	111	**Haliplus**												
	47	Dytiscidae												
	6	Elmidae												
6		Diptera												
		pupae					5	5	2	4 0				
	35	Tipulidae												
		Chaoboridae												
	112	**Chaoborus**	3	2	5	3.3	9	10	2	7.0	4	1	5	3.3
	7	Simuliidae												
		pupae												
	37	Ceratopogonidae												
	8	Chironomidae	7	1	3	3.7	2	6	4	4.0	32	5	21	19.3
	38	Tabanidae												
	46	Empididae												
		COLUMN TOTALS	**12**	**5**	**9**	**8.6**	**18**	**23**	**8**	**16.4**	**36**	**6**	**26**	**22.6**
		TAXA		**5**				**5**				**2**		

Notes: MTC = major taxonomic category; MTG = major taxonomic group; Ekman grab sampler: area = 0 023 m^2, sieve mesh size = 0.250 mm

Table D25 Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples from station PCR B4 on Poplar Creek Reservoir, 1984.

SYNCRUDE Code		Taxa	Spring (16 June)				Summer (26 July)				Fall (25 September)			
MTC	MTG		1	2	3	x̄	1	2	3	x̄	1	2	3	x̄
		COELENTERATA												
		Hydrozoa												
	12	**Hydra**												
	15	NEMATODA												
8		MOLLUSCA												
		Pelecypoda												
	29	Sphaeriidae												
	65	Unionidae												
		Gastropoda												
		Valvatidae												
	66	**Valvata**												
		Valvata sincera sincera												
		Valvata tricarinata												
		Lymnaeidae												
	32	**Lymnaea**												
		Physidae												
	10	**Physa**												
		Planorbidae												
	67	**Armiger**												
	11	**Gyraulus**												
	50	**Helisoma**												
	68	**Promenetus**												
		Ancylidae												
	18	**Ferrissia**												
9		ANNELIDA												
	23	Hirudinea												
		Glossiphoniidae												
	69	**Glossiphonia complanata**												
	70	**Helobdella stagnalis**												
		Hirudinidae												
	71	**Haemopis grandis**												
		Erpobdellidae												
	72	**Nephelopsis obscura**												
	22	Oligochaeta			1	0.3					1	1		0.7
		ARTHROPODA												
		Arachnida												
	13	Acari									1			0.3
	10	Crustacea												
		Malacostraca												
		Amphipoda												
	24	**Gammarus lacustris**												
	73	**Hyalella azteca**												
		Insecta												
	74	Collembola												
1		Emphemeroptera						1		0.3				
		Siphlonuridae												
	33	**Ameletus**												
	75	**Siphlonurus**												
		Metretopodidae												
	76	**Metretopus**												
		Baetidae												
	1	**Baetis**												
		Callibaetis												
	77	**Centroptilum**												
	44	**Pseudocloeon**												
		Heptageniidae												
	2	**Heptagenia**												
	78	**Rhithrogena**												
	79	**Stenonema**												
		Leptophlebiidae												
	80	**Leptophlebia**												
	30	**Paraleptophlebia**												
		Ephemerellidae												
	19	**Ephemerella**												
		Tricorythidae												
	43	**Tricorythodes**												
		Caenidae												
	45	**Caenis**												
		Baetiscidae												
	81	**Baetisca**												
5		Odonata												
		Calopterygidae												
	82	**Calopteryx**												
		Lestidae												
	83	**Lestes**												
		Coenagrionidae												
	84	**Coenagrion**												
	85	**Ischnura**												

Continued ...

Table D25. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (16 June) 1	2	3	x̄	Summer (26 July) 1	2	3	x̄	Fall (25 September) 1	2	3	x̄
		Gomphidae												
	28	**Gomphus**												
	86	**Ophiogomphus**												
		Aeshnidae												
	42	**Aeshna**												
	87	**Anax**												
		Corduliidae												
	39	**Somatochlora**												
	88	Libellulidae												
2		Plecoptera												
		Pteronarcyidae												
	3	**Pteronarcys**												
		Taeniopterygidae												
	89	**Taeniopteryx**												
		Nemouridae												
	59	**Malenka**												
	34	**Nemoura**												
		Perlidae												
	90	**Acroneuria**												
	91	**Claassenia**												
		Perlodidae												
	58	**Arcynopteryx**												
	48	**Isoperla**												
	92	Chloroperlidae												
		Hemiptera												
	93	Notonectidae												
	94	Corixidae												
		Gerridae												
	95	**Gerris**												
3		Trichoptera												
		pupae												
		Philopotamidae												
	17	**Wormaldia**												
		Psychomyiidae												
	96	**Psychomyia**												
		Polycentropodidae												
	20	**Neureclipsis**												
	97	**Polycentropus**												
		Hydropsychidae												
	98	**Cheumatopsyche**												
	4	**Hydropsyche**												
		Rhyacophilidae												
	51	**Rhyacophila**												
		Glossosomatidae												
	5	**Glossosoma**												
		Hydroptilidae												
	41	Hydroptila												
	99	**Ochrotrichia**												
		Phryganeidae												
	101	**Agrypnia**												
	102	**Ptilostomis**												
		Brachycentridae												
	27	**Brachycentrus**												
		Lepidostomatidae												
	103	**Lepidostoma**												
		Limnephilidae												
	104	**Clostoeca**												
	105	**Grammotaulius**												
	106	**Hesperophylax**												
	107	**Nemotaulius**												
		Helicopsychidae												
	108	**Helicopsyche**												
		Leptoceridae												
	9	**Ceraclea**												
	109	**Oecetis**												
4		Coleoptera												
	110	Gyrinidae												
		Haliplidae												
	111	**Haliplus**												
	47	Dytiscidae												
	6	Elmidae												
6		Diptera												
		pupae		1		0.3			1	0.3				
	35	Tipulidae												
		Chaoboridae												
	112	**Chaoborus**	8	1		3.0		1	5	2.0	129	131	8	89.3
	7	Simuliidae												
		pupae												
	37	Ceratopogonidae												
	8	Chironomidae	13	5	5	7.7	2	20	3	8.3	14	15	4	11.0
	38	Tabanidae												
	46	Empididae												
		COLUMN TOTALS	**21**	**7**	**6**	**11.3**	**2**	**22**	**9**	**10.9**	**145**	**147**	**12**	**101.3**
		TAXA		**4**					**4**				**4**	

Notes: MTC = major taxonomic category; MTG = major taxonomic group; Ekman grab sampler: area = 0.023 m^2, sieve mesh size = 0.250 mm.

Table D26. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples from station PCR B5 on Poplar Creek Reservoir, 1984.

SYNCRUDE Code		Taxa	Spring (16 June)				Summer (26 July)				Fall (25 September)			
MTC	MTG		1	2	3	x̄	1	2	3	x̄	1	2	3	x̄
		COELENTERATA												
		Hydrozoa												
	12	**Hydra**												
	15	NEMATODA			1	0.3			1	0.3				
8		MOLLUSCA												
		Pelecypoda												
	29	Sphaeriidae												
	65	Unionidae												
		Gastropoda												
		Valvatidae												
	66	**Valvata**												
		Valvata sincera sincera												
		Valvata tricarinata												
		Lymnaeidae												
	32	**Lymnaea**												
		Physidae												
	10	**Physa**												
		Planorbidae												
	67	**Armiger**												
	11	**Gyraulus**												
	50	**Helisoma**												
	68	**Promenetus**												
		Ancylidae												
	18	**Ferrissia**												
9		ANNELIDA												
	23	Hirudinea	1			0.3								
		Glossiphoniidae												
	69	**Glossiphonia complanata**												
	70	**Helobdella stagnalis**												
		Hirudinidae												
	71	**Haemopis grandis**												
		Erpobdellidae												
	72	**Nephelopsis obscura**												
	22	Oligochaeta	2			0.7		1		0.3			1	0.3
		ARTHROPODA												
		Arachnida	1			0.3	1			0.3				
	13	Acari												
	10	Crustacea												
		Malacostraca												
		Amphipoda												
	24	**Gammarus lacustris**												
	73	**Hyalella azteca**												
		Insecta												
	74	Collembola												
1		Emphemeroptera												
		Siphlonuridae												
	33	**Ameletus**												
	75	**Siphlonurus**												
		Metretopodidae												
	76	**Metretopus**												
		Baetidae												
	1	**Baetis**												
		Callibaetis												
	77	**Centroptilum**												
	44	**Pseudocloeon**												
		Heptageniidae												
	2	**Heptagenia**												
	78	**Rhithrogena**												
	79	**Stenonema**												
		Leptophlebiidae												
	80	**Leptophlebia**												
	30	**Paraleptophlebia**												
		Ephemerellidae												
	19	**Ephemerella**												
		Tricorythidae												
	43	**Tricorythodes**												
		Caenidae												
	45	**Caenis**												
		Baetiscidae												
	81	**Baetisca**												
5		Odonata												
		Calopterygidae												
	82	**Calopteryx**												
		Lestidae												
	83	**Lestes**												
		Coenagrionidae												
	84	**Coenagrion**												
	85	**Ischnura**												

Continued ...

Table D26. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (16 June) 1	2	3	$\bar{x}$	Summer (26 July) 1	2	3	$\bar{x}$	Fall (25 September) 1	2	3	$\bar{x}$
		Gomphidae												
	28	**Gomphus**												
	56	**Ophiogomphus**												
		Aeshnidae												
	42	**Aeshna**												
	87	**Anax**												
		Corduliidae												
	39	**Somatochlora**												
	88	Libellulidae												
2		Plecoptera												
		Pteronarcyidae												
	3	**Pteronarcys**												
		Taeniopterygidae												
	89	**Taeniopteryx**												
		Nemouridae												
	59	**Malenka**												
	34	**Nemoura**												
		Perlidae												
	90	**Acroneuria**												
	91	**Claassenia**												
		Perlodidae												
	58	**Arcynopteryx**												
	48	**Isoperla**												
	92	Chloroperlidae												
		Hemiptera												
	93	Notonectidae												
	94	Corixidae												
		Gerridae												
	95	**Gerris**												
3		Trichoptera												
		pupae												
		Philopotamidae												
	17	**Wormaldia**												
		Psychomyiidae												
	96	**Psychomyia**												
		Polycentropodidae												
	20	**Neureclipsis**												
	97	**Polycentropus**												
		Hydropsychidae												
	98	**Cheumatopsyche**												
	4	**Hydropsyche**												
		Rhyacophilidae												
	51	**Rhyacophila**												
		Glossosomatidae												
	5	**Glossosoma**												
		Hydroptilidae												
	41	Hydroptila												
	99	**Ochrotrichia**												
		Phryganeidae												
	101	**Agrypnia**												
	102	**Ptilostomis**												
		Brachycentridae												
	27	**Brachycentrus**												
		Lepidostomatidae												
	103	**Lepidostoma**												
		Limnephilidae												
	104	**Clostoeca**												
	105	**Grammotaulius**												
	106	**Hesperophylax**												
	107	**Nemotaulius**												
		Helicopsychidae												
	108	**Helicopsyche**												
		Leptoceridae												
	9	**Ceraclea**												
	109	**Oecetis**												
4		Coleoptera												
	110	Gyrinidae												
		Haliplidae												
	111	**Haliplus**												
	47	Dytiscidae												
	6	Elmidae												
6		Diptera												
		pupae			1	0.3	1	2	1	1.3				
	35	Tipulidae												
		Chaoboridae												
	112	**Chaoborus**	41	19	4	21.3	2	2	5	3.0	25	55	26	35.3
	7	Simuliidae												
		pupae												
	37	Ceratopogonidae												
	8	Chironomidae	6	4	6	5.3	6	5	6	5.7	2	4	3	3.0
	38	Tabanidae												
	46	Empididae												
		COLUMN TOTALS	**51**	**23**	**12**	**28.5**	**10**	**10**	**13**	**10.9**	**27**	**59**	**30**	**38.9**
		TAXA			**7**				**6**				**3**	

Notes: MTC = major taxonomic category; MTG = major taxonomic group; Ekman grab sampler: area = 0.023 m^2, sieve mesh size = 0.250 mm.

Table D27. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Ekman grab samples and dipnet samples from station PC-B1 on Poplar Creek, 1984.

SYNCRUDE Code		Taxa	Spring (18 June)					Summer (27 July)					Fall (25 September)				
			1	2	3	$\bar{x}$	Dip	1	2	3	$\bar{x}$	Dip	1	2	3	$\bar{x}$	Dip
MTC	MTG																
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**						77	81	68	75.3				2	0.7	
	15	NEMATODA	18	7	15	13.3		2	11	6	6.3		7	1	6	4.7	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae								17	5.7		1			0.3	
	63	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**					P										
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**					P					P					
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta	2		1	1.0		6	2	5	4.3		13	15	29	19.0	
		ARTHROPODA															
		Arachnida															
	13	Acari	4			1.3			1		0.3		6	4	1	3.7	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae											5	13	2	6.7	
	1	**Baetis**		2	2	1.3	A	37	27	5	23.0	P	3	5	4	4.0	P
		Callibaetis															
	77	**Centroptilum**															
	44	**Pseudocloeon**	2			0.7											
		Heptageniidae							1		0.3			1		0.3	
	2	**Heptagenia**					P	3	1		1.3		1	2	5	2.7	
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															P
	30	**Paraleptophlebia**											1			0.3	
		Ephemerellidae															
	19	**Ephemerella**								1	0.3						
		Tricorythidae															
	43	**Tricorythodes**							1		0.3	P			1	0.3	
		Caenidae															
	45	**Caenis**					P										P
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D27. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (18 June) 1	2	3	x̄	Dip	Summer (27 July) 1	2	3	x̄	Dip	Fall (25 September) 1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**											1			0.3	
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															P
		Corduliidae															
	39	**Somatochlora**															
	88	Libellulidae															
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**											1			0.3	
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															P
	94	Corixidae															
		Gerridae															
	95	**Gerris**															
3		Trichoptera						3			1.0		2	2	1	1.7	
		pupae															
		Philopotamidae															
	17	**Wormaldia**								4	1.3						
		Psychomyiidae															
	96	**Psychomyia**												2	8	3.3	
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae											5	2		2.3	
	98	**Cheumatopsyche**											1	3		1.3	
	4	**Hydropsyche**						2	3	1	2.0		3	3	3	3.0	A
		Rhyacophilidae															
	51	**Rhyacophila**															
		Glossosomatidae															
	5	**Glossosoma**						16	10	5	10.3		1	1		0.7	
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															P
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**					A										
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**					P						4	2	2	2.7	P
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae					P										P
	6	Elmidae	4	3	1	2.7		4	4	5	4.3		1	1	4	2.0	P
6		Diptera															
		pupae	5	3		2.7		3	7	4	4.7		2	2	2	2.0	
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**					P										
	7	Simuliidae	70	74	118	87.3	A	65	225	483	257.7	A	14	54	8	25.3	
		pupae	3	1	11	5.0	A	19	8	16	14.3	P					
	37	Ceratopogonidae												1		0.3	
	8	Chironomidae	41	18	43	34.0		28	17	96	47.0		70	69	41	60.0	A
	38	Tabanidae															
	46	Empididae													1	0.3	
		COLUMN TOTALS	**149**	**110**	**192**	**150.3**		**165**	**399**	**717**	**460.0**		**142**	**183**	**120**	**148.2**	
		TAXA		**19**			**11**		**21**			**5**			**32**		**11**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D28. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station PC B2 on Poplar Creek, 1984.

SYNCRUDE Code		Taxa	Spring (18 June)					Summer (27 July)					Fall (25 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**						128	55	557	246.7		52	25	30	35.7	
	15	NEMATODA	10	3	1	4.7							7	8		5.0	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae						1	2	1	1.3				3	1.0	
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															P
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**					P										
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**					P							2	1	1.0	
9		ANNELIDA												1	1	0.7	
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta	7			2.3	P	10	16	34	20.0		313	68	19	133.3	
		ARTHROPODA															
		Arachnida															
	13	Acari	1	1	1	1.0							11	7	2	6.7	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**											1	1		0.7	P
	73	**Hyalella azteca**															P
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**												2		0.7	
		Baetidae															
	1	**Baetis**	8	2	1	3.7	A	7	8	13	9.3	P	4			1.3	P
		Callibaetis															
	77	**Centroptilum**											1			0.3	
	44	**Pseudocloeon**						2		5	2.3			5		1.7	
		Heptageniidae															
	2	**Heptagenia**							2	1	1.0						
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
		Leptophlebia												1	2	1.0	
	30	**Paraleptophlebia**															
		Ephemerellidae															
	19	**Ephemerella**						1	2	2	1.7		2			0.7	
		Tricorythidae															
	43	**Tricorythodes**										P	3	11		4.7	
		Caenidae															
	45	**Caenis**								1	0.3				12	4.0	P
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															P
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D28. Continued.

SYNCRUDE Code		Taxa	Spring (18 June)					Summer (27 July)					Fall (25 September)				
MTC	MTG		1	2	3	$\bar{x}$	Dip	1	2	3	$\bar{x}$	Dip	1	2	3	$\bar{x}$	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**															
	88	Libellulidae															
2		Plecoptera															
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**															
	34	**Nemoura**											1	2		1.0	
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															
		Gerridae															
	95	**Gerris**					P										
3		Trichoptera								1	0.3			1		0.3	
		pupae							1		0.3						
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**								2	0.7		8	3		3.7	
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae											5			1.7	
	98	**Cheumatopsyche**								2	0.7		3	4	1	2.7	
	4	**Hydropsyche**							2	3	1.7		6	3		3.0	
		Rhyacophilidae															
	51	**Rhyacophila**	1			0.3	P										
		Glossosomatidae															
	5	**Glossosoma**							1	4	1.7						
		Hydroptilidae															
	41	**Hydroptila**											1			0.3	
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**								1	0.3		6	8	6	6.7	
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**					P										
	47	Dytiscidae															
	6	Elmidae	1		1	0.7			1		0.3		1	1	3	1.7	
6		Diptera															
		pupae	1			0.3		5	3	9	5.7	P	4		1	1.7	
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	201	95	132	142.7	A	27	5	77	36.3	A					
		pupae	3	5	1	3.0	A	2		9	3.7						
	37	Ceratopogonidae															
	8	Chironomidae	11	13	5	9.7	P	63	141	125	109.7	P	1283	421	892	865.3	A
	38	Tabanidae															
	46	Empididae											1	2		1.0	
		COLUMN TOTALS	**244**	**119**	**142**	**168.4**		**246**	**239**	**847**	**444.0**		**1713**	**576**	**973**	**1087.6**	
		TAXA		**14**			**10**		**21**			**5**		**31**			**7**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals). P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D29. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station PC B3 on Lower Poplar Creek, 1984.

SYNCRUDE Code		Taxa	Spring (18 June)					Summer (27 July)					Fall (25 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**															
	15	NEMATODA	6			2.0									2	0.7	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae															
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															
		Planorbidae													1	0.3	
	67	**Armiger**															
	11	**Gyraulus**															
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta	1	3	2	2.0		2	1	1	1.7		5	22	25	17.3	
		ARTHROPODA															
		Arachnida															
	13	Acari	1	2	5	2.7								4		1.3	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Emphemeroptera															
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae													2	0.7	
	1	**Baetis**		2		0.7	A		2	11	4.3	A			1	0.3	
		Callibaetis															
	77	**Centroptilum**													1	0.3	
	44	**Pseudocloeon**															
		Heptageniidae															
	2	**Heptagenia**															
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															
	30	**Paraleptophlebia**															
		Ephemerellidae															
	19	**Ephemerella**						1	3	11	5.0	A					
		Tricorythidae															
	43	**Tricorythodes**															
		Caenidae															
	45	**Caenis**					P										
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae															
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D29. Continued.

SYNCRUDE Code MTC	MTG	Taxa	Spring (18 June) 1	2	3	x̄	Dip	Summer (27 July) 1	2	3	x̄	Dip	Fall (25 September) 1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															
	87	**Anax**															
		Corduliidae															
	39	**Somatochlora**					P										
	88	Libellulidae															
2		Plecoptera						2			0.7						
		Pteronarcyidae															
	3	**Pteronarcys**															
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae								1	0.3						
	59	**Malenka**															
	34	**Nemoura**							1		0.3		2		10	3.3	P
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															
		Gerridae															
	95	**Gerris**										P					
3		Trichoptera	1			0.3											
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**												2		0.7	
	4	**Hydropsyche**															
		Rhyacophilidae															
	51	**Rhyacophila**		1		0.3											
		Glossosomatidae															
	5	**Glossosoma**													1	0.3	
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**															
	106	**Hesperophylax**															
	107	**Nemotaulius**															
		Helicopsychidae															
	108	**Helicopsyche**															
		Leptoceridae															
	9	**Ceraclea**															
	109	**Oecetis**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae		1		0.3											
	6	Elmidae		2		0.7			1		0.3						
6		Diptera															
		pupae		2		0.7									1	0.3	
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	5	3	9	5.7	P	1			0.3						
		pupae															
	37	Ceratopogonidae															
	8	Chironomidae	6		4	3.3		7	1	1	3.0	P	20	28	143	63.7	
	38	Tabanidae	1			0.3								1	2	0.7	
	46	Empididae															
		COLUMN TOTALS	**21**	**16**	**20**	**19.0**		**13**	**9**	**25**	**15.9**		**27**	**57**	**189**	**89.9**	
		TAXA		**14**			**4**		**10**			**4**		**13**			**1**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals), P = present; Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D30. Taxonomic composition and abundance of benthic macroinvertebrates in replicate Neill samples and dipnet samples from station PC-B4 on Poplar Creek, 1984.

SYNCRUDE Code		Taxa	Spring (18 June)					Summer (27 July)					Fall (25 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		COELENTERATA															
		Hydrozoa															
	12	**Hydra**															
	15	NEMATODA	1	1		0.7		1		1	0.7		2		1	1.0	
8		MOLLUSCA															
		Pelecypoda															
	29	Sphaeriidae	1			0.3											
	65	Unionidae															
		Gastropoda															
		Valvatidae															
	66	**Valvata**															
		Valvata sincera sincera															
		Valvata tricarinata															
		Lymnaeidae															
	32	**Lymnaea**															
		Physidae															
	10	**Physa**															
		Planorbidae															
	67	**Armiger**															
	11	**Gyraulus**	1			0.3											
	50	**Helisoma**															
	68	**Promenetus**															
		Ancylidae															
	18	**Ferrissia**															
9		ANNELIDA															
	23	Hirudinea															
		Glossiphoniidae															
	69	**Glossiphonia complanata**															
	70	**Helobdella stagnalis**															
		Hirudinidae															
	71	**Haemopis grandis**															
		Erpobdellidae															
	72	**Nephelopsis obscura**															
	22	Oligochaeta			5	1.7		5	1	4	3.3		36	3	33	24.0	
		ARTHROPODA															
		Arachnida															
	13	Acari			2	0.7	P	1	1		0.7		4	4		2.7	
	10	Crustacea															
		Malacostraca															
		Amphipoda															
	24	**Gammarus lacustris**															
	73	**Hyalella azteca**															
		Insecta															
	74	Collembola															
1		Emphemeroptera						11			3.7						
		Siphlonuridae															
	33	**Ameletus**															
	75	**Siphlonurus**															
		Metretopodidae															
	76	**Metretopus**															
		Baetidae						4			1.3			2		0.7	
	1	**Baetis**	2	1	1	1.3	A	24	6	8	12.7	P	1	1		0.7	P
		Callibaetis															
	77	**Centroptilum**										P					
	44	**Pseudocloeon**						1			0.3						
		Heptageniidae															
	2	**Heptagenia**						1	3		1.3		1	2	2	1.7	
	78	**Rhithrogena**															
	79	**Stenonema**															
		Leptophlebiidae															
	80	**Leptophlebia**															P
	30	**Paraleptophlebia**															
		Ephemerellidae															
	19	**Ephemerella**						12	1		4.3	P		4	9	4.3	
		Tricorythidae															
	43	**Tricorythodes**															
		Caenidae															
	45	**Caenis**										P					
		Baetiscidae															
	81	**Baetisca**															
5		Odonata															
		Calopterygidae															
	82	**Calopteryx**															
		Lestidae															
	83	**Lestes**															
		Coenagrionidae													1	0.3	
	84	**Coenagrion**															
	85	**Ischnura**															

Continued ...

Table D30. Continued.

SYNCRUDE Code		Taxa	Spring (18 June)					Summer (27 July)					Fall (25 September)				
MTC	MTG		1	2	3	x̄	Dip	1	2	3	x̄	Dip	1	2	3	x̄	Dip
		Gomphidae															
	28	**Gomphus**															
	86	**Ophiogomphus**															
		Aeshnidae															
	42	**Aeshna**															P
	87	**Anax**										P					
		Corduliidae															
	39	**Somatochlora**												1		0.3	
	88	Libellulidae															
2		Plecoptera							52	5	19.0						
		Pteronarcyidae															
	3	**Pteronarcys**															
		Perlodidae															
		Arcynopteryx													1	0.3	
		Isoperla							2		0.7						P
		Taeniopterygidae															
	89	**Taeniopteryx**															
		Nemouridae															
	59	**Malenka**										P					
	34	**Nemoura**						18			6.0		244	112	151	169.0	
		Perlidae															
	90	**Acroneuria**															
	91	**Claassenia**															
		Perlodidae															
	58	**Arcynopteryx**															
	48	**Isoperla**															
	92	Chloroperlidae															
		Hemiptera															
	93	Notonectidae															
	94	Corixidae															
		Gerridae															
	95	**Gerris**										P					
3		Trichoptera															
		pupae															
		Philopotamidae															
	17	**Wormaldia**															
		Psychomyiidae															
	96	**Psychomyia**															
		Polycentropodidae															
	20	**Neureclipsis**															
	97	**Polycentropus**															
		Hydropsychidae															
	98	**Cheumatopsyche**															
	4	**Hydropsyche**											9		5	4.7	
		Rhyacophilidae															
	51	**Rhyacophila**	1			0 3			1		0.3						
		Glossosomatidae															
	5	**Glossosoma**								2	0.7		4	10		4.7	
		Hydroptilidae															
	41	Hydroptila															
	99	**Ochrotrichia**															
		Phryganeidae															
	101	**Agrypnia**															
	102	**Ptilostomis**															
		Brachycentridae															
	27	**Brachycentrus**															
		Phryganeidae															
		Ptilostomis															P
		Lepidostomatidae															
	103	**Lepidostoma**															
		Limnephilidae															
	104	**Clostoeca**															
	105	**Grammotaulius**					P										
	106	**Hesperophylax**															
	107	**Nemotaulius**															
4		Coleoptera															
	110	Gyrinidae															
		Haliplidae															
	111	**Haliplus**															
	47	Dytiscidae															
	6	Elmidae	1			0.3		6	2	2	3.3		6	6	5	5.7	
6		Diptera													1	0.3	
		pupae	1			0.3				1	0.3			2	1	1.0	
	35	Tipulidae															
		Chaoboridae															
	112	**Chaoborus**															
	7	Simuliidae	2		1	1.0	P	1	1		0.7						
		pupae															
	37	Ceratopogonidae												4		1.3	
	8	Chironomidae	2	6		2.7		20	17	22	19.7		312	387	472	390.3	A
	38	Tabanidae	1	3	1	1.7									1	0.3	
	46	Empididae							2		0.7						
		COLUMN TOTALS	**13**	**11**	**10**	**11.3**		**94**	**100**	**45**	**79.7**		**619**	**538**	**683**	**613.3**	
		TAXA			**13**		**4**			**24**		**7**			**23**		**6**

Notes: MTC = major taxonomic category; MTG = major taxonomic group; A = abundant (five or more individuals). P = present: Neill sampler: area = 0.1 m^2, mesh size = 0.210 mm; Dipnet: mesh size = 0.250 mm.

Table D31. Size distribution and estimated biomass of macroinvertebrates at MacKay River system stations, 1984.

Waterbody	Station	Replicate	Total number per 0.1 m^2	Percentage of organisms in sieves Mesh opening (mm) 0.25-0.5	0.5-1	1-2	2-4	>4	Estimated biomass (mg)
SPRING									
MacKay R.	MR-B1	1	22	0	68	23	9	0	3.14
		2	25	16	48	20	16	0	4.46
		3	19	11	58	21	11	0	2.78
									$\bar{x} \pm$ S.E. 3.46 $\pm$ 0.511
	MR-B2	1	1	0	100	0	0	0	0.05
		2	7	0	86	0	14	0	1.02
		3	7	14	0	86	0	0	1.15
									$\bar{x} \pm$ S.E. 0.74 $\pm$ 0.349
	MR-B3	1	65	12	48	40	0	0	6.54
		2	87	8	62	30	0	0	7.65
		3	68	3	66	29	1	0	6.74
									$\bar{x} \pm$ S.E. 6.98 $\pm$ 0.342
	MR-B4	1	411	1	21	64	15	0	97.65
		2	366	4	33	63	0	0	49.95
		3	219	1	26	73	0	0	32.92
									$\bar{x} \pm$ S.E. 60.17 $\pm$ 19.372
Creek M2	M2-B	1	48	2	29	69	0	0	6.94
		2	45	0	60	40	0	0	4.72
		3	49	10	67	2	20	0	9.16
									$\bar{x} \pm$ S.E. 6.94 $\pm$ 1.282
Dover R.	DR-B	1	60	13	33	38	10	0	18.26
		2	86	23	67	9	0	0	4.61
		3	53	13	49	19	19	0	10.54
									$\bar{x} \pm$ S.E. 11.14 $\pm$ 3.952
Creek M6	M6-B	1	44	7	30	64	0	0	5.97
		2	116	5	59	32	2	2	17.55
		3	97	6	72	19	2	1	11.19
									$\bar{x} \pm$ S.E. 11.57 $\pm$ 3.348
SUMMER									
MacKay R.	MR-B1	1	54	22	54	22	2	0	4.57
		2	40	18	42	40	0	0	3.95
		3	59	30	56	14	0	0	3.36
									$\bar{x} \pm$ S.E. 3.96 $\pm$ 0.349
	MR-B2	1	191	42	50	8	0	0	8.59
		2	235	25	65	9	L 1	2	20.63
		3	153	44	52	3	0	0	5.70
									$\bar{x} \pm$ S.E. 11.64 $\pm$ 4.572
	MR-B3	1	133	20	50	27	0	4	24.47
		2	364	15	74	10	L 1	0	21.89
		3	88	44	50	6	0	0	3.61
									$\bar{x} \pm$ S.E. 16.66 $\pm$ 6.566
	MR-B4	1	69	10	59	30	0	0	6.07
		2	104	34	39	25	2	0	8.84
		3	88	30	40	27	3	0	8.78
									$\bar{x} \pm$ S.E. 7.90 $\pm$ 0.913
M2	M2-B	1	28	21	46	29	4	0	2.96
		2	26	12	46	42	0	0	2.71
		3	54	11	57	22	4	6	13.78
									$\bar{x} \pm$ S.E. 6.48 $\pm$ 3.649
Dover R.	DR-B	1	138	14	42	33	8	3	31.08
		2	151	28	58	13	L 1	L1	12.00
		3	183	19	53	27	1	0	15.93
									$\bar{x} \pm$ S.E. 19.67 $\pm$ 5.817
M6	M6-B	1	146	13	38	29	20	0	32.07
		2	66	50	21	27	0	2	7.34
		3	86	38	42	17	2	0	6.49
									$\bar{x} \pm$ S.E. 15.30 $\pm$ 8.389

continued . . .

Table D31. Continued.

Waterbody	Station	Replicate	Total number per 0.1 m^2	Percentage of organisms in sieves Mesh opening (mm) 0.25-0.5	0.5-1	1-2	2-4	>4	Estimated biomass (mg)
FALL									
MacKay R.	MR-B1	1	256	48	40	12	0	0	12.63
		2	202	28	52	17	1	1	20.19
		3	322	48	46	5	1	L1	18.00
									$\bar{x} \pm$ S.E. 16.94 ± 2.246
	MR-B2	1	10	10	70	10	0	10	3.36
		2	11	27	64	9	0	0	0.57
		3	10	10	70	10	0	10	3.36
									$\bar{x} \pm$ S.E. 2.43 ± 0.930
	MR-B3	1	12	25	50	17	8	0	1.44
		2	94	20	63	16	1	0	6.70
		3	43	47	49	5	0	0	1.67
									$\bar{x} \pm$ S.E. 3.27 ± 1.716
	MR-B4	1	769	36	54	2	8	L1	76.82
		2	393	58	37	5	L 1	0	14.53
		3	781	22	57	21	L 1	L1	60.67
									$\bar{x} \pm$ S.E. 50.67 ± 18.663
M2	M2-B	1	46	24	26	48	2	0	5.62
		2	136	26	18	49	8	0	22.12
		3	40	52	25	22	0	0	2.46
									$\bar{x} \pm$ S.E. 10.07 ± 6.095
Dover R.	DR-B	1	90	29	70	0	1	0	4.15
		2	214	21	53	22	2	1	26.62
		3	114	43	50	7	0	0	4.94
									$\bar{x} \pm$ S.E. 11.90 ± 7.362
Creek M6	M6-B	1	1 846	57	39	4	L 1	0	65.89
		2	1 160	49	40	9	1	L1	63.92
		3	2 752	50	47	3	L 1	0	100.17
									$\bar{x} \pm$ S.E. 76.66 ± 11.769

L = less than.

Table D32. Size distribution and estimated biomass of macroinvertebrates at stations associated with the West Interception Ditch, Bridge Creek and Lower Beaver Creek, 1984.

Waterbody	Station	Replicate	Total number per 0.1 m^2	Percentage of organisms in sieves Mesh opening (mm) 0.25-0.5	0.5-1	1-2	2-4	>4	Estimated biomass (mg)
SPRING									
W.I.D.	WID-B1	1	9	0	44	0	55	0	3.84
		2	70	9	29	44	11	7	26.84
		3	234	35	56	9	0	0	11.59
									$\bar{x} \pm$ S.E. 14.09 ± 6.756
Creek W3	W3-B	1	22[a]	20	20	40	0	20	14.18
		2	13	0	100	0	0	0	0.64
		3	39	44	55	0	0	0	1.29
									$\bar{x} \pm$ S.E. 5.37 ± 4.409
W.I.D.	WID-B2	1	50	30	48	12	10	0	6.15
		2	18	33	44	17	6	0	1.77
		3	28	0	25	71	4	0	4.85
									$\bar{x} \pm$ S.E. 4.26 ± 1.299
Bridge Creek	BRC-B	1	32	9	72	16	3	0	2.84
		2	7	14	57	29	0	0	0.59
		3	7	0	57	29	14	0	1.30
									$\bar{x} \pm$ S.E. 1.58 ± 0.664
Lower Beaver Creek	LBC-B2	1	61	7	25	48	18	3	19.92
		2	274	11	68	14	4	3	44.68
		3	321	4	73	12	9	2	62.28
									$\bar{x} \pm$ S.E. 42.29 ± 12.286
Lower Beaver Creek	LBC-B1	1	7	14	43	0	14	29	6.53
		2	34	29	59	9	3	0	2.41
		3	65	5	48	48	0	0	7.42
									$\bar{x} \pm$ S.E. 5.45 ± 1.543
SUMMER									
W.I.D.	WID-B1	1	175	21	36	41	0	1	20.00
		2	130	37	44	19	0	0	8.14
		3	350	21	37	42	0	L1	37.77
									$\bar{x} \pm$ S.E. 21.97 ± 8.610
Creek W3	W3-B	1	230[a]	19	81	0	0	0	9.72
		2	183	19	69	12	0	0	10.79
		3	491	29	55	16	0	0	29.83
									$\bar{x} \pm$ S.E. 16.78 ± 6.532
W.I.D.	WID-B2	1	88	2	18	27	52	0	38.88
		2	80	39	48	14	0	0	4.34
		3	111	47	30	17	3	4	19.35
									$\bar{x} \pm$ S.E. 20.86 ± 9.999
Bridge Creek	BRC-B	1	33	58	30	9	0	3	4.12
		2	15	7	67	27	0	0	1.26
		3	46	50	37	13	0	0	2.27
									$\bar{x} \pm$ S.E. 2.55 ± 0.837
Lower Beaver Creek	LBC-B2	1	1 514	20	17	57	7	L1	263.63
		2	499	11	34	51	L 1	4	108.64
		3	942	12	63	22	1	1	116.50
									$\bar{x} \pm$ S.E. 162.92 ± 50.404
Lower Beaver Creek	LBC-B1	1	209	13	36	44	6	1	36.53
		2	100	3	48	46	2	1	15.36
		3	135	9	39	49	3	0	18.14
									$\bar{x} \pm$ S.E. 23.34 ± 6.642

continued . . .

Table D32. Continued.

Waterbody	Station	Replicate	Total number per 0.1 m^2	Percentage of organisms in sieves Mesh opening (mm) 0.25-0.5	0.5-1	1-2	2-4	>4	Estimated biomass (mg)
<u>FALL</u>									
W.I.D.	WID-B1	1	3 294	49	40	5	5	L1	275.17
		2	2 398	40	49	9	1	1	194.50
		3	1602	66	29	5	L 1	L1	64.54
									$\bar{x} \pm$ S.E. 178.07 $\pm$ 61.356
Creek W3	W3-B	1	454	56	8	37	0	0	36.69
		2	101	17	17	66	0	0	13.72
		3	538	12	50	38	0	0	52.23
									$\bar{x} \pm$ S.E. 34.21 $\pm$ 11.186
W.I.D.	WID-B2	1	2	48	48	2	0	0	100.72
		2	6	12	74	9	0	0	102.47
		3	1	27	71	1	0	0	80.33
									$\bar{x} \pm$ S.E. 94 51 $\pm$ 7.106
Bridge Creek	BRC-B1	1	9	33	44	22	0	0	0.61
		2	5	20	20	60	0	0	0.63
		3	11	45	18	36	0	0	0.92
									$\bar{x} \pm$ S.E. 0.72 $\pm$ 0.099
Lower Beaver Creek	LBC-B2	1	358	19	60	18	2	1	39.21
		2	397	44	47	5	20	1	32.58
		3	306	27	48	22	3	0	42.72
									$\bar{x} \pm$ S.E. 38.17 $\pm$ 2.973
Lower Beaver Creek	LBC-B1	1	312	43	24	27	6	0	30.67
		2	329	37	39	19	4	0	18.11
		3	54	59	20	17	4	0	4.11
									$\bar{x} \pm$ S.E. 17.63 $\pm$ 7.670

[a] Eckman grab samples (area 0.023 m^2) were taken at station W3-B. Densities have been converted to 0.1 m^2.

L = less than.

Table D33. Seasonal changes in size distribution and estimated biomass of macroinvertebrates in Upper Beaver Creek and Creek B-1, 1984.

Waterbody	Station	Replicate	Total number[a] per 0.1 m^2	Percentage of organisms in sieves Mesh opening (mm) 0.25-0.5	0.5-1	1-2	2-4	>4	Estimated biomass (mg)
SPRING[b]									
Upper Beaver Creek	UBC-B	1	409	5	37	35	22	0	101.42
		2	9	0	0	100	0	0	1.70
		3	0	0	0	0	0	0	0.0
									$\bar{x} \pm$ S.E. 34.37 ± 33.527
SUMMER									
Upper Beaver Creek	UBC-B	1	335	14	62	22	0	1	37.08
		2	922	14	73	10	L 1	2	117.04
		3	491	2	60	26	11	2	101.00
									$\bar{x} \pm$ S.E. 85.04 ± 24.423
Creek B1	B1-B	1	123	16	43	33	8	0	17.71
		2	71	24	42	28	6	0	8.39
		3	10	10	80	10	0	0	0.59
									$\bar{x} \pm$ S.E. 8.90 ± 4.947
FALL									
Upper Beaver Creek	UBC-B	1	1 058	21	79	0	0	0	43.99
		2	1 530	23	70	7	0	0	76.40
		3	807	25	69	6	0	0	39.27
									$\bar{x} \pm$ S.E. 53.22 ± 11.670
Creek B1	B1-B	1	320	44	31	23	2	L1	23.26
		2	126	65	33	2	0	0	5.10
		3	182	42	49	8	0	0	8.25
									$\bar{x} \pm$ S.E. 12.20 ± 5.604

[a] Ekman grab samples (area 0.023 m^2) were taken at the Upper Beaver Creek station. Densities have been converted to 0.1 m^2.
[b] No samples were collected at Station B1-B in spring.
L = less than.

Table D34. Seasonal changes in size distribution and estimated biomass of macroinvertebrates in Beaver Creek Reservoir, 1984.

Season	Station and Depth	Replicate	Total number per 0.1 m^2	Percentage of organisms in sieves Mesh opening (mm) 0.25-0.5	0.5-1	1-2	2-4	>4	Estimated biomass (mg)
SPRING	BCR-B1	1	1 270	24	68	6	2	L1	88.26
	(1 m)	2	461	11	63	16	9	0	60.62
		3	400	23	58	15	3	1	45.75
									$\bar{x} \pm$ S.E. 64.88 ± 12.45
	BCR-B2	1	70	12	31	19	25	12	40.84
	(3 m)	2	165	3	21	8	68	0	86.64
		3	261	12	50	12	27	0	87.77
									$\bar{x} \pm$ S.E. 71.75 ± 15.458
	BCR-B3	1	252	55	22	10	9	3	40.87
	(5 m)	2	365	31	42	19	8	0	44.26
		3	252	24	45	26	5	0	23.17
									$\bar{x} \pm$ S.E. 40.77 ± 6.503
SUMMER	BCR-B1	1	570	35	55	9	1	0	30.97
	(1 m)	2	400	20	73	6	1	0	23.39
		3	539	35	47	16	2	0	40.73
									$\bar{x} \pm$ S.E. 31.70 ± 5.019
	BCR-B2	1	126	41	28	31	0	0	9.25
	(3 m)	2	113	8	23	23	42	4	53.45
		3	348	51	20	20	9	0	41.06
									$\bar{x} \pm$ S.E. 34.59 ± 13.164
	BCR-B3	1	135	55	35	10	0	0	5.77
	(5 m)	2	217	24	62	12	2	0	15.38
		3	526	18	33	28	21	0	116.95
									$\bar{x} \pm$ S.E. 46.03 ± 35.567
	BCR-B4	1	348	31	59	6	2	0	21.87
	(1 m)	2	500	22	63	16	0	0	31.54
		3	313	22	58	17	3	0	26.05
									$\bar{x} \pm$ S.E. 26.49 ± 2.800
	BCR-B5	1	87	40	25	30	0	5	18.71
	(3 m)	2	578	9	33	20	33	5	256.68
		3	304	11	36	29	10	14	166.97
									$\bar{x} \pm$ S.E. 147.45 ± 69.386
FALL	BCR-B1	1	1 087	14	53	26	7	0	139.81
	(1 m)	2	904	10	35	42	8	6	286.59
		3	852	4	5	29	16	0	169.21
									$\bar{x} \pm$ S.E. 198.54 ± 44.837
	BCR-B2	1	1 148	30	42	9	14	5	309.30
	(3 m)	2	539	16	42	23	10	10	220.34
		3	504	14	34	28	10	14	269.87
									$\bar{x} \pm$ S.E. 266.50 ± 25.736
	BCR-B3	1	565	26	52	15	5	2	76.38
	(5 m)	2	696	10	52	32	5	0	86.87
		3	1 809	6	63	31	0	0	162.79
									$\bar{x} \pm$ S.E. 108.68 ± 27.224
	BCR-B4	1	3 896	17	59	19	3	1	496.05
	(1 m)	2	1 113	37	42	19	2	0	80.56
		3	2 383	28	42	31	0	0	195.22
									$\bar{x} \pm$ S.E. 257.28 ± 123.890
	BCR-B5	1	261	17	73	7	3	0	19.57
	(3 m)	2	348	5	70	20	0	5	74.33
		3	644	4	55	28	7	5	185.13
									$\bar{x} \pm$ S.E. 93.01 ± 48.697

L = less than.

Table D35. Seasonal changes in size distribution and estimated biomass of macroinvertebrates in Ruth Lake, 1984.

Season	Station and Depth	Replicate	Total number per 0.1 m^2	Percentage of organisms in sieves Mesh opening (mm) 0.25-0.5	0.5-1	1-2	2-4	>4	Estimated biomass (mg)
SPRING	RL-B	1	17	0	25	50	25	0	5.03
	(1 m)	2	61	0	14	36	50	0	26.72
		3	22	40	20	20	20	0	4.32
									$\bar{x} \pm$ S.E. 12.02 $\pm$ 7.351
SUMMER	RL-B	1	39	33	44	0	11	11	16.45
	(1 m)	2	39	55	44	0	0	0	1.13
		3	157	42	3	56	0	0	17.50
									$\bar{x} \pm$ S.E. 11.69 $\pm$ 5.290
FALL	RL-B	1	783	11	46	41	0	2	79.41
	(1 m)	2	1 061	14	50	33	3	0	119.01
		3	939	20	35	40	3	2	157.40
									$\bar{x} \pm$ S.E. 118.61 $\pm$ 22.515

Table D36. Seasonal changes in size distribution and estimated biomass of macroinvertebrates in Poplar Creek Reservoir, 1984.

Season	Station and Depth	Replicate	Total number per 0.1 m^2	Percentage of organisms in sieves Mesh opening (mm) 0.25-0.5	0.5-1	1-2	2-4	>4	Estimated biomass (mg)
SPRING	PCR-B1 (1 m)	1	139	12	47	41	0	0	14.10
		2	257	29	71	0	0	0	9.91
		3	226	0	83	15	0	2	15.74
									$\bar{x} \pm$ S.E. 39.75 $\pm$ 1.736
	PCR-B2 (3 m)	1	126	21	45	24	7	3	27.46
		2	135	26	58	13	3	0	10.74
		3	91	0	29	71	0	0	13.60
									$\bar{x} \pm$ S.E. 17.27 $\pm$ 5.163
	PCR-B3 (5 m)	1	52	17	17	42	25	0	14.16
		2	22	0	40	0	60	0	9.94
		3	39	22	22	22	33	0	11.69
									$\bar{x} \pm$ S.E. 11.93 $\pm$ 1.224
	PCR-B4 (10 m)	1	91	10	0	5	10	76	203.39
		2	30	0	57	0	0	43	37.62
		3	26	33	33	0	0	33	25.05
									$\bar{x} \pm$ S.E. 88.69 $\pm$ 57.466
	PCR-B5 (15 m)	1	222	2	2	84	2	10	61.28
		2	100	0	0	35	61	4	63.21
		3	52	8	0	17	42	33	66.58
									$\bar{x} \pm$ S.E. 63.69 $\pm$ 1.549
SUMMER	PCR-B1 (1 m)	1	1 174	17	51	24	7	0	149.79
		2	517	24	41	34	2	0	51.23
		3	909	25	68	6	1	0	52.56
									$\bar{x} \pm$ S.E. 84.53 $\pm$ 32.634
	PCR-B2 (3 m)	1	161	51	32	5	11	0	17.95
		2	104	62	12	8	0	17	52.16
		3	287	9	68	23	0	0	22.25
									$\bar{x} \pm$ S.E. 30.79 $\pm$ 10.759
	PCR-B3 (5 m)	1	78	0	11	33	44	11	55.23
		2	100	4	0	26	22	48	155.66
		3	35	0	0	38	0	62	63.75
									$\bar{x} \pm$ S.E. 91.55 $\pm$ 32.151
	PCR-B4 (10 m)	1	9	0	0	0	100	0	6.34
		2	96	0	0	5	5	91	249.13
		3	39	0	0	22	33	44	60.18
									$\bar{x} \pm$ S.E. 105.22 $\pm$ 73.616
	PCR-B5 (15 m)	1	43	0	10	10	20	60	80.92
		2	43	20	20	10	50	0	17.21
		3	55	8	54	0	8	31	58.00
									$\bar{x} \pm$ S.E. 52.04 $\pm$ 18.63
FALL	PCR-B1 (1 m)	1	13 187	46	42	9	1	2	1 451.44
		2	6 483	24	61	11	1	2	859.60
		3	16 492	64	31	5	L 1	L1	619.21
									$\bar{x} \pm$ S.E. 976.75 $\pm$ 247.282
	PCR-B2 (3 m)	1	117	22	37	37	4	0	13.86
		2	261	18	52	23	7	0	31.41
		3	126	17	31	41	3	7	39.74
									$\bar{x} \pm$ S.E. 28.34 $\pm$ 7.627
	PCR-B3 (5 m)	1	157	3	14	28	33	22	145.43
		2	26	33	17	50	0	0	2.79
		3	113	0	8	27	50	15	96.41
									$\bar{x} \pm$ S.E. 81.54 $\pm$ 41.842
	PCR-B4 (10 m)	1	630	0	3	89	2	6	214.63
		2	639	0	1	91	3	5	209.01
		3	52	8	0	67	0	25	39.29
									$\bar{x} \pm$ S.E. 154.31 $\pm$ 57.533
	PCR-B5 (15 m)	1	117	0	0	48	52	0	55.06
		2	257	3	20	31	46	0	103.04
		3	130	3	7	87	0	3	34.11
									$\bar{x} \pm$ S.E. 64.07 $\pm$ 20.402

L = less than.

APPENDIX E

FISHERIES

Table E1. Summary of boat electoshocking (ES) and backpack electrofishing (EF) CUE (catch per unit effort) for sample stations in the MacKay River and Dover River, 1984.

Waterbody (Station)	Survey Date	Species CUE[a]																Effort (min)	Efficiency[b]
		LW	MW	AG	GE	NP	YW	LING	LNS	WS	FHC	LKC	LND	PD	NRD	SS	TP		
MacKay R.																			
MR-ES1	28 May		L0.1[c]		0.2	L0.1	0.3		0.1	1.0	0.03	0.2						66.6	1
	25 July	L0.1	0.1		0.6	L0.1	0.1			0.4	0.1							47.0	1
MR-ES2	27 May				L0.1		L0.1	L0.1	0.1	0.3	0.1	L0.1					L0.1	46.4	2
	24 July		L0.1		0.4	L0.1	L0.1		0.1	0.2	0.1							47.0	2
MR-ES3	27 May		L0.1	L0.1	0.2	L0.1	0.2			0.1		0.1						46.3	2
	24 July				0.2	L0.1	L0.1		0.1	0.2	L0.1							43.0	2
MR-EF1	26 Sept.											14.1		1.4	0.7			2.9	1
MR-EF2	26 Sept.									0.2		7.9					0.4	5.3	1
MR-EF3	26 Sept.											3.6					0.6	7.2	1
MR-EF4	25 Sept.								0.8			2.1						4.8	1
MR-EF5	25 Sept.								0.5			1.9	0.9				0.2	6.4	2
MR-EF6	25 Sept.											3.8	0.6		0.2		0.4	5.2	2
MR-EF7	25 Sept.								0.3			3.8	0.2				1.2	6.6	1
MR-EF8	25 Sept.								0.3			0.9	0.4					7.0	1
MR-EF9	25 Sept.			0.1					3.3	2.2		3.2	0.2	2.3	3.2		1.9	9.1	1
Dover R.																			
DR-EF1	29 May							0.1				0.9						10.2	1
	25 July								0.1			1.9	0.4			0.3	1.2	12.2	1
	24 Sept.									1.1		2.7			0.1	0.4	1.4	8.1	2
DR-EF2	24 Sept.									0.8		5.0	0.3		0.2	0.3	1.9	10.6	2
DR-EF3	24 Sept.								0.6	0.5		5.0				0.9	1.4	11.0	2
DR-EF4	24 Sept.								0.7	1.3		6.8				0.5	2.1	12.0	2

[a] For species code explanation, see text Table 3.6; CUE = catch (captured and observed) per electrofishing minute.
[b] Efficiency rating (1 = optimum efficiency; 4 = lowest efficiency).
[c] L = Less than

Table E2. Age-length and age-weight relationships for goldeye, walleye and mountain whitefish captured in the MacKay River, 1984.

Scale Age	Fork Length (mm) Mean	S.D.	Range	Weight (g) Mean	S.D.	Range	Number
Goldeye[a]							
0							0
1							0
2	145.0	8.89	135 to 152	32.7	4.93	27 to 36	3
3	226.2	14.20	203 to 241	125.2	23.59	89 to 146	5
4	264.4	15.79	235 to 284	193.0	37.78	141 to 150	7
5	278.0	4.24	275 to 281	204.5	21.92	189 to 220	2
6	326.8	12.06	309 to 341	383.3	68.90	300 to 480	6
7	352.6	8.27	343 to 362	463.0	54.27	375 to 510	5
8	368.3	23.07	348 to 395	546.3	85.38	450 to 630	4
Walleye[b]							
0							0
1							0
2							0
3	270.8	15.98	247 to 291	182.8	32.32	150 to 225	5
4	310.3	19.28	285 to 330	293.8	31.46	250 to 325	4
5	351.0	15.56	340 to 362	412.5	88.39	350 to 475	2
6	394.0			580.0			1
7	422.5	16.91	385 to 443	889.6	121.80	575 to 990	10
8							0
9	467.0	24.04	450 to 484	1095.0	346.48	850 to 1340	2
Mountain Whitefish[a]							
0							0
1	142.0	3.94	136 to 146	40.8	2.95	37 to 45	5
2							0
3	279.0			300.0			1
4	336.0			480.0			1

[a]Scale age

[b]Fin-ray age

Table E3. Summary of sampling effort and CUE (catch per unit effort) from seine stations (S) on the MacKay River and Dover River, 1984.

Waterbody (Station)	Survey Date	Species CUE[a]													Haul Area (m^2)
		NP	YW	YP	LNS	WS	FHM	LKC	LND	PD	NRD	SS	TP	ES	
MacKay River															
MR-S1	28 May	L0.1[b]	L0.1	L0.1	0.2	L0.1		1.3					3.3	0.1	450.0
	25 July				L0.1	0.4	1.5	7.6	1.4			L0.1	0.9		450.0
MR-S1A	26 Sept.			L0.1				0.1		0.1				360.0	
MR-S1B	26 Sept.			L0.1		0.1		0.3		0.1	0.4		0.2		519.0
MR-S2	28 May		L0.1		0.1	L0.1		2.5	0.1			L0.1	0.2		705.0
	25 July				0.1	L0.1	L0.1	4.4	1.1			0.1	0.5		500.0
MR-S2A	26 Sept.							0.2				L0.1	0.1		420.0
MR-S3	28 May				L0.1			2.6	L0.1				L0.1		547.5
	25 July	L0.1				1.0		6.9	0.1		L0.1	L0.1	0.4		450.0
MR-S3A	25 Sept.							0.1	L0.1			L0.1			210.0
MR-S4	25 Sept.					0.1		0.2	0.3				0.1		140.0
MR-S5	25 Sept.				0.1			1.9	0.3		0.2				120.0
Dover River															
DR-S1	24 Sept.							0.8					0.5		84.0
DR-S2	24 Sept.							0.8					0.3		90.0

[a]For species code explanation, see text Table 3.6; CUE = catch per 10 m^2 of surface area.

[b]L = Less than.

Table E4. Summary of electrofishing (EF) CUE (catch per unit effort) from sample stations in the West Interception Ditch/Lower Beaver Creek System, 1984

Waterbody (Station)	Survey Date	Species CUE[a]					Effort (min)	Efficiency[b]
		LNS	WS	FHM	LKC	BS		
W.I.D.								
WID-EF1	30 May						4.8	1
	26 July			0.5			3.0	1
	27 Sept.			0.2		0.9	5.3	1
WID-EF2	30 May						5.4	1
	26 July						3.4	1
	27 Sept.					0.4	4.8	1
WID-EF3	26 July					0.3	3.3	1
	27 Sept.				0.3	0.6	3.4	2
W.I.D. Tributaries								
W2-EF	30 May			1.1		0.1	7.4	1
Beaver Creek								
LBC-EF1	25 May					2.4	6.8	1
	21 July		0.1		0.4	2.8	12.9	1
	21 Sept.					2.4	8.7	2
LBC-EF2	25 May					6.3	6.2	1
	21 July					4.8	12.6	1
	22 Sept.					6.2	8.6	3
Bridge Creek								
BRC-EF1	26 May				0.1	0.2	8.0	1
	21 July	0.5	0.4				8.5	1
	21 Sept.						7.6	1
BRC-EF2	21 July						6.5	1
	22 Sept.						5.9	1
BRC-EF3	30 May					0.1	8.1	1
	26 July			0.4	1.6	1.4	4.4	1
	27 Sept.					2.8	9.2	1
BRC-EF4	30 May			8.1		1.5	7.9	1
	26 July			1.0		3.1	3.9	1
	27 Sept.			2.1		1.0	2.9	2

[a]For species code explanation, see text Table 3.6; CUE = catch (captured and observed) per electrofishing minute.
[b]Efficiency rating (1 = optimum efficiency; 4 = lowest efficiency).

Table E5. Summary of boat electroshocking (ES) and backpack electrofishing (EF) CUE (catch per unit effort) from sample stations in the Beaver Creek Diversion System, 1984.

Waterbody (Station)	Survey Date	Species CUE[a]										Effort (min)	Efficiency[b]
		AG	NP	LING	LNS	WS	FHM	FHC	LKC	NRD	BS		
Upper Beaver Creek													
UBC-ES	13 June					0.1	3.2		9.9			13.2	2
UBC-EF	26 Sept.					0.5	0.6		0.6		0.9	14.1	2
Creek B1													
B1-EF1	31 May					256.7			110.0			0.3	1
	27 Sept.					1.6	3.0		15.4		1.7	8.7	2
B1-EF2	26 July					2.5	1.2		4.7		8.9	7.2	2
	27 Sept.					11.9	15.5		35.1		6.8	4.7	1
Beaver Creek Reservoir													
BCR-ES1	13 June					3.0	0.1		0.1			9.6	2
BCR-ES2	13 June					4.2						26.4	2
Ruth Lake													
RL-ES	13 June					8.5	6.9				1.6	13.2	2
Poplar Creek													
PC-EF1	31 May											10.7	1
	23 July					1.8	1.0		0.2			16.0	1
	22 Sept.					1.7	0.4					12.9	1
PC-EF2	31 May					1.1	15.2		0.7		15.5	8.5	2
	23 July					1.5	3.6		0.1	0.2	0.9	11.9	1
	23 Sept.					3.4	0.2			0.2	0.4	5.0	2
PC-EF3	31 May	0.3			0.1	5.6	33.4		1.6		17.9	10.3	1-2
	23 Sept.					1.9	0.2		2.7		0.2	6.2	2-3
PC-EF5	25 May				0.4	1.7	17.0				1.9	6.9	2
	22 July				0.1	34.0[c]	6.1[c]		1.0		1.6	13.7	1-2
	23 Sept.			0.1	0.9	6.0	0.7		2.5		0.4	16.6	2
PC-EF6	25 May		0.1			0.8			14.0		5.9	11.2	2
	22 July					11.1[d]	9.1[d]		0.5			10.7	1-3
	23 Sept.				4.1	2.9			7.0			12.9	2

[a]For species code explanation, see text Table 3.6; CUE = catch (captured and observed) per electrofishing minute.

[b]Efficiency rating (1 = optimum efficiency; 4 = lowest efficiency).

[c]Does not include more than 10 000 fry observed. Identified subsamples consisted of approximately 98% white sucker y-o-y and 2% fathead minnow y-o-y.

[d]Does not include more than 5 000 fry observed. Identified subsamples consisted of approximately 98% white sucker y-o-y and 2% fathead minnow y-o-y.

Table E6. Summary of sample effort and CUE (catch per unit effort) for seine collections in the Beaver Creek Diversion System, 1984.

Waterbody (Station)	Survey Date	Species CUE[a]			Haul Area (m^2)
		White Sucker	Fathead Minnow	Brook Stickleback	
BCR-S3	15 July	3.4	8.2	7.0	525.0
RL-S2	16 July	0.2	37.6	12.5	400.0
PCR-S3	17 July		0.2	3.8	475.0

[a]CUE = catch per 10 m^2 of surface area.

Table E7. Summary of sample effort and CUE (catch per unit effort) for overnight gillnet sets in the Beaver Creek Diversion System, 1984.

Waterbody (Station)	Survey Date	Species CUE[a] White Sucker	Set Duration (h)
BCR-G1	15-16 July	5.1 (6)	14.0
BCR-G2	16-17 July	32.6 (38)	14.0
RL-G2	16-17 July	68.3 (74)	13.0
PCR-G1	17-18 July	10.5 (11)	12.6
PCR-G2	17-18 July	11.7 (13)	13.3

[a]CUE based on standard net-unit (15.2 m x 2.8 m panels of 3.8 cm, 6.4 cm, 8.9 cm monofilament mesh). Results expressed as number of fish/net-unit/12 h; number of fish/standard net unit/overnight set given in parentheses.

Table E8. Percentage composition and CUE (catch per unit effort) for various fish species in seine collections from Beaver Creek Reservoir, Ruth Lake and Poplar Creek Reservoir (summer 1978, 1981 and 1984).[a]

	White Sucker Juv. and y-o-y			Fathead Minnow			Lake Chub			Brook Stickleback		
Location	1978	1981	1984	1978	1981	1984	1978	1981	1984	1978	1981	1984
Beaver Creek Reservoir (BCR-S3)	0.7[b] (0.6)	5.2 (5.3)	18.3 (3.4)	48.1 (42.4)	65.1 (65.5)	44.0 (8.2)	2.2 (2.0)	0.3 (0.3)	0 (0)	49.0 (43.3)	29.4 (29.6)	37.7 (7.0)
Ruth Lake (RL-S2)	L0.1[c] L0.1	0.7 (1.6)	0.4 (0.2)	92.6 (281.2)	85.0 (198.6)	74.7 (37.6)	L0.1 (L0.1)	0 (0)	0 (0)	7.4 (22.4)	14.3 (33.5)	24.9 (12.5)
Poplar Creek Reservoir (PCR-S3)	1.8 (0.3)	0.8 (0.2)	0 (0)	57.1 (9.8)	29.1 (7.9)	4.2 (0.2)	0.1 (L0.1)	0 (0)	0 (0)	41.0 (7.1)	70.1 (18.9)	95.8 (3.8)

[a] 1978 data from O'Neil (1979); 1981 data from O'Neil (1982); 1984 data from present study.

[b] First number given is percentage composition of catch; CUE (catch per 10 m^2 of surface area) given in parentheses; both values based on three hauls conducted at each station during the summer period.

[c] L = Less than

Table E9. Sampling effort and CUE (catch per unit effort) for overnight gillnet sets in the Beaver Creek Diversion System (summer 1978, 1981 and 1984).[a]

		Species CUE[b]			
Location	Year	Longnose sucker	White sucker	Lake chub	Set Duration (h)
Beaver Creek Reservoir					
BCR-G1	1978	9.2(10)	95.1 (103)	0 (0)	13.0
	1981	0 (0)	42.6 (63)	0.7 (1)	17.8
	1984	0 (0)	5.1 (6)	0 (0)	14.0
BCR-G2	1981	0 (0)	41.2 (52)	0 (0)	15.2
	1984	0 (0)	32.6 (38)	0 (0)	14.0
Ruth Lake					
RL-G2	1978	0 (0)	31.7 (41)	0 (0)	15.5
	1981	0 (0)	17.0 (33)	0 (0)	23.2
	1984	0 (0)	68.3 (74)	0 (0)	13.0
Poplar Creek Reservoir					
PCR-G1	1978	0 (0)	32.3 (43)	0 (0)	16.0
	1981	0 (0)	12.4 (21)	0 (0)	20.2
	1984	0 (0)	10.5 (11)	0 (0)	12.6
PCR-G2	1981	0 (0)	8.2 (13)	0 (0)	19.0
	1984	0 (0)	11.7 (13)	0 (0)	13.3

[a] 1978 data from O'Neil (1979); 1981 data from O'Neil (1982); 1984 data from present study.

[b] CUE based on a standard net-unit (15.2 m X 2.8 m panels of 3.8 cm, 6.4 cm, 8.9 cm monofilament mesh). Results expressed as number of fish/net-unit/12 h; number of fish/standard net-unit/overnight set given in parentheses.

Table E10. Length frequency distribution for white sucker captured by all sample methods in Beaver Creek Reservoir, Ruth Lake and Poplar Creek Reservoir, 1984.

Fork Length (mm)	Beaver Creek Reservoir		Ruth Lake		Poplar Creek Reservoir		Combined	
	Number	% Frequency	Number	% Frequency	Number	% Frequency	Number	% Frequency
0-19	1	1.3	0	0	0	0	1	0.4
20-39	11	14.5	0	0	0	0	11	5.0
40-59	0	0	0	0	0	0	0	0
60-79	6	7.9	0	0	0	0	6	2.7
80-99	4	5.3	3	2.7	2	5.7	9	4.0
100-119	0	0	11	9.9	4	11.4	15	6.8
120-139	0	0	10	9.0	1	2.9	11	5.0
140-159	10	13.2	19	17.1	8	22.9	37	16.7
160-179	12	15.8	41	36.9	9	25.7	62	27.9
180-199	2	2.6	9	8.1	0	0	11	5.0
200-219	1	1.3	3	2.7	1	2.9	5	2.2
220-239	1	1.3	0	0	0	0	1	0.4
240-259	4	5.3	4	3.6	2	5.7	10	4.5
260-279	3	3.9	1	0.9	6	17.1	10	4.5
280-299	6	7.9	0	0	0	0	6	2.7
300-319	5	6.6	1	0.9	0	0	6	2.7
320-339	5	6.6	4	3.6	0	0	9	4.0
340-359	2	2.6	3	2.7	0	0	5	2.2
360-379	0	0	1	0.9	2	5.7	3	1.4
380-399	1	1.3	1	0.9	0	0	2	0.9
400-419	2	2.6	0	0	0	0	2	0.9
Total No.	76		111		35		222	

APPENDIX F

SITE SPECIFIC COMMENTS RELATING TO THE DISTRIBUTION OF AQUATIC MACROPHYTES IN THE FOUR STANDING WATERBODIES IN THE STUDY AREA

Table F1. Site specific comments relating to distribution of macrophytes in Beaver Creek Reservoir, July 1984.

Site[a]	Description
Site 1	At 0.5 m depth - patches of **Sparganium** and **Nuphar**. At 0.9 m, **Potamogeton pusillus** and **P. richardsonii.** At shore - **Carex** with patches of **Typha** and **Scirpus** with **Salix** on higher ground.
Site 2	**Myriophyllum** towards the shore with **P. pectinatus** growing at depths up to 1.5 m. Shore - **Typha.**
Site 3	**Myriophyllum, Ceratophyllum, P. pectinatus, P. zosteriformis** with smaller amounts of **P. pusillus** and **P. richardsonii.** Shore - **Typha** with small areas of **Scirpus.**
Site 4	**Myriophyllum, Ceratophyllum, P. pectinatus, P. zosteriformis** with smaller amounts of **P. pusillus** and **P. richardsonii.** Shore - **Typha** with small areas of **Scirpus.**
Site 5	Mixture of **Ceratophyllum, Myriophyllum, P. zosteriformis** and **P. richardsonii.**
Site 6	Mixture of **Ceratophyllum, Myriophyllum, P. zosteriformis** and **P. richardsonii.**
Site 7	**P. pectinatus, P. zosteriformis,** some **Myriophyllum. Typha** thinning out on shore.
Site 8	Patches of **Sparganium** near shore with isolated patches of **Nuphar.** Shoreline has a narrow band of **Carex** with a few plants of **Equisetum** near the water's edge.
Site 9	Well developed colonies of **Sparganium** extending from the point in an arc towards the southeast.
Site 10 & 11	Very thick beds of **Myriophyllum.**
Site 12	Start of **Typha** on shore with a few small **Typha** islands off shore. Submersed vegetation consisting almost exclusively of **Myriophyllum** growing to a depth of 2 m with much smaller amounts of **P. zosteriformis.**
Site 13	Large numbers of **Typha** islands which are surrounded with **Ceratophyllum** with lesser amounts of **Myriophyllum** and **P. zosteriformis.** Much of the **Typha** is last year's growth. Some **Lemma minor** was seen among the **Typha.** The depth increased rapidly away from the islands to about 1 - 1.5 m.
Site 14	**Typha** islands surrounded by **Ceratophyllum** and **Myriophyllum** with smaller amounts of **P. zosteriformis** and **P. pectinatus** with about 60% cover.
Site 15	**Myriophyllum, Ceratophyllum** and **P. zosteriformis.**
Site 16	Shore - **Typha** being replaced by **Scirpus** and some **Salix.** Submersed vegetation almost exclusively **Myriophyllum** with almost 100% cover with one well developed patch of **P. praelongus,** the only one seen in the reservoir.

[a] For site location see Figure 5.8.

Table F2. Site specific comments relating to distribution of macrophytes in Ruth Lake, July 1984.

Site[a]	Description
Site 1	**Myriophyllum** dominant with small amounts of **P. pectinatus**, **P. zosteriformis**, **Ranunculus**, and isolated plants of **Nuphar**. A few plants of **P. praelongus** were seen. Clumps of **Scirpus** in 0.9 m of water with an understorey of **Ceratophyllum** and **Lemna trisulca**.
Site 2	Dense **Myriophyllum** and small patches of **Nuphar** with an understorey of **Ceratophyllum** and **L. trisulca**.
Site 3	Numerous small **Scirpus** islands with small amounts of **Typha**. The islands are surrounded by extremely dense **Myriophyllum**.
Site 4	Dense **Myriophyllum** which at 10 m from shore thins out in the shallow water. Shore - a narrow band of **Typha** with **Salix** and **Populus** behind.
Site 5	**Myriophyllum** dominant. In a few small patches **Chara** occurs as an understorey beneath the **Myriophyllum**. Small amounts of **P. pusillus** and **P. richardsonii**. Shore - **Typha**.
Site 6	Entrance to discharge canal. **Myriophyllum** and **P. pectinatus** growing in a slow current. Shore - dense **Typha** on both sides.
Site 7	**Myriophyllum** with small amounts of **P. zosteriformis** and **Ceratophyllum**. A patch of **Chara** occurring beneath **Myriophyllum** was seen.
Open Area	Roughly follows the 2 m contour and is occupied by scattered **Nuphar** plants and occasional plants of **Myriophyllum** and **P. zosteriformis**.
Site 8	The open area ends abruptly with the appearance of dense **Myriophyllum** with smaller amounts of **Ceratophyllum**. Shore - **Carex** with **Eleocharis** and **Scirpus**.
Site 9	**Ceratophyllum** is dominant with **Myriophyllum** sub-dominant.
Site 10	A fan of **P. pectinatus** extends from the mouth of the diversion canal.

[a] For site location see Figure 5.16.

Table F3. Site specific comments relating to distribution of macrophytes in Poplar Creek Reservoir, July 1984.

Site[a]	Description
Sites 1 & 2	The east side has submersed vegetation moderate density consisting of a mixture of **Myriophyllum**, **Sagittaria** and **Sparganium** growing on a fairly firm bottom. Shore - **Carex** with small amounts of **Typha** and **Scirpus**.
Site 3	A few small **Typha** islands situated in a dense bed of **Myriophyllum** with lesser amounts of **Utricularia** and some emergent **Hippuris** and **Ranunculus**.
Site 4	Near the mouth of the diversion canal is a fan of **P. pectinatus** in <0.5 m of water which extends into the canal itself.
Site 5	A very large marshy area of **Menyanthes trifoliata** of unestimated extent on both sides of the canal. The west side of the diversion canal has a narrow band of **Typha**.
Site 6	The west side of the upper section of the reservoir is populated by occasional plants of **Sparganium** reaching the surface with some **Sagittaria** and **Myriophyllum**. Overall density of plants is low.
Site 7	The west side of the lower section (south of the causeway) is sparsely occupied with a mixed community of **Sparganium** and **Sagittaria**. Near the dam, **Myriophyllum** and **Utricularia** form a small bed near shore.
Site 8	Along the dam face patches of **P. zosteriformis** and **Myriophyllum** grow on a fairly firm and rocky bottom.
Site 9	The area near the entrance of the discharge canal contains fairly dense **Myriophyllum** with patches of **P. vaginatus** which grows into the canal. The south side of the canal has a band of **Typha**.
Site 10	The east side of the lower section of the reservoir has patches of **Sparganium** with lesser amounts of **Sagittaria**, **Myriophyllum** and a few plants of **Polygonum**. Shore - **Carex**, patches of **Typha** with **Salix** behind.
Site 11	A few plants of **Chara** seen in shallow water close to shore.

[a] For site location see Figure 5.22.

Table F4. Site specific comments relating to distribution of macrophytes in Horseshoe Lake, July 1984.

Site[a]	Description
Site 1	**Ceratophyllum** dominant with **Elodea** and **P. pectinatus** growing in 0.5 m. Small amounts of **P. pusillus, L. trisulca** and **L. minor** with a localized patch of **Nuphar.** Small amounts of emerging **Hippuris** and **Sparganium** were seen near shore. Shore - **Eleocharis.** Outlet channel overgrown with very dense **Typha** and **Carex.**
Site 2	**Elodea** dominant, heavily marled with lesser amounts of **P. pectinatus** and **Ceratophyllum.** In some areas a light understorey of **Chara** occurred in about 0.6 m. Shore - **Carex** with **Eleocharis** and small amounts of **Sagittaria** with occasional **Typha** on the east side. The west side of the arm is occupied by **Carex.**
Site 3	Dense **Elodea** (male plants with some flowering) growing in 2.5 m of water.
Site 4	**Nuphar** becomes dominant growing on both sides of the channel leaving a narrow **Nuphar**-free strip down the middle. **Elodea, P. pectinatus** and **Ceratophyllum** form an understorey. Shore - **Carex, Sparganium** and small amounts of **Typha** and **Eleocharis.**
Site 5	**Nuphar** growing almost completely across the channel. **Elodea** is much less abundant. Understorey composed of a mixture of **P. pectinatus, Ceratophyllum** with **Elodea, L. trisulca** and occasional plants of **P. zosteriformis.**
Site 6	Heavy growth of **Nuphar** with **L. trisulca** beneath. The channel is blocked at this point by a dense bed of **Scirpus** with some **Sparganium.** The bed extends to Site 7.
Site 7	**Nuphar** with an understorey of **Ceratophyllum** and **L. trisulca.** The centre of the channel has a number of small colonies of **Hippuris** and some **Typha.** Shore - **Sparganium, Carex** and **Salix** on east side, **Sparganium** and **Salix** on the west side.
Site 8	**Nuphar** forming an almost continuous cover with **L. trisulca** beneath the small amounts of **Utricularia** and **Elodea. P. pectinatus** and some **Chara** was found in some areas where **Nuphar** was less dense. Several large patches of the moss **Drepanocladus** mixed with **L. trisulca** occurred in the area.
Site 9	Abundant **Nuphar** with an understorey of **Utricularia** with occasional mats of partly floating **Drepanocladus** in 0.4 m of water. Small amounts of **L. trisulca.** Shore - **Typha** and **Sparganium.**
Site 10	**Nuphar** with **Elodea** and some **Ceratophyllum.**
Site 11	**Elodea** in 1.3 m of water. Shore - **Sparganium** with **Carex** and **Salix** behind.

Continued ...

Table F4. Continued.

Site 12	**Nuphar** with an understorey of **Ceratophyllum** and **Utricularia** with areas of **Sparganium** and **Hippuris**. A large area of emergent **Hippuris** growing in water up to 0.3 m occurs at the north end of the lake. This bed is surrounded by **Nuphar** and **Ceratophyllum**.
Site 13	The northwest arm is occupied by patches of **Nuphar** extending right across the arm with an understorey of **Elodea** and **Ceratophyllum** and a few areas of **P. pectinatus**. Smaller amounts of **P. zosteriformis** and **P. praelongus** in 0.5 to 0.75 m of water occur. Shore - **Carex** and **Sparganium** with **Salix** behind.
Site 14	Dense **Nuphar** with **L. trisulca** and **Ceratophyllum** beneath with lesser amounts of **Elodea** and **P. pectinatus**. Shore - **Carex** and **Sparganium**.
Site 15	An area without **Nuphar** cover extends out to 5 m from the shore. The bottom in this area is covered with **L. trisulca, Myriophyllum** and **Ceratophyllum**. In the area covered with **Nuphar** the understorey consists of **P. pectinatus** and **Elodea** in 0.4 m of water.
Site 16	Variable density of **Nuphar** with varying proportions of **P. pectinatus, Elodea** and **Ceratophyllum** with small amounts of **L. trisulca** and **P. pusillus**. Shore - **Carex** and **Sparganium** with **Salix** behind.

[a] For site location see Figure 6.1.

APPENDIX G

PHYTOPLANKTON

Table G1 Cell counts (cells·mL^{-1}) and cell volumes ($\mu m^3 \cdot 10^3 \cdot mL^{-1}$) of phytoplankton from Beaver Creek Reservoir (Station BCR-P), 1984.

	15 June		24 July		23 September	
	Number	Volume	Number	Volume	Number	Volume
BACILLARIOPHYTA						
Melosira granulata (large)	260	142	457	362	293	173
Melosira granulata (small)	N	N	123	21.6	479	75.0
Nitzschia acicularis	21.7	3.22	P	P	P	P
Unidentified centric	N	N	61.5	36.1	52.4	34.6
Asterionella formosa	P	P	43.9	11.3	13.3	3.54
Stephanodiscus hantzschii	101	61.7	N	N	N	N
Diatoma elongatum	14.5	8.67	8.79	3.42	P	P
Synedra acus	3.62	11.0	8.79	24.5	3.33	4.99
Synedra cyclopum	7.23	27.6	N	N	13.1	34.9
Unidentified	239	57.4	35.1	6.01	26.2	6.07
Unidentified	14.5	11.0	N	N	26.2	19.8
Gyrosigma sp.	P	P	N	N	N	N
Tabellaria fenestra	N	N	P	P	N	N
Gomphonema sp.	N	N	P	P	P	P
Synedra ulna	N	N	N	N	26.2	324
Fragilaria sp.	N	N	N	N	P	P
Cocconeis sp.	N	N	N	N	P	P
CRYPTOPHYTA						
Rhodomonas minuta	470	24.4	N	N	2491	39.6
Cryptomonas erosa	231	636	N	N	426	303
Cryptomonas curvata	P	P	N	N	49.9	184
Cryptomonas reflexa	181	147	N	N	N	N
Cryptomonas sp.	94.0	90.0	N	N	N	N
CHRYSOPHYTA						
Kephyrion sp.	7.23	0.80	N	N	N	N
Dinobryon divergens	36.2	40.5	N	N	N	N
Dinobryon sertularia	36.2	37.7	N	N	P	P
Desmarella sp.	P	P	N	N	N	N
Unidentified statospore	N	N	N	N	P	P
PYRROPHYTA						
Glenodinum sp.	28.9	17.4	N	N	N	N
Ceratium hirundinella	N	N	P	P	N	N
EUGLENOPHYTA						
Phacus pyrum	253	219	N	N	N	N
Phacus sp.	7.23	35.4	4.39	8.30	P	P
Trachelomonas planctonica	68.7	264	4.39	32.8	156	471
Euglena acus	N	N	P	P	6.66	24.8
CHLOROPHYTA						
Sphaerocystis schroeteri	N	N	527	24.0		
Scenedesnys acynubatys	P	P	26.4	1.47	52.4	2.26
Scenedesnys arcyatys	57.9	1.89	141	4.22	P	P
Scenedesmus bijuga	325	4.87	483	7.41	1692	18.0
Scenedesmus quadricauda	130	7.35	158	10.1	246	12.7
Quadrigula closteroides	P	P	N	N	N	N
Ankistrodesmus convolutus	181	2.60	35.1	0.36	26.2	0.24
Koliella sp.	N	N	P	P	20.0	1.02
Kirchneriella elongata	N	N	N	N	20.0	1.03
Kirchneriella lunaris	36.2	2.20	52.7	1.70	P	P
Dictyosphaerium sp.	P	P	501	12.0	118	2.43
Oocystis sp.	79.6	10.0	1467	158	341	56.5
Gloeotilla pelagica	499	11.3	N	N	N	N
Binuclearia eriensis	N	N	70.3	6.33	P	P
Coeloastrum microporum	N	N	N	N	420	43.5
Pediastrum tetras	N	N	70.3	6.71	P	P
Pediastrum boryanum	P	P	P	P	P	P
Elakatothrix sp.	P	P	96.6	2.78	P	P
Tetrastrum glabrum	N	N	70.3	1.54	93.7	1.35
Tetraedrom trignum	7.23	3.84	P	P	N	N
Chlamydomonas sp.	116	17.0	N	N	P	P
Chlamydomonas sp.	43.4	2.77	N	N	N	N
Lagerheimia quadriseta	14.5	0.11	N	N	N	N
Chlamydomonas sp.	21.7	3.03	N	N	N	N
Crucigenia tetrapedia	P	P	N	N	P	P
Cosmarium sp.	P	P	N	N	N	N
Eudorina elegans	P	P	P	P	P	P
Clostserium actum	N	N	4.39	2.73	N	N
Crucigenia rectangularis	N	N	141	3.33	P	P
Volvox aureus	N	N	P	P	N	N
Mougeotia sp.	N	N	P	P	N	N
Coeclaostrum cambricum	N	N	P	P	N	N
Closterium sp.	N	N	P	P	N	N
Pediastrum duplex var calthratum	N	N	N	N	P	P
Char racium sp.	N	N	N	N	P	P
Staurastrum sp.	N	N	N	N	P	P
Crucigenia quadrata	N	N	N	N	P	P
Sorastrum spinulosum	N	N	P	P	N	N
CYANOPHYTA						
Oscillatoria sp.	333	11.0	N	N	N	N
Oscillatoria limnetica	362	4.18	N	N	N	N
Anabaena sp.	166	7.86	1722	166	N	N
Anabaena planetonica	N	N	237	37.6	N	N
Aphanizomenom flos-aquae	N	N	6633	280	1710	64.7
Pseudanabaena sp.	N	N	351	2.30	511	7.29
Chroococcus limneticus	N	N	378	4.63	772	7.03
Unidentified akinete	N	N	8.79	5.73	N	N
Gomphosphaeria naegelianum	N	N	N	N	998	3.34
Merismopedia sp.	N	N	N	N	52.4	0.03
TOTAL	**4448**	**1925**	**13 960**	**1245**	**11 134**	**1920**

P = present but not encountered in routine cell counts; N = not observed.

Table G2 Cell counts (cells·mL^{-1}) and cell volumes (µm^3·10^3·mL^{-1}) of phytoplankton from Ruth Lake (Station RL-P), 1984.

	15 June		24 July		23 September	
	Number	Volume	Number	Volume	Number	Volume
BACILLARIOPHYTA						
Melosina granulata (large)	416	250	172	87.1	N	N
Melosira granulata (small)	N	N	159	24.4	15.7	2.60
Nitzschia acicularis	98.4	16.0	36.9	9.24	6.55	2.30
Nitzschia palea	36.5	8.78	P	P	5.24	1.01
Unidentified centric	139	72.8	P	P	P	P
Asterionella formosa	7.29	1.74	N	N	N	N
Unidentified diatoms (4)	14.58	2.82	6.06	1.81	5.24	5.17
Synedra sp.	N	N	3.03	12.9	N	N
Diatoma elongatum	P	P	P	P	P	P
Cocconeis sp.	P	P	N	N	P	P
Fragilaria sp.	P	P	P	P	P	P
Fragilaria crotonensis	P	P	N	N	P	P
Nitzschia sp.	P	P	N	N	N	N
Synedra acus	P	P	N	N	P	P
Stephanodiscus hantzschii	N	N	P	P	N	N
Cymbella sp.	N	N	N	N	P	P
Tabellaria floculosa	N	N	N	N	P	P
Synedra ulna	N	N	N	N	P	P
Gyrosigma sp.	N	N	N	N	P	P
Gomphonema sp.	N	N	N	N	P	P
CRYPTOPHYTA						
Rhodomonas minuta	N	N	12.3	1.19	435	60.9
Cryptomonas erosa	65.6	53.7	36.4	22.3	73.4	41.1
Cryptomonas curvata	14.6	77.9	P	P	9.18	39.9
CHRYSOPHYTA						
Dinobryon divergens	416	428	N	N	N	N
PYRROPHYTA						
Peridinium sp.	14.6	99.7	6.06	26.2	P	P
Ceratium hirundinella	N	N	6.06	272	N	N
Glenodinium sp.	N	N	N	N	10.5	14.0
EUGLENOPHYTA						
Trachelomonas sp.	29.2	142	24.2	106	36.7	84.1
Euglena acus	14.6	101	P	P	P	P
Phacus sp.	21.9	62.4	P	P	3.77	13.0
Trachelomonas plactonica	72.9	339	N	N	N	N
Trachelomonas sp.	N	N	N	N	1.26	3.75
CHLOROPHYTA						
Sphaerocystis schroeteri	2384	332	P	P	N	N
Scenedesmus acuminatus	29.2	0.52	54.5	5.58	86.5	5.32
Scenedesmus arcuatus	N	N	P	P	N	N
Scenedesmus bijuga	766	12.6	578	11.8	49.8	1.18
Scenedesmus incrassatulus	N	N	P	P	N	N
Scenedesmus quadricuata	401	19.8	P	P	N	N
Quadrigula closteroides	14.6	0.59	P	P	N	N
Ankistrodesmus convolutus	314	19.2	42.4	0.97	15.7	0.14
Koliella sp.	7.29	0.45	P	P	2.51	0.19
Kirchneriella lunaris	160	4.50	N	N	10.5	0.30
Dictyosphaerium sp.	124	6.24	443	10.2	N	N
Oocystis sp.	277	54.0	1266	49.7	13.1	5.34
Gloetilla pelagica	1575	37.3	N	N	N	N
Binuclearia eriensis	N	N	49.2	5.43	N	N
Coeloastrum microporum	21.9	12.0	424	22.7	N	N
Pediastrum tetras	80.2	6.35	P	P	N	N
Pediastrum boryanum	P	P	N	N	N	N
Elakatothrix sp.	21.9	0.70	18.2	0.55	N	N
Tetrastrum glabrum	29.2	0.42	P	P	N	N
Tetraedron trigonum	21.9	20.9	N	N	N	N
Tetraedron caudatum	7.29	1.10	N	N	N	N
Cosmarium sp.	7.29	3.76	P	P	N	N
Chlamydomonus sp.	36.5	5.33	N	N	N	N
Tetraedron minimum	P	P	P	P	N	N
Closterium actum var. variabile	P	P	N	N	N	N
Staurodesmus sp.	P	P	P	P	N	N
Tedraedron limneticum	P	P	N	N	N	N
Crucigenia tetrapedia	P	P	N	N	N	N
Crucigenia rectangularis	N	N	242	12.6	N	N
Chlamydomonas sp.	N	N	73.8	106	N	N
Closterium actum	N	N	12.3	9.19	N	N
Staurastrum sp.	N	N	P	P	N	N
Coeloastrum cambricum	N	N	P	P	N	N
Scenedesmus denticulatus	N	N	P	P	N	N
Caracium sp.	N	N	N	N	1.26	2.98
Sorastrum spinulosum	N	N	N	N	P	P
CYANOPHYTA						
Pseudanabaena sp.	437	4.02	148	1.23	133	1.10
Chroococcus limneticus	87.5	0.90	545	6.68	N	N
Chroococcus dispersus	241	0.74	N	N	N	N
Anabaena sp.	2333	97.3	1139	125	N	N
Anabaena planctonica	P	P	160	43.2	N	N
Aphanizomenom flos-aquae	N	N	43338	139	P	P
Gomphosphaeria naegelianum	N	N	1770	9.29	N	N
Lyngbya sp.	P	P	N	N	N	N
Merismopedia glauca	P	P	N	N	N	N
Pseudanabaena constricta	P	P	N	N	P	P
Dactylococcus Smithii	N	N	N	N	P	P
Spirulina sp.						
TOTAL	10 738	2297	50 765	1122	915	284

P = present but not encountered in routine cell counts; N = not observed.

Table G3 Cell counts (cells·mL^{-1}) and cell volumes ($\mu m^3 \cdot 10^3 \cdot mL^{-1}$) of phytoplankton from Poplar Creek Reservoir (Station PCR-P), 1984.

	15 June		24 July		23 September	
	Number	Volume	Number	Volume	Number	Volume
BACILLARIOPHYTA						
Melosira granulata (large)	P	P	216	144	269	219
Melosira granulata (small)	N	N	111	16.9	96.2	16.3
Nitzschia acicularis	32.1	5.28	P	P	P	P
Nitzschia palea	12.8	1.26	N	N	6.41	1.58
Asterionella formosa	25.7	6.36	P	P	12.8	3.41
Unidentified centric	38.5	30.0	6.56	10.1	P	P
Diatoma elongatum	64.1	30.5	9.83	5.47	P	P
Synedra acus	23.5	39.5	19.7	31.5	4.17	9.31
Unidentified	N	N	6.56	5.40	N	N
Tabellaria fenestra	N	N	P	P	N	N
Synedra sp.	N	N	P	P	N	N
Gyrosigma sp.	N	N	P	P	P	P
Amphora sp.	N	N	P	P	P	P
Stephanodiscus hantzschii	N	N	N	N	12.5	8.44
Gomphonema sp.	N	N	N	N	P	P
Nitzschia linearis	N	N	N	N	P	P
Synedra cyclopum	N	N	N	N	P	P
Fragilaria sp.	N	N	N	N	P	P
Synedra ulna	N	N	N	N	P	P
CRYPTOPHYTA						
Rhodomonas minuta	135	31.4	N	N	325	67.5
Cryptomonas erosa	44.9	42.1	6.56	2.39	70.5	124
Cryptomonas curvata	12.8	60.6	N	N	P	P
Cryptomonas reflexa	25.7	19.9	N	N	6.41	3.84
CHRYSOPHYTA						
Dinobryon divergens	6.41	6.38	13.1	14.3	N	N
Dinobryon sertularia	11.8	9.98	N	N	N	N
PYRROPHYTA						
Peridinium sp.	22.4	30.4	P	P	N	N
Glenodinium sp.	P	P	N	N	25.0	19.4
Gymnodinium umberrimun	P	P	N	N	N	N
Ceratium hirundinella	P	P	N	N	N	N
EUGLENOPHYTA						
Trachelomonas planctonica	35.3	117	197	379	76.6	235
Trachelomonas spinulosa	P	P	P	P	12.5	60.5
Phacus sp.	25.7	77.2	6.56	18.4	N	N
Euglena acus	P	P	P	P	P	P
CHLOROPHYTA						
Sphaerocystis schroeteri	205	26.9	26.2	1.97	500	69.8
Scenedesmus acuminatus	12.8	0.47	N	N	P	P
Scenedesmus arcuatus	N	N	P	P	87.9	6.59
Scenedesmus bijuga	115	1.03	117	1.43	788	10.9
Scenedesmus incrassatulus	N	N	26.2	1.01	N	N
Scenedesmus quadricauda	69.8	3.16	P	P	113	5.78
Quadrigula closteroides	P	P	26.2	0.38	N	N
Ankistrodesmus convolutus	231	1.30	85.2	1.20	713	10.4
Koliella sp.	38.5	1.50	P	P	62.5	3.17
Kirchneriella elongata	N	N	N	N	51.3	0.59
Kirchneriella lunaris	6.41	0.15	N	N	25.7	0.39
Dictyosphaerium sp.	802	22.2	269	8.46	1251	39.2
Oocystis sp.	160	14.2	315	30.5	350	21.3
Gloeotilla pelagica	83.4	1.59	N	N	N	N
Binuclearia eriensis	N	N	1275	19.9	19.2	2.43
Pediastrum tetras	N	N	P	P	N	N
Pediastrum boryanum	N	N	P	P	N	N
Elakatothrix sp.	N	N	19.7	1.02	N	N
Tetrastsruk glabrum	P	P	N	N	50.0	1.08
Chlanydomonas sp.	6.41	0.27	N	N	N	N
Lagerheimia quadriseta	12.8	0.32	N	N	N	N
Characium sp.	6.41	0.19	N	N	N	N
Crucigenia rectangularis	32.1	0.19	157	4.62	385	8.20
Crucigenia tetrapedia	51.3	0.38	N	N	100	1.14
Glenodinium sp.	P	P	N	N	N	N
Closterium actum	P	P	P	P	N	N
Tetraedron minimum	P	P	P	P	N	N
Mougeotia sp.	P	P	N	N	N	N
Treubaria varia	N	N	6.56	2.85	N	N
Coeloastrum cambricum	N	N	P	P	N	N
Staurastrum sp.	N	N	P	P	N	N
Sorastrum spinulosum			P	P	N	N
Cosmarium sp.	N	N	P	P	N	N
Closterium actum var variabile	N	N	N	N	P	P
Closterium sp.	N	N	N	N	P	P
Cosmarium sp.	N	N	N	N	P	P
CYANOPHYTA						
Pseudanabaena sp.	1449	11.6	85.2	0.68	10142	92.4
Aphanizomenom flos-aquae	526	180	19301	498	4662	170
Gomphosphaeria naegelianum	345	1.16	446	1.49	705	2.36
Dactylococcus sp.	423	3.29	N	N	N	N
Chroococcus dispersus	323	1.32	184	1.39	638	4.41
Anabaena sp.	1122	71.6	275	16.7	P	P
Unidentified akinete (2)	N	N	52.5	29.3	N	N
Anabaena planctonica	P	P	52.4	12.0	327	74.8
Oscillatoria sp.	P	P	N	N	N	N
Lyngbya sp.	P	P	N	N	N	N
Chroococcus limneticus	N	N	164	0.85	N	N
Marssoniella elegans	N	N	P	P	N	N
Unidentified	N	N	P	P	N	N
Merismopedia sp.	N	N	N	N	P	P
TOTAL	**6538**	**851**	**23 476**	**1261**	**21 868**	**1293**

P = present but not encountered in routine cell counts; N = not observed.

APPENDIX H

ZOOBENTHOS
MULTIVARIATE ANALYSES

By

Dr. J. Ciborowski

APPENDIX H

ZOOBENTHOS MULTIVARIATE ANALYSES

Resolution of the 19 lotic benthic stations within the Syncrude Development area into discrete groupings based on composition of abundant zoobenthos taxa was good in spring and summer, but poor in fall. In spring, both principal component analysis (PCA, Figure H1) and similarity analysis (SA, Figure H2) detected two groupings of benthic stations (A/B and C/D/E, separated by a solid line). The first principal component axis accounted for 39.0% of variation among stations. High scores along this axis were positively correlated with abundance of **Baetis**, Simuliidae, Chironomidae, and Oligochaeta, and were negatively correlated with abundance of **Caenis**. Included in the former grouping were the two upstream MacKay River stations (MR-B3 and MR-B4), MacKay River tributary stations (M2-B and M6-B), and station WID-B1. These stations were characterized by moderate to rapid flow over relatively unsilted substrate; both are factors conducive to development of a strongly rheophilic fauna. Within this grouping, two subgroups (A and B) were discerned. These were separated along the second principal component, which accounted for 25.6% of variation. High scores were associated with high densities of Simuliidae, whereas low scores were correlated with abundant Oligochaeta and Chironomidae populations. Stations in one subgroup (A) included MR-B3, MR-B4, M2-B, DR-B, PC-B1, and PC-B2. These stations exhibit a relatively wide, exposed, shallow channel form that provides ample solar radiation to permit a large degree

CODE	STATION	CODE	STATION
1	MR-B1	10	PC-B3
2	MR-B2	11	PC-B4
3	MR-B3	12	WID-B1
4	MR-B4	13	W3-B
5	M2-B	14	WID-B2
6	DR-B	15	BRC-B
7	M6-B	16	LBC-B2
8	PC-B1	17	LBC-B1
9	PC-B2	18	UBC-B
		19	B1-B

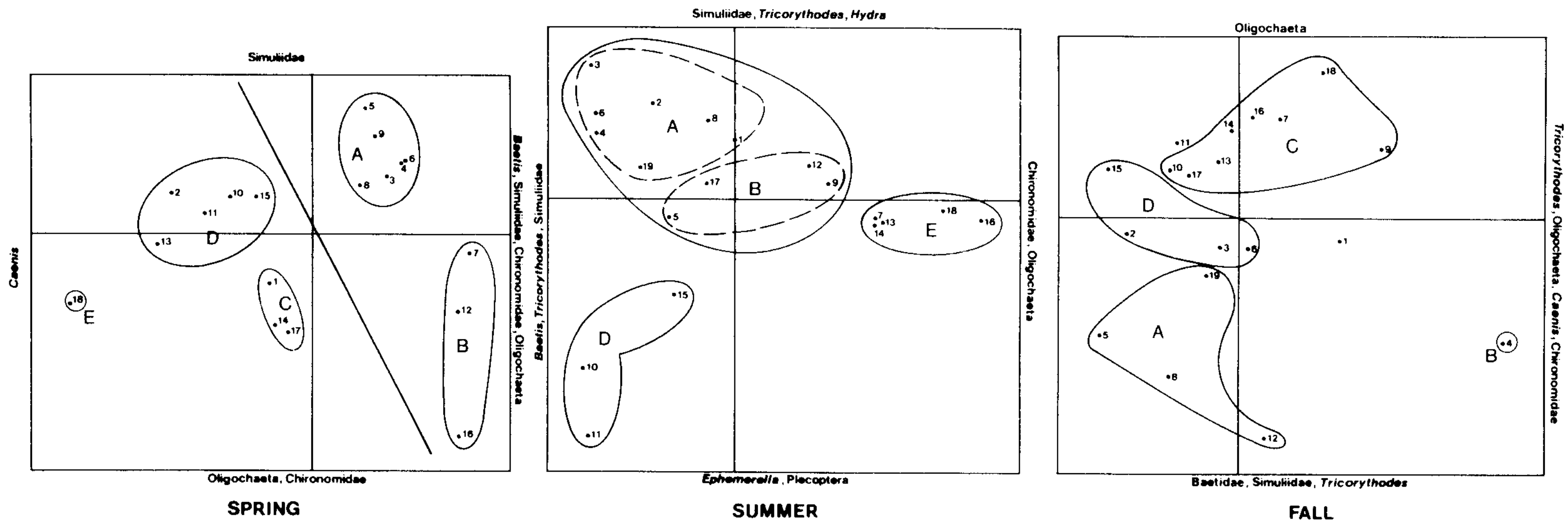

Figure H1 Principal component analysis of benthic samples in study area, 1984.

CODE	STATION	CODE	STATION
1	MR-B1	10	PC-B3
2	MR-B2	11	PC-B4
3	MR-B3	12	WID-B1
4	MR-B4	13	W3-B
5	M2-B	14	WID-B2
6	DR-B	15	BRC-B
7	M6-B	16	LBC-B2
8	PC-B1	17	LBC-B1
9	PC-B2	18	UBC-B
		19	B1-B

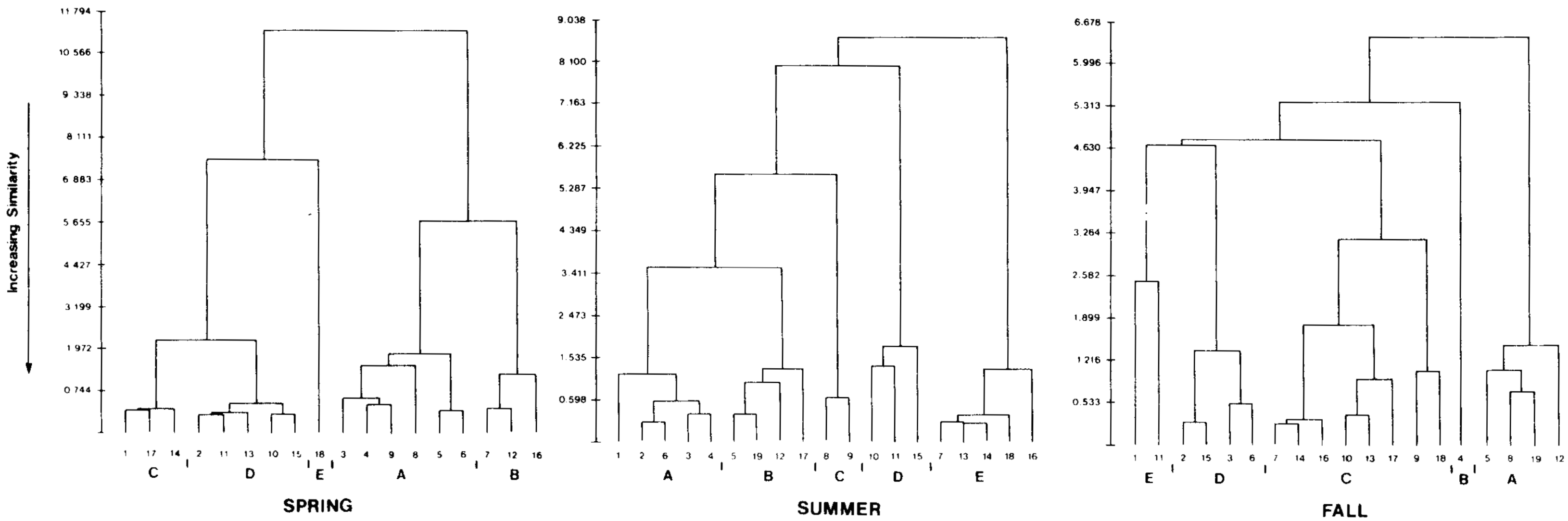

Figure H 2 Cluster Dendograms indicating similarity among benthic sites, 1984.

of autotrophy. These factors enhance the development of a high quality seston source, which is of major importance in filter-feeding based benthic communities. The remaining three stations (Group B) were not well clustered. Stations M6-B and WID-B1 were structurally dissimilar, but both received poor quality carbon inputs from upstream sources -- a beaver pond in the former instance, and stands of macrophytes in the latter. Zoobenthos at station LBC-B2 were highly autotrophic, which may be the result of abundant growths of periphyton on the rock substrates inhibiting development of a dense filter-feeding population.

Stations that clustered in the second major grouping (C/D/E) could also be subdivided. The separation cannot be ascribed to abundance or rarity of any single taxonomic group, except in the case of UBC-B (subgroup E), where **Caenis** was abundant. Clustering of stations within subgroup C was somewhat anomalous from a structural perspective. Stations MR-B1 and LBC-B1 were both moderate-flow stations that showed evidence of siltation; however, the closely clustered station WID-B2 was markedly depositional, with minimal flow and dense macrophytic growth. With regard to subgroup D, stations PC-B3, PC-B4, and BRC-B were similar in terms of flow, substrate composition, and shading, yet the biotic similarity of these with MR-B2 (a wide, fast-flowing, silted station) and W3-B (an open, dystrophic, depositional station) cannot readily be explained.

Similarity analysis of summer data provided discrete clustering of stations into five general groups (A to E; Figure H2). The MacKay River mainstem and Dover River stations formed a single group (A) of high similarity. These were linked to a second group (B) consisting of smaller creeks that had an open canopy and moderate flow over gravel or cobble substrate (stations M2-B, B1-B, WID-B1, and LBC-B1). The downstream Poplar Creek stations (PC-B1 and PC-B2) were similar to each other (group C), but joined the above two groups at a relatively low level of similarity.

Small shaded creeks with moderate flow and low overall benthic densities formed a fourth group (D; stations PC-B3, PC-B4, and BRC-B). The remaining group (E) consisted of the depositional stations (W3-B, WID-B2, UBC-B) and two small creeks with erosional characteristics but high organic input from either autochthonous (LBC-B2) or allochthonous (M6-B) sources.

Principal component analysis of the summer data accounted for 56.1% of variation among stations. The first principal component axis accounted for 30.1% and was positively correlated with abundance of Chironomidae and Oligochaeta, but negatively associated with **Baetis, Tricorythodes** (Ephemeroptera), and Simuliidae. Depositional stations tended to have high densities of the former organisms and formed a fairly compact group (E; Figure H1). The second principal component accounted for 26.0% of variation among stations. High scores were positively associated with abundance of filter-feeding organisms (Simuliidae, **Hydra**) and **Tricorythodes**, whereas low scores correlated with the mayfly **Ephemerella** and detritivorus plecopterans. Two diffuse groupings could be distinguished on the basis of this axis. The first (A/B; solid circle) consisted of open-canopy, erosional stations, which presumably are capable of maintaining a high quality seston supply resulting from periphytic growth on hard substrates. MacKay River mainstem stations (MR-B1 to MR-B4), DR-B, and PC-B1 appeared to form a subgroup (A; dashed circle) within this cluster. The smaller streams and PC-B2 seemed to fall within another subgroup (B; dashed circle), having higher densities of Chironomidae. This subgrouping may reflect differences in the amount of particulate detrital material in substrates. The second grouping (D) consisted of shaded, erosional stations, where benthic communities likely rely heavily on allochthonous energy inputs.

Analysis of fall data provided relatively poor resolution of station groupings. Principal component analysis accounted for 46.3% of variation among stations. The first principal component accounted for 25.6% of variation and was positively correlated with abundance of the mayflies **Tricorythodes** and **Caenis**, Chironomidae, and Oligochaeta. Stations MR-B1, MR-B4, PC-B2, and UBC-B could be distinguished from other stations as supporting these taxa in abundance, yet they were dissimilar to one another (Figure H2). The second principal component was positively correlated with Oligochaeta abundance, but negatively correlated with abundance of Simuliidae, Baetidae, and **Tricorythodes**. Stations M2-B, PC-B1, B1-B, and WID-B1 exhibited similar high Simuliidae densities and low Oligochaeta abundance (group A; Figure H1). Large Oligochaeta populations were found at stations M6-B, PC-B2, PC-B3, W3-B, WID-B2, LBC-B1, LBC-B2, and UBC-B (group C); these stations also supported low to moderate densities of mayflies. A third grouping (D) showed relatively high interstation similarity (stations MR-B2, MR-B3, DR-B, and BRC-B; Figure H2), and formed an intermediate cluster between the other two groupings (Figure H1).

Grouping on the basis of zoobenthic composition could not be related to structural or geographic characteristics of stations during fall. This may be partly because the taxa that best separated stations (excepting Simuliidae) are forms that overwinter as immatures and rely largely on detrital material for nutrients. Furthermore, few of these taxa actually grow during the winter months. It is possible that the distribution of overwintering organisms among stations is more constrained by microtopographical features that contribute to factors such as winter discharge conditions, depth of ice formation, groundwater inputs, and severity of spring runoff, than by aspects of the stream habitats themselves. Analysis of such features, however, is beyond the scope of the present study.

Conditions of Use

R.L. & L. Environmental Services Ltd. and A.A. Aquatic Research Ltd., 1985. A study of aquatic environments in the Syncrude development area, 1984. Syncrude Canada Ltd., Edmonton, Alberta. Environmental Research Monograph 1985-3. 361 pp. plus appendices