WATER QUALITY AND AQUATIC RESOURCES OF THE BEAVER CREEK DIVERSION SYSTEM, 1977

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Chemical and Geological Laboratories Ltd.

Environmental Research Monograph 1978-3

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Syncrude Canada Ltd.

FOREWORD

Syncrude Canada Ltd. is producing synthetic crude oil from Crown Lease 17, Alberta. Chemical and Geological Laboratories Ltd. was commissioned to study the water quality and aquatic resources of the system which was formed when Beaver Creek was diverted away from the developed area. The study is the third in a continuing program to assess the environmental impact of the diversion.

Syncrude's Environmental Research Monographs are published verbatim from the final reports of professional environmental consultants. Only proprietary technical or budget-related information is withheld. Because we do not necessarily base our 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 questions or comments to Syncrude Environmental Affairs, 10030 - 107 Street, Edmonton, Alberta T5J 3E5.

RECLAIMING TAILINGS SAND

Once oil sand has yielded its valuable content of bitumen, only fine clay and coarse sand are left.

At the Syncrude plant, the clay remains suspended in the hot water that is used to release the bitumen from the sand. However, the tailings sand (as it is called) settles as soon as the water stops moving.

The tailings sand, clay and water are piped out of the plant as a slurry. The sand is being used to build a dyke around the tailings pond north of the plant, to enable all of Syncrude's waste process water to be held within the lease boundaries.

Once the tailings pond dykes have been built (a job that will take several years) the slurry will be pumped south from the plant to the centre of the mine pit. The tailings sand will be deposited in a cell between two dykes which extend across the pit. The clay/water mixture will be pumped north to the tailings pond for settling and eventual re-use.

When the pile of tailings sand between the in-pit dykes is big enough, reclamation of its surface will begin. Syncrude plans to mix peat (drained muskeg) and clay into the tailings sand to improve its fertility and to strengthen it to support plant growth.

Next a mixture of fertilizer and seeds of both native and commercially available plants will be applied to protect the surface and to provide the basis for a diverse plant community.

While the initial mix of grasses and legumes is stabilizing the surface and beginning to recycle nutrients in the soil, native and "introduced" tree and shrub seedlings grown in Syncrude's on-site greenhouse will be planted. Meanwhile, new cells of tailings sand will be started on either side of the first cell, and the same sequence of surface reclamation will begin for them.

The objective of the program is to create a stable land surface covered with a mixture of vegetation that is self-supporting and at least as productive as the surrounding undisturbed plant communities. Syncrude's reclamation personnel are confident that it can be done.

Syncrude

ENVIRONMENT

BULLETIN

Does Syncrude's tailings pond pose a threat to birds?

Yes it does, and Syncrude is committed to minimizing that threat.

The tailings pond holds water that has been used in the plant to extract bitumen from tar sand. A small portion of the bitumen is unrecoverable in the plant and ends up floating on the tailings pond. It is this bitumen which could be hazardous to birds.

The bitumen can destroy the insulating properties of feathers, and it can hinder a bird's ability to fly. In addition, an oiled bird can ingest bitumen while trying to preen itself.

Syncrude has initiated a broad program to minimize the contact between birds and bitumen.

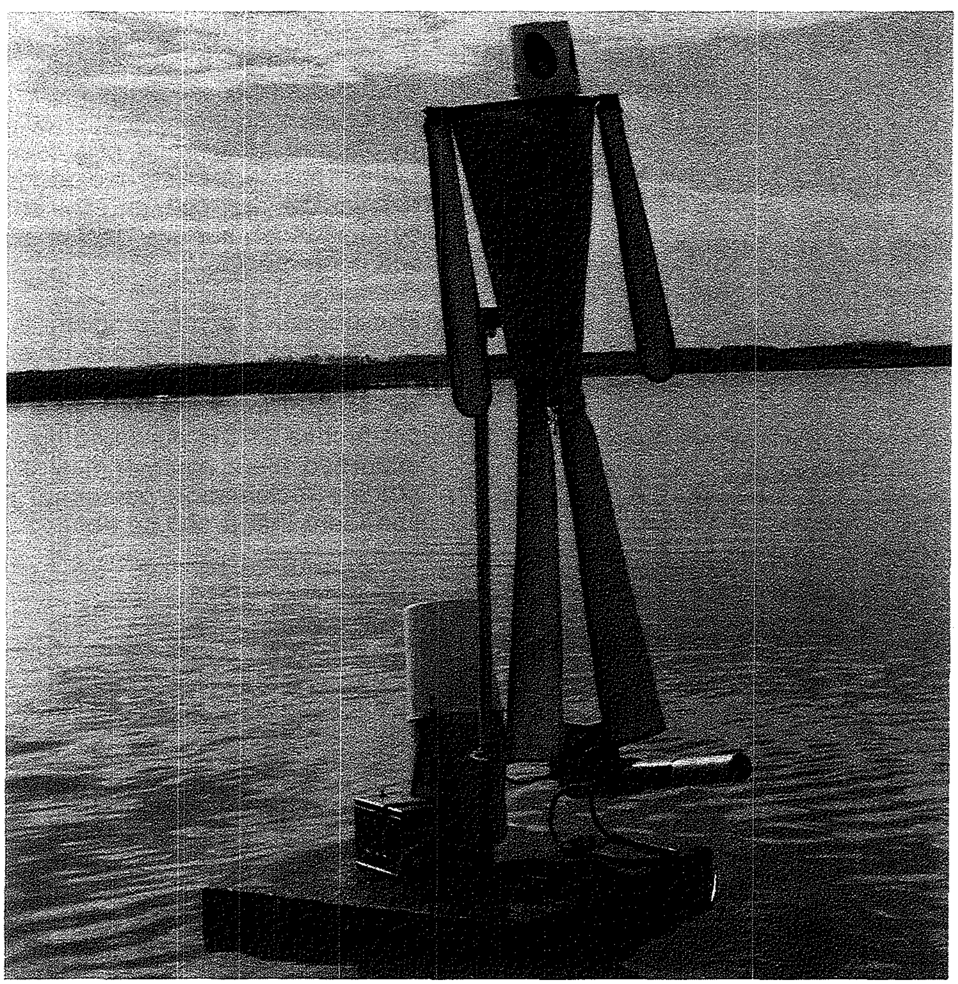
The shorelines of the pond are being kept clear of vegetation to make them as unattractive to birds as possible. Meanwhile, habitats elsewhere on the lease have proven to be attractive and healthy to both resident and migratory birds.

Bitumen on the pond is being confined by surface booms, and a skimming device is being tested to collect the bitumen from the surface of the pond.

The most novel component of the program is a mechanical scarecrow (fondly called Bitu-man) developed by Syncrude's environmental staff. Bitu-man stands almost 2½ meters tall and is mounted on a raft. The figure is balanced to imitate human movements when the wind is blowing, while a pair of eyes give additional realism to the life-like effect. To cap it off, a propane noise-maker on the raft makes a shotgun-like explosion at frequent intervals. Syncrude plans a small army of these Bitu-men to keep migratory birds away from the oily areas of the pond.

In the remote chance that a member of a rare or endangered species should become oiled with bitumen, Syncrude will co-operate with Alberta Fish & Wildlife in capturing the bird and transporting it safely to a treatment and rehabilitation centre such as the one planned for Brooks, Alberta.

In summary, Syncrude is minimizing the contact between birds and bitumen with a three-step program. First the whole tailings pond is made as unattractive as possible relative to the surrounding habitats. Second, the portion of the pond potentially hazardous to birds is kept as small as possible through the use of oil containment and clean-up devices. Finally, a mechanical scarecrow is deterring birds from landing on the potentially hazardous areas.



Bitu-man, Syncrude's mechanical scarecrow, keeps migrating birds away from the hazardous portions of the tailings pond.

How does Bitu-man work?

Bitu-man, Syncrude's mechanical scarecrow, works by convincing birds that it is alive and a possible threat. The birds' first reaction is to seek a less risky landing site.

Bitu-man is 2½ meters tall and covered in conspicuous orange fabric. The illusion of life is created through erratic wind-driven movements of the carefully balanced figure, and by two exaggerated eyes on the head. A propane noise-maker imitates the sound of a shotgun every three minutes, day and night. To be visible at night, the figure is illuminated softly from within. Bright lights were avoided so as not to attract birds.

Water birds are accustomed to objects which bob on waves, so the raft holding Bitu-man is heavily stabilized and weighted. The raft is anchored with a long chain, so that the deterrent moves downwind to confront approaching birds, which usually land into the wind.

The devices require fresh propane and batteries once a week. The most effective spacing on the pond is being determined through field trials.

A recent government report said that the technology exists for Syncrude to reduce its SO_2 emissions from 287 long tons per day to between 58 to 78 long tons per day. Why isn't Syncrude using this technology?

(A joint federal-provincial study described the development of sulphur dioxide control technology between 1972 and 1975. According to the report, the technology became available by 1976 that would enable Syncrude to reduce its sulphur dioxide emissions from 287 long tons per day to between 58 and 78 long tons per day.)

Syncrude does not dispute the committee's conclusion that by 1976 the technology existed to further reduce sulphur emissions. But environmental need, the reason for sulphur control technology in the first place, is not addressed in the report. Is there a real environmental need to use the new technology? Will the combined emissions of Syncrude and Great Canadian Oil Sands, the other operational oil sands plant, pose a threat to the environment?

The evidence says no. The predicted concentrations of sulphur dioxide at ground level are below the levels known to endanger plants and animals. For this reason, additional sulphur control systems have not been installed.

The design of the Syncrude plant was finalized in 1972. The plant incorporated the best proven technology available at that time and the design satisfies all legal and environmental requirements. So here's Syncrude's case. At some point in time the design of a large plant must be finalized. For Syncrude that point occurred in 1972, when it became clear that environmental standards could be met using existing, proven technology.

Technology has naturally continued to advance and several techniques have evolved since 1972 that seem to be effective. Syncrude's emissions do not pose a threat to the environment. There is no apparent environmental need to reduce emissions.

Of course the actual levels of sulphur dioxide, not the predicted levels, are what determine the effect on the environment. So monitoring systems are necessary to show what is actually happening downwind of the plant.

Syncrude has three separate air quality monitoring programs: a set of five continuous electronic monitors, which report at one-minute intervals; a system of forty static "candles", which are analyzed monthly for total sulphur; and a unique living grid of 56 lichen plots. Lichens are sensitive to low levels of sulphur dioxide, and function as an "early warning system" of environmental damage. All of these monitoring systems were in place a year before plant start-up.

Based on what is known today, implementing additional sulphur removal techniques for normal plant operations just doesn't make sense. There is no potential for serious environmental damage, partly because Syncrude is removing and storing 89 per cent of the sulphur that enters the plant via the oil sand. According to the government report, removing all or part of the remaining 11 per cent that is dispersed from the stack could require an initial investment of \$28 - \$48 million for the purchase of equipment, plus the cost of modifications to the plant, plus an additional \$6.6 - \$10.6 million yearly to operate the equipment. That's a great deal to spend without necessarily providing any benefit to the environment.

How do Alberta's sulphur dioxide regulations compare with those in the rest of Canada?

The following table summarizes the SO_2 information that the Syncrude Environment Bulletin received from the various provinces and the federal government.

MAXIMUM AVERAGE CONCENTRATIONS OF SO_2, IN PPM (BY VOLUME)

	ALTA.	FEDERAL		B.C.		SASK.	MAN.		ONT.	QUE.	N.B.	N.S.	P.E.I.	NFLD.
		D*	A**	D*	A**		D*	A**						
½ hr.	.20	—	—	—	—	—	—	—	.30	No Information Supplied		No Information Supplied	.30	.30
1 hr.	.17	.17	.34	.17	.34	.17	.17	.34	.25		.17		.25	.25
24 hr.	.06	.06	.11	.06	.10	.06	.06	.11	.10		.06		.11	.10
1 yr.	.01	.01	.02	.01	.02	.01	.01	.02	.02		.01		.02	.02

D* — Desirable
A** — Acceptable

Publications from Syncrude

Syncrude is continuing to add to the scientific literature by publishing environmental research monographs. Monographs are published verbatim from the final reports of professional environmental consultants. Individuals and organizations may request specific monographs or be included on the mailing list for forthcoming publications by writing to Environmental Affairs, Syncrude Canada Ltd., 10030 - 107 Street, EDMONTON, Alberta T5J 3E5.

Recently Published Monographs

1977-3 Toxicity of Saline Groundwater from Syncrude's Lease 17 to Fish and Benthic Macroinvertebrates

Mining the oil sand on Lease 17 requires that the mine area first be dewatered. A variety of fish and aquatic insects were tested to determine an environmentally safe concentration of the mine water, so that the water could be added to natural surface drainage with little or no risk of toxic effects.

1977-4 Continued Studies of Soil Improvement and Revegetation of Tailings Sand Slopes

The second year of detailed research into the revegetation of tailings sand slopes provided information about the effects of different surface amendments and fertilizer applications on erosion, nutrient run-off and plant growth. It was concluded that plants cannot successfully be established on unfertilized tailings sand, but that peat added to the surface will encourage rooting and growth. However, initial rooting is largely limited to the peat layer.

1977-5 Air Quality Monitoring with a Lichen Network: Baseline Data

Before plant operations began, Syncrude established a network of 56 lichen plots in a pattern radiating outward from the plant. Lichens are sensitive to changes in air quality. Although the vitality of only a few lichen species will be monitored at the 56 sites, a total of 121 species of lichens and 136 species of mosses are recorded in the report.

1977-6 Vegetation Types and Forest Productivity, West Part of Syncrude's Lease 17, Alberta

Vegetation types in the undisturbed portion of Syncrude's lease were mapped and the productivity of the forest was assessed. The information on productivity is especially useful for setting reclamation objectives, as it shows Syncrude's reclamation specialists how productive the reclaimed mine site should be.

1978-1 Soil Survey of a Portion of the Syncrude Lease 17 Area, Alberta

Soils in the undisturbed portion of Lease 17 were surveyed to provide an inventory of materials available for reclamation activities (which require peat and clay) and construction activities (requiring mainly sand and gravel). Chemical and physical analyses were performed on fifteen soil profiles, and a map was produced from information collected at 413 inspection sites.

1978-2 Historical Resources Impact Assessment, Western Portion of Syncrude Lease No. 17, Alberta

In 1973 Syncrude surveyed the archaeological potential of the area of Lease 17 that was about to be developed for the current plant. The rest of the lease was surveyed during 1977, and in contrast with the developed portion, remarkably little evidence was found of prehistoric or historic use by man. The difference is likely due to the predominance of muskeg in the undeveloped area, which would hinder the early hunters' travel during the warm months of the year.

1978-3 Water Quality and Aquatic Resources of the Beaver Creek Diversion System, 1977

In 1975 Beaver Creek was diverted away from the mine area and into the drainage basin of Poplar Creek. Two new waterbodies were created, and the flow in Poplar Creek more than doubled. During 1977, physical, chemical and biological parameters were measured, and comparisons were made with the conditions before the diversion occurred. Although the new system is still stabilizing, the environmental effects of the diversion do not appear to have been serious.

SYNCRUDE ENVIRONMENT BULLETIN

The Syncrude Environment Bulletin is published to provide a continuing report on the environmental aspects of the Syncrude Project, and to aid in opening a two-way line of communication with the public. The Bulletin is distributed without charge to individuals and organizations concerned with the ecology of the tar sands region. For more information about Syncrude's environmental activities, or to be included on the mailing list please send your request to:

Syncrude Environment Bulletin
10030 - 107 Street
EDMONTON, Alberta
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Public and High School students are requested to include the name of their school.

Bulletin VI-I, Summer 1978

ISSN 0705-1778

Syncrude Canada Ltd.
10030 - 107 Street, Edmonton, Alberta T5J 3E5
Area Code 403 - 429-9110

Syncrude

File No: EA 620.2

September, 1978

ENVIRONMENTAL RESEARCH MONOGRAPHS 1978-1, 1978-2, 1978-3

Syncrude Canada Ltd. is continuing its program to publish environmental information, and the enclosed monographs are the twenty-third, twenty-fourth and twenty-fifth in a series.

Monograph 1978-1, "Soil Survey of a Portion of the Syncrude Lease 17 Area, Alberta", presents the results of a program which sampled 413 inspection sites in the undisturbed portion of the lease. The study provided Syncrude with an inventory of materials which can be used in construction and reclamation activities.

Monograph 1978-2, "Historical Resources Impact Assessment, Western Portion of Syncrude Lease No. 17, Alberta", reports on an archaeological survey of the undisturbed muskeg-covered portion of the lease. No important archaeological resources were discovered.

Monograph 1978-3, "Water Quality and Aquatic Resources of the Beaver Creek Diversion System, 1977" describes the environmental conditions prevalent in the Beaver Creek Diversion System, two years after it was finished. The diversion of Beaver Creek was necessary to enable the Syncrude mine to be developed.

At Syncrude we welcome your interest in our environmental activities. Please address your questions or comments to:

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ABSTRACT

The Beaver Creek Diversion System was investigated from March to November, 1977, to describe post-diversion conditions in Beaver Creek, Ruth Lake and Poplar Creek and to characterize the two newly created water bodies in the system. Ten sites in the system were sampled regularly for physical-chemical parameters, phytoplankton, zooplankton and benthic macroinvertebrates. Additional surveys were done for fish, aquatic macrophytes, stream drift and stream habitat.

Upper Beaver Creek was sampled regularly at one site. In the vicinity of the reservoir it is a meandering brown-water stream with mud banks and substrate. Creek water was well oxygenated and moderately alkaline. Benthic invertebrates were collected seasonally and although low in numbers in spring and summer, were quite abundant in fall when chironomids and the mayfly *Caenis* were prevalent. Seven species of fish still occur in the creek. Brook sticklebacks, fathead minnows, lake chub, white suckers and longnose suckers were most abundant, and northern pike and Arctic grayling were also present.

Beaver Creek was sampled regularly at two sites. This reservoir contained brown, somewhat turbid water of similar quality to Beaver Creek, showed only weak thermal stratification, and was poorly oxygenated. Floating rafts of muskeg were common. Blue-green algae bloomed in midsummer, but total phytoplankton was not dense at other times. Ultraplankton, flagellates, and green algae were the other main types of phytoplankton; Euglenophyta were common. A limited number of species of submergent plants were well established in the reservoir, but emergent macrophytes were not abundant. Crustacean zooplankton were most abundant in midsummer when cladocerans predominated. Cyclopoids were prevalent in spring and fall. Zooplankton were well distributed throughout the water column in midsummer. Chironomids and oligochaetes dominated the benthos in the profundal zone where densities were low in spring but moderate in late summer and fall. Littoral benthos was much more abundant and diverse. Brook sticklebacks, fathead minnows, white suckers and lake chub were abundant in the reservoir, and northern pike and longnose suckers were common.

Ruth Lake is a shallow water body with mud and organic substrates and a well developed littoral zone. It now receives the diverted flow of Beaver Creek via Beaver Creek Reservoir. Water levels fluctuated considerably in

1977 (they had been stable in 1974-75), and the water was browner and more turbid than before diversion. Oxygen saturation was lower than in previous years, and nutrient concentrations were much higher. These changes were probably due to the supplanting of the former lake water by diversion flows. Accompanying the higher nutrient concentrations, phytoplankton were much more abundant and diverse this year, and a blue-green algal bloom occurred. Blue-greens were unimportant in 1974-75. The submergent macrophyte *Chara* disappeared from extensive areas it dominated in 1974-75, and much of the lake's emergent plant community was stranded by low water levels this year. Crustacean zooplankton have changed noticeably in composition and abundance since 1974-75, but the exact reasons for change are less evident than for the phytoplankton. Benthic macroinvertebrates were of the same general composition and level of abundance as in previous years although organisms normally associated with aquatic vegetation declined slightly in abundance. Brook sticklebacks and fathead minnows are still abundant in the lake. White suckers have entered from the diversion canal in large numbers, and longnose suckers have appeared in smaller numbers.

Poplar Creek Reservoir, which occupies a deep ravine leading to Poplar Creek, was sampled regularly at two sites. Its water was brown-coloured, slightly turbid and resembled the other two lakes in general quality. The reservoir stratified thermally, developed an anaerobic hypolimnion, and was poorly oxygenated even near the surface. Although a blue-green algal bloom occurred in midsummer, the abundance of other phytoplankton was lower than would be expected from the high nutrient levels which occurred. Submergent aquatic plants were moderately abundant and widespread in the reservoir. Except for a dense, extensive stand of buck bean (*Menyanthes trifoliata*) at the north end of the reservoir, emergent plants were rare. Cyclopoid copepods dominated the crustacean zooplantkon in spring; cladocerans dominated in summer; and calanoid copepods were dominant in fall. Zooplankton were concentrated above the thermocline when investigated in August. Benthic macroinvertebrates were quite low in numbers but increased in late fall. The low numbers were probably due to oxygen depletion in bottom waters. *Chaoborus* and *Chironomus* were, by far, the most common organisms collected from the benthos. Sites in shallower waters contained more organisms and higher oxygen concentrations. Brook sticklebacks and fathead minnows were abundant and reproducing in the reservoir, and white suckers were present in low numbers.

Poplar Creek has been channelized from the spillway confluence to the highway to accomodate discharge from the diversion system. The discharge more than doubled flow in the lower creek but has not markedly altered its water chemistry. However, considerable organic input occurs with this inflow and benthic macroinvertebrates have increased greatly in abundance. The benthos at an upstream control site did not show distinct differences before and after diversion. Downstream of the spillway chironomids and filter feeding Simuliidae and Trichoptera increased markedly. Fish were more abundant and diverse (fifteen species) in the creek this year than in 1974-75 (five species). Brook sticklebacks, fathead minnows, and lake chub were most abundant in 1977 while white and longnose suckers were the most abundant large fish. Northern pike and Arctic grayling were common and were the most abundant sports species found.

ACKNOWLEDGEMENTS

The authors extend thanks to the personnel of Syncrude Canada Ltd., Environmental Affairs, who communicated freely with us and provided assistance throughout the study. Dr. Mike Aleksiuk and Mr. John Retallack were most understanding and communicative during the project and undertook a thorough and appreciated review of the draft report. Jerry Marchak, Terry van Meer, and others from the Syncrude Environmental Laboratory, Ft. McMurray, were most helpful and made every effort to facilitate the field work.

Thanks are due to people who were employed on the project and enabled the work to be accomplished. These persons and their areas of endeavor were as follows: Elizabeth McGuinness for processing benthic samples, tabulating and checking data, and drafting all figures; Bob Salahub for field assistance; Tim Jantzie for ageing fish scales and reviewing fisheries sections of the text; Bruce Murray for handling chemical analyses; Joe Weisgerber for assisting in identifications of macrophytes and benthic invertebrates, and Elaine Butler for providing professional editing services. Several professional persons from the University of Alberta were retained for special services: Mr. Wayne Roberts (Curator, Museum of Zoology) identified small species and larval stages of fish and amphibians; Dr. D.A. Craig (Dept. of Entomology) identified blackfly larvae; Dr. J.G. Packer (Dept. of Botany, Herbarium) confirmed identifications of aquatic macrophytes; and Dr. D.N. Gallup (Dept. of Zoology) reviewed the zooplankton discussion and provided unpublished data. Pat Mitchell and Joe Rasmusson gratuitously discussed the ecology of certain invertebrates and confirmed identifications.

Water Survey Canada, Calgary, Alberta are acknowledged for providing streamflow data. Final thanks are due Ms. Carol Henderson for her dedication to the typing of the report.

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Plate 1. August, 1977.
Beaver Creek in the cleared area above the reservoir. For at least a kilometre upstream of the reservoir, Beaver Creek is a slow-flowing, meandering stream contained by mud banks. Beaver dams are common, and the creek is about 2 m deep in midstream. The substrate is predominantly sand-silt with occasional accumulations of debris and deadwood: gravel and rubble riffles are absent. Stream water is brown coloured.

Plate 2. August 1977.
Low lying shorelines of Beaver Creek Reservoir. Dam in background. The reservoir is situated in the broad, shallow valley of Beaver Creek and overlies land of low relief, formerly covered by forests and muskegs. As a result, the reservoir has extensive shallow areas. Lake water was brown coloured. Floating, stationary mats of muskeg (left background) were common in the reservoir and probably were pieces of original substrate that has floated to the surface after flooding.

Plate 3. August, 1977.
Shoreline of Ruth Lake exposed by declining water level. The lake is shallow with much aquatic vegetation and soft mud and organic substrates. Increased fluctuation of lake levels accompanying the diversion will probably produce distinct changes in the emergent aquatic plant communities.

Plate 4. May, 1977.
Poplar Creek Reservoir from the southeast. Causeway in background. The reservoir was formed by a dam across a ravine leading to Poplar Creek and is fairly deep. Most shorelines slope rather abruptly into the lake. Floating mats of muskeg, similar to those in Beaver Creek Reservoir, occurred in the north half of the basin. Reservoir water was brown coloured.

Plate 5. August, 1977.
Buckbean (Menyanthes trifoliata) growth at north end of Poplar Creek Reservoir. This shoreline slopes gently and was the only area in the reservoir with more than scattered emergent vegetation.

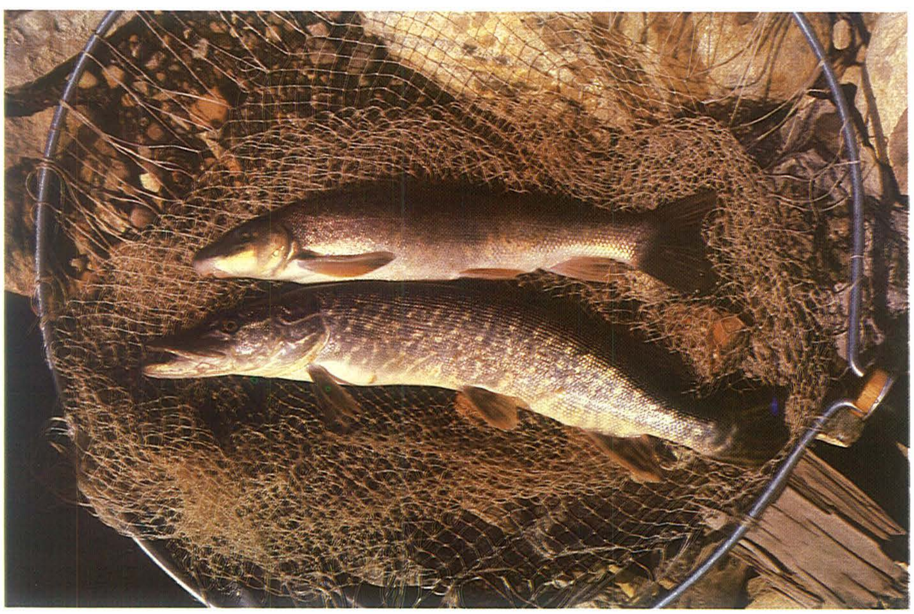

Plate 6. May, 1977.
Common residents of Poplar Creek, longnose sucker and northern pike. Other fish common in 1977 were white sucker, Arctic grayling, brook stickleback, fathead minnow, and lake chub. Fish were more abundant and diverse in Poplar Creek in 1977 than before diversion.

Plate 7. March, 1977.
The spillway and stilling basin. Water from Beaver Creek is impounded in Beaver Creek Reservoir and flows from there through canals to Ruth Lake and then to Poplar Creek Reservoir. From there it flows over the spillway to the stilling basin and enters Poplar Creek which joins the Athabasca River.

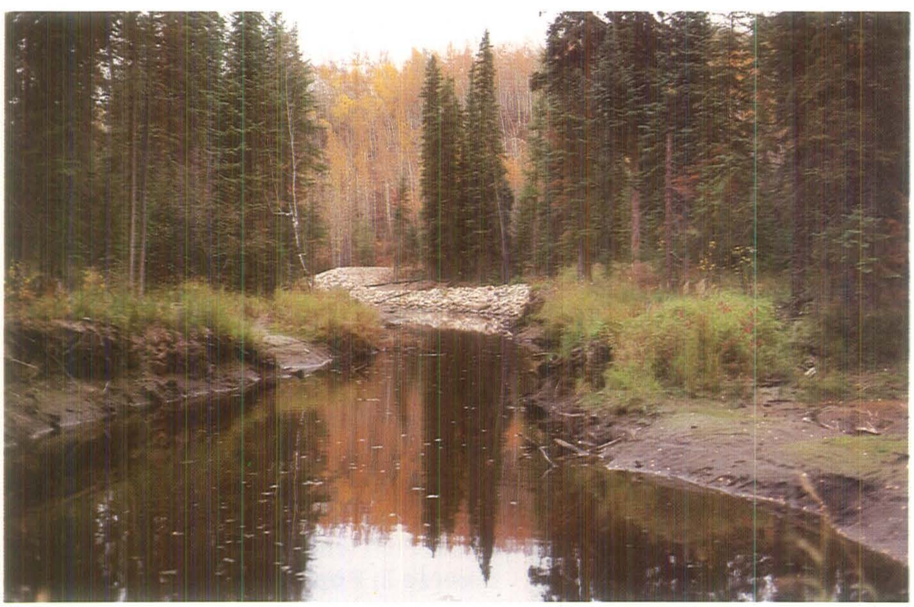

Plate 8. September, 1977.
Long pools in the upper portion of channelized Poplar Creek. To prevent excessive erosion and to accomodate the flow from the diversion system, Poplar Creek was channelized from the stilling basing to a point downstream of the highway bridge. Eleven drop structures (low weirs) now control the descent of the water through this reach.

Plate 9. April, 1977.
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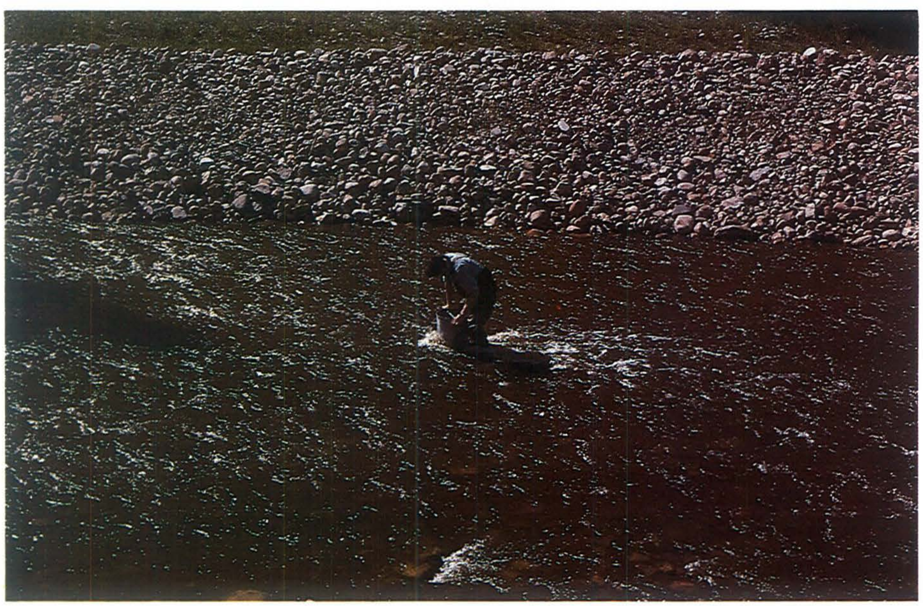


Plate 10. May, 1977.
Sampling benthos at PC-1, Poplar Creek, with a Hess-type cylinder sampler. The cylinder, toothed on the bottom edge, is turned into the substrate to enclose a known area of stream bottom. The substrate is cleaned and scoured and dislodged organisms are swept by the current (entering through an upstream screen) into a net attached to a downstream spout. Organically rich diversion water and a firm, stable substrate promoted a high abundance of benthos at this site.

INTRODUCTION AND OBJECTIVES

The diversion of Beaver Creek was undertaken by Syncrude Canada Ltd. to permit mining and extraction of bitumen in the Beaver Creek valley. Work on the diversion began with site clearing in the winter of 1974-75 and proceeded with construction of the Beaver Creek Dam and the Poplar Creek Dam and spillway in 1975. The diversion was implemented with closure of the Beaver Creek Dam in fall of 1975 and the subsequent filling of Beaver Creek Reservoir. This reservoir was filled by spring of 1976. Poplar Creek Reservoir was filled in July, 1976, and water first flowed over the spillway at that time. Channelization work to accomodate higher flows had been carried out in Poplar Creek in early 1976. Surface drainages before and after construction of the Syncrude plant and diversion system are illustrated in Figures 1 and 2.

The Beaver Creek Diversion System involves two creeks, two reservoirs, a series of diversion canals and Ruth Lake. These water bodies lie along the redirected course of Beaver Creek in the now combined Poplar Creek - Beaver Creek watershed. The slow-flowing brown water of Beaver Creek is impounded in its valley and flows from there through diversion canals to Ruth Lake and then to a second impoundment, Poplar Creek Reservoir. From the reservoir it descends to Poplar Creek via a spillway. Poplar Creek has been partly channelized downstream of the spillway to accomodate the additional flow as it passes to the Athabasca River.

In order to describe and understand the environmental changes accompanying this diversion, Syncrude commissioned studies in 1974 and 1975 of baseline conditions in Ruth Lake and Poplar Creek (RRCS, 1975; Noton and Chymko, 1977). This study reports the findings of a post-diversion investigation on the Beaver Creek Diversion System. The general objective of this study was to determine post-diversion conditions in Ruth Lake and Poplar Creek and to describe conditions existing in the two impoundments. Additional investigation was to be done on upper Beaver Creek and the diversion canals. Specifically, the following study objectives and plans were set.

<u>Upper Beaver Creek</u>

1. Regular sampling of physical and chemical parameters upstream of the reservoir
2. Seasonal sampling of benthic macroinvertebrates at one site upstream of the reservoir

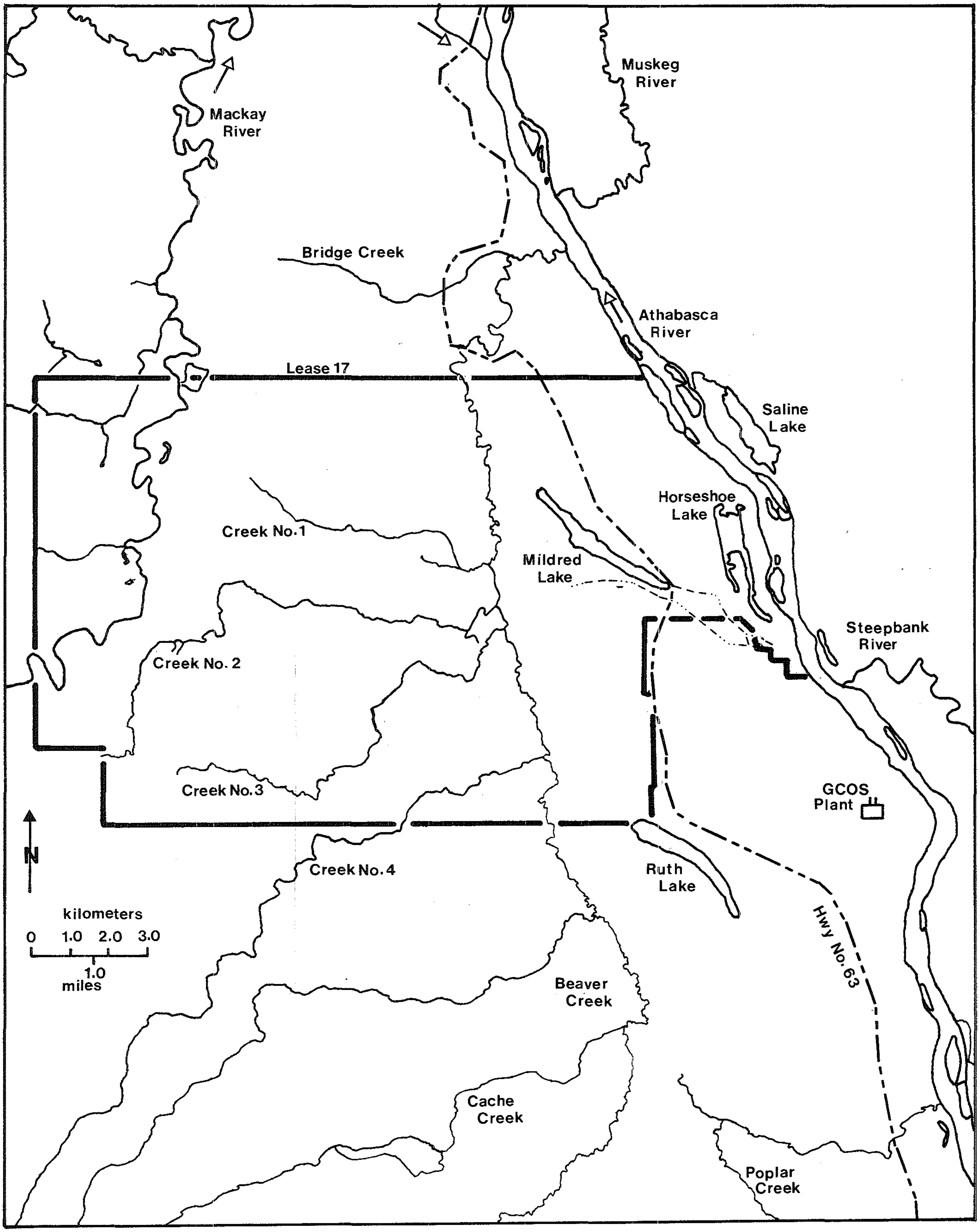


Figure 1. Surface drainage in the Syncrude lease area prior to plant construction.

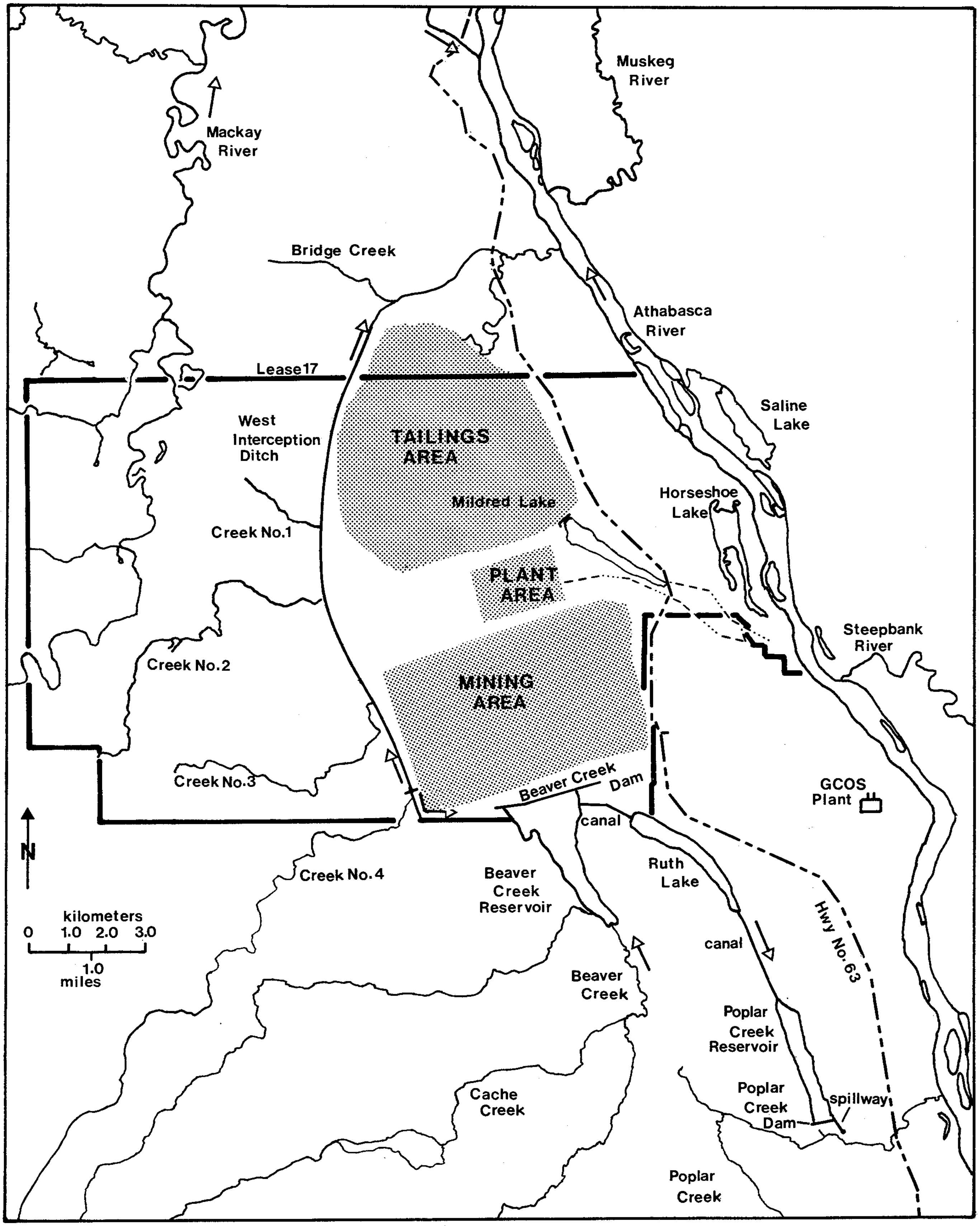


Figure 2. Surface drainage in the Syncrude lease area as modified for plant construction and operation, 1977.

3. A midsummer sampling of fish in the section above the reservoir

Beaver Creek Reservoir, Ruth Lake, Poplar Creek Reservoir

1. Regular sampling of physical and chemical parameters at two sites in each water body
2. Regular sampling of phytoplankton, zooplankton and benthic macroinvertebrates at the two sites to determine their composition and abundance
3. Additional investigation of zooplankton stratification, littoral zooplankton communities and zoobenthos distribution in the two reservoirs
4. A survey of aquatic macrophytes to determine their composition, abundance, and distribution
5. Two fish collections during the open season to determine the species present and their relative abundance

Poplar Creek

1. Regular sampling of physical and chemical parameters at three sites
2. Regular sampling of benthic macroinvertebrates at the three sites to determine their composition, abundance, and distribution
3. One sampling of macroinvertebrate drift above and below the spillway confluence
4. Monitor spring usage of the creek by fish and survey fish present in summer and fall

The report is largely organized by water body. Methods specific to each water body (e.g. sampling times and locations) are described under headings for each of those waters. Methods applicable to all study areas (e.g., analytical procedures and equipment specifications) are detailed in the section 'General Methods'. Integration of results from all the water bodies is placed in the section 'General Discussion'.

METHODS - GENERAL

This section covers methods and equipment used throughout the study and the general plan of investigations. Sampling regimes specific to each water body are discussed later in sections pertaining to those water bodies.

An outline of the study plan is provided in Table 1. Parameters to be sampled were divided into a 'regular' group and a 'special' group. The study commenced in late March with the first regular sampling of the diversion system. The next regular sampling was carried out shortly after break-up in early May and then every 4 weeks until mid-November. Ten sampling stations were established in the system, from upper Beaver Creek at the upstream end to Poplar Creek at the downstream end. These sites were sampled for the appropriate regular parameters including phytoplankton, zooplankton, benthic macro-invertebrates, temperature, oxygen and water quality. Additional surveys were conducted in the system for aquatic macrophytes and fish, and in Poplar Creek for physical habitat.

Physical and chemical parameters

The following parameters were analyzed on water and substrate samples collected from the sampling stations in the diversion system.

Water:

Regular:

Temperature	pH
Dissolved oxygen (DO)	Alkalinity
$NO_2 + NO_3 - N$	Total organic carbon (TOC)
Total Kjeldahl nitrogen (TKN)	Turbidity
Orthophosphate - P	Suspended solids
Total phosphorus	Filtrable residue
Reactive silicate	Loss on ignition
	Conductivity

Seasonal:

True colour	Major ions: Na, Mg, Ca, K, Cl, SO_4
Oil and grease	Metals: Fe, Cu, Cr, Pb, Zn, Ni, Co, Al, Cd, B
Phenolics	
Chemical oxygen demand (COD)	
Hardness	

Substrate:

Organic and inorganic fractions
Metals: Fe, Cu, Cr, Pb, Zn, Ni, Co, Al, Cd.

Regular parameters were analyzed on each occasion; seasonal parameters were analyzed in early May, late July, and mid-October; and substrate samples

Table 1 . Study outline, Beaver Creek Diversion System.

	Upper Beaver Creek	Beaver Creek Reservoir	Ruth Lake	Poplar Creek Reservoir	Poplar Creek
<u>Regular Sampling</u>[1]:					
No. of Stations-	1	2	2	2	3
Parameters:					
Physical[2]-	std.	std. & Secchi vis.	std. & Secchi vis.	std. & Secchi vis.	std.
Chemical[3]-	std.	std.	std.	std.	std.
Biotic-		phytoplankton zooplankton zoobenthos	phytoplankton zooplankton zoobenthos	phytoplankton zooplankton zoobenthos	zoobenthos plankton inflow from reservoir
<u>Special Sampling</u>	fish-once in summer zoobenthos-spring, summer & fall	macrophytes-once in summer fish-twice in summer zoobenthos-horizontal variation-once in summer zooplankton stratification-once in summer	macrophytes-once in summer fish-twice in summer	macrophytes-once in summer fish-twice in summer zoobenthos-horizontal variation-once in summer zooplankton, stratification-once in summer	stream habitat-once in fall drift-June fish-spring, summer, & fall plus monitor spring movements

1 Regular sampling frequency: approximately monthly, late March to mid November.
2 Standard (std.) physical parameters: temperature, turbidity, suspended solids.
3 Standard (std.) chemical parameters: regular, seasonal, and substrate - see text.

were collected in late July. Table 2 outlines the analytical methods employed. Water samples were collected from the lakes with a clear plastic, Kemmerer water bottle.

Dissolved oxygen was measured with a meter or with the azide-Winkler chemical method. Samples taken for pH and alkalinity were analyzed the same day. All other parameters were analyzed from samples returned to Edmonton. Water samples from lakes were drawn from either the mid-point of the water column or, at deeper sites, from two evenly spaced depths in the column. Separate collections from above and below the thermocline were made when it occurred. Samples for conductivity analysis were collected from the top, middle and bottom of the water column in lakes. Substrate samples at each site were drawn from the mixed, pooled contents of three Ekman dredge grabs.

Phytoplankton

Unconcentrated water samples for phytoplankton analysis were collected at the regular sampling times at the lake stations. Samples were preserved in the field in 1% acidic Lugol's iodine solution and were then allowed to settle in columns in the laboratory. Permanent, quantitative, microscope slide preparations were made of the settled algae and examined under compound microscopes at 400x for identification and enumeration. The publications of Smith (1950), Prescott (1962) and Bourrelly (1966, 1968, 1970) were used in algal identification.

The phytoplankton were placed into five major groups: Cyanophyta (blue-green algae); Chlorophyta (green algae); Bacillariophyceae (diatoms); Flagellates (including some members of Chrysophyceae, Cryptophyceae, Dinophyceae, and Euglenophyta); and ultraplankton. The last group is not a distinct taxonomic assemblage, nor is it a group based on common anatomical features as are the flagellates; rather, it represents the small unidentifiable plankters of 1 to 5 microns in size as discussed by Hutchinson (1967: p. 235-236). It does not include all the small plankters encountered because when algae in this size range could be identified they were put in one of the other four groups (e.g., specimens of *Rhodomonas* were often less than 5 microns in length). The members of the group are pigmented and often coccoid but, otherwise, are fairly featureless. They may include both green and blue-green algae and the possibility can not be ruled out that some of the smaller members may be bacteria. Exact identification would require intensive examination of live

Table 2. Analytical methods for physical and chemical parameters.

Parameter	Instrument or Technique
Field:	
Dissolved oxygen	- oxygen - temperature meter (Model 490-051, Int. Biophysics Corp.) - azide-Winkler method (APHA)
pH	- meter (Model PHM 29, Radiometer Ltd.)
Alkalinity	- APHA
Laboratory:	
Unfiltered samples:	
Total Kjeldahl nitrogen	- APHA
Total phosphorus	- persulphate digestion (ADoE)
Total organic carbon	- infrared analysis (ADoE)
Conductivity	- meter (Type CDM2e, Radiometer Ltd.)
Turbidity	- nephelometer (ADoE)
Suspended solids	- ADoE
Chemical oxygen demand	- ADoE
Hardness (Ca & Mg)	- calculation (APHA)
Oil and grease	- separatory funnel extraction (ADoE)
Phenolics	- 4-Aminoantipyrene with chloroform extraction (ADoE)
Metals (incl. Na, Mg, Ca, K)	- atomic emission (Model 975 Plasma Atomcomp, Jarrell-Ash Ltd.)
Filtered samples (0.45 μ):	
Orthophosphate - P	- automated ascorbic acid reduction (ADoE)
$NO_2 + NO_3$ - N	- automated cadmium reduction (ADoE)
Reactive silicate	- automated heteropoly blue (ADoE)
Filtrable residue	- ADoE
Filtrable residue - fixed	- ADoE
True colour	- APHA
Chloride	- automated thiocyanate (ADoE)
Sulfate	- automated methylthymol blue (ADoE)
Substrate samples:	
Metals	- perchloric digestion, atomic emission (model 975 Plasma Atomcomp, Jarrell-Ash Ltd.)

ADoE: 1977. Methods manual for chemical analysis of water and wastes. Alberta Environment, Pollution Control Laboratory, Water Analysis Section.

APHA: 1975. Standard methods for the examination of water and wastewater. 14th ed.

samples and probably the use of culture techniques. Their importance in phytoplankton communities has perhaps been underestimated in the past (Happey-Wood, 1976).

Aquatic macrophytes

Surveys of submergent, floating-leafed, and emergent aquatic plants were carried out in each of the three lakes in early August when aquatic plants were at, or near, maximum development. Plant specimens, preserved in the field in weak formalin solutions, were identified using Fassett (1957), Fernald (1950) and Moss (1959). The more difficult identifications were confirmed by the University of Alberta Botany Herbarium. Details of surveys used for each lake are outlined later by water body.

Zooplankton

Six vertical hauls were taken at each station for zooplankton with a No. 20 Wisconsin plankton net (mesh size = 80 microns), combined and preserved in 5% formalin.

Crustacean zooplankton were generally identified to the species level. All identifications were according to Edmondson (1959) and Brandlova *et al.*, (1972). The latter reference was used for *Ceriodaphnia*, *Diaphanosoma* and the "pulex" group of the genus *Daphnia*. Specimens of the genus *Diaphanosoma* were difficult to identify since diagnostic characters were not in complete agreement with the descriptions of either *D. brachyurum* or *D. leuchtenbergianum*. Specimens were often distorted by the preservative, and distinguishing features were hard to assess. Characteristics were closer to those of *D. leuchtenbergianum*, and specimens in the diversion system have been provisionally identified as such.

Nauplii and early copepodites (stages I-III) of cyclopoid copepods could not be accurately identified during counting procedures. These stages were grouped and tabulated individually as cyclopoid nauplii and cyclopoid copepodites I-III. Late stages copepodites (stages IV-V) and adults could be distinguished at the species level; however, there was difficulty discerning between stages IV-V of *Cyclops vernalis* and *Cyclops navus*, therefore the late stages for these two species were grouped.

The calanoid copepods found in these water bodies were *Diaptomus leptopus* and *D. oregonensis*. Nauplii could not be separated but copepodites and adults were distinguished by size, *D. leptopus* being larger than *D. oregonensis*.

Although only crustacean zooplankton were to be investigated under the study plan, rotifers were abundant in the water bodies, and total counts of them were made. The types present were identified, and the dominants noted. Identifications were according to Ruttner-Kolisko (1974) and were to the genus or species level, depending on the ease of identification.

Subsamples containing approximately 200 to 500 organisms (excluding rotifers and nauplii) were withdrawn from the zooplankton samples and were counted in plastic petri dishes using a stereomicroscope. Rotifers and nauplii were subsampled and counted separately in a Sedgwick-Rafter cell under a compound microscope.

At the same time the counts were made, body lengths were recorded to the nearest 0.01 mm for the purpose of biomass calculations. Cladocerans were measured from the front of the head to the end of the carapace (the tale spine was not included for *Daphnia*). Copepods were measured from the front of the cephalothorax to the end of the caudal ramus (excluding the caudal setae). To assure random selection, the first 30 individuals encountered of each species were measured. Cyclopoid copepodites that could not be distinguished at the species level were treated as a group. The measurements of each species were used to calculate a mean length for use in biomass computations. As in previous studies (RRCS, 1975; Noton and Chymko, 1977), biomass was calculated from published formulae (Table 3) and expressed in mg wet weight. To ensure comparability, the same formulae were used for organisms occurring in previous study years.

In comparing the zooplankton data in Ruth Lake in 1977 with previous data, and also in comparing stations within a water body, as well as the water bodies themselves, only generalities can be discussed. Zooplankton can undergo large, rapid changes in population size, and a four week sampling interval hinders comparisons since it is unlikely that seasonal dynamics are exactly in phase at the different stations. Further, station depths are often different. Due to the uneven vertical distribution of organisms within a water column, it is difficult to compare abundance among stations with different depths. For these reasons number/m^3 values presented in tables and figures should only be considered as very general indications of abundance. Detailed statistical analyses are precluded and discussions must be general in nature.

Table 3 . Formulae used in the determination of zooplankton biomass.

Organism	Formula	Source
Bosmina longirostris	$w(mg) = 0.124\ L\ (mm)^{2.181}$	Pechen, 1965
Ceriodaphnia (all species)[1]	$w^{-3}(mg) = 0.57L\ (mm)\ -0.02$	Osmera, 1966
Chydorus sphaericus	*Bosmina* formula used[2]	
Daphnia (all species)	$w(mg) = 0.052L\ (mm)^{3.012}$	Pechen, 1965
Diaphanosoma leuchtenbergianum	$w(mg) = 0.092L\ (mm)^{2.449}$	Pechen, 1965
COPEPODA (copepodites and adults)	$w(mg) = 0.055L\ (mm)^{2.73}$	Klekowski & Shuskina (1966)

[1] The formula of Osmera (1966) is for *Ceriodaphnia pulchella* and is applied here on the basis of similar body shape.

[2] Applied on the basis of similar body shape.

Additional zooplankton collections were made in the shallow, weedy areas of the water bodies to document the composition and abundance of littoral crustacean zooplankton (i.e., species that occupy the weedy zones and are not found in the open water). Two locations were sampled in each water body in spring, summer and fall with a No. 20 Wisconsin plankton net (mesh size = 80 microns) attached to a pole. The samples should be considered semi-quantitative since net tow lengths were estimated visually, and plants and debris interfered to an unknown extent with the passage of water through the net. In the laboratory, subsamples were taken to count abundant organisms, and at least half the sample was examined for less common species. Cladocera and adult copepods were counted at the species level; immature copepod stages were enumerated as a group.

Benthic macroinvertebrates

At each lake station on each regular sampling date, three samples were collected with a 6" x 6" Ekman dredge (15 cm x 15 cm = 0.023 m^2). Samples were washed in the field in a screen bottom bucket (aperture size 0.6 mm), bagged fresh, then sorted within 48 hours and preserved in 70% ethanol.

To examine colonization and distribution of benthic macroinvertebrates in the two reservoirs, ten transect sites were sampled in each reservoir. Three Ekman dredge samples were collected at each site and treated the same as in the regular sampling. Depth, temperature, dissolved oxygen, and substrate conditions were recorded at each site. Identification methods were identical to those used in the regular sampling program.

Lake bottom fauna typically show a non-random distribution (Elliott, 1971; Brinkhurst, 1974) and consequently a high variability in numbers collected in dredge samples. This variability was assessed in 1975 (Noton and Chymko, 1977) by collecting, on one occasion, ten replicate dredge samples from Site RL-3 in Ruth Lake. Among these replicates the ranges in number of individuals collected of the important major groups were as follows: Amphipoda: 2-40, Chironomidae: 38-147, Mollusca: 11-130, total numbers: 58-296. Due to this variability, discussions on the basis of three samples must be general. Further, in 1974 and 1975, only one dredge sample could be taken at each site, and therefore when comparing 1977 data to pre-diversion data, only the most obvious trends in benthic characteristics will be considered.

Seasonal samples of benthos were collected from upper Beaver Creek with a pole-mounted Ekman dredge. Benthic macroinvertebrates in Poplar Creek were sampled with a Hess-type cylinder sampler. This sampler was similar to that described by Edmondson and Winberg (1971: p. 69) but contained an upstream, mesh-covered opening and a downstream collecting net, as described for the circular Hess sampler in Welch (1948). The cylinder was made of galvanized metal with handles at the top and a serrated bottom that allowed it to be turned into the substrate to completely seal off the sampled area. The enclosed substrate was thoroughly stirred to a depth of about 10 cm, and organisms scraped from the larger rocks into the collecting net. The net was of nitex, 250 microns aperture size. Three samples were collected at each site, preserved with 70% ethanol in the field, and then sorted in the laboratory.

Organisms from both lake and stream samples were recorded at the generic or species level when possible (e.g., Amphipoda, Ephemeroptera, Odonata, Coleoptera, Gastropoda, Pelecypoda). Chironomids, the most important major group, were identified to subfamily and tribe levels, except when a genus was distinctive and easy to identify. The keys of Needham and Westfall (1955), Walker (1953) and Walker and Corbet (1957) were used to identify the nymphs of Odonata (damselflies and dragonflies). The Mollusca (snails and clams) were identified following Clarke (1973). Wiggins (1977) was used for the Trichoptera (caddisflies). The remainder of the macroinvertebrates were identified using the keys in Edmondson (1959).

Adequacy of benthic sampling in reservoirs

An Ekman dredge is best suited to sample soft substrates and some doubt arose about its sampling efficiency on the hard substrates (gravel, muskeg, forest floor) in the two new reservoirs. To examine this problem a Ponar dredge, which is better suited for sampling compact substrates than an Ekman dredge (Howmiller, 1971; Lind, 1974), was used to take three replicate samples alongside three replicate Ekman samples at each of the two regular stations in Beaver Creek Reservoir. The collected samples were handled in the normal manner, and the organisms were separated into broad taxonomic groups. Differences in numbers of organisms collected were tested for significance with the non-parametric Wilcoxon two-sample test (Marascuilo and McSweeney, 1977). Results of the collections are placed in Table 4.

Table 4. Results of Ponar and Ekman dredge collections in Beaver Creek Reservoir, July 28, 1977.

	Ponar 1	Ponar 2	Ponar 3	Ekman 1	Ekman 2	Ekman 3
Station BCR-1						
Chironomidae	2	15	3	2	2	14
Oligochaeta	1	12	1	0	0	3
Mollusca	0	0	0	5	0	0
Others	4	9	8	3	2	2
Total	7	36	12	10	4	19
$\bar{x}$		18			11	
s		16.5			7.5	
CV		92%			68%	
Station BCR-2						
Chironomidae	3	47	110	75	8	55
Oligochaeta	0	9	27	17	0	35
Mollusca	0	1	0	0	0	0
Others	1	2	0	3	2	0
Total	4	59	137	95	10	90
$\bar{x}$		67			65	
s		66.8			47.7	
CV		98%			73%	

Both samplers collected more individuals at BCR-2 than at BCR-1, and although the Ponar dredge collected a slightly higher average number of organisms at each station, the difference was not statistically significant. It was necessary to use the 10% level because critical values for lower significance levels (5%, 1%) could not be calculated for this small a sample size. The total number collected by each dredge was highly variable (Table 4) and, if anything, the Ekman was less variable in the total numbers of organisms it collected.

These results indicate that the Ekman dredge was not significantly less efficient than a Ponar dredge in collecting benthos in the reservoirs. The actual efficiency of either dredge in sampling reservoir substrates is not known and would require detailed experimentation to determine. Also, collection efficiency may vary between samples depending on the exact nature of the substrate encountered. Since the Ponar dredge is specifically designed for compact substrates and yet did not collect significantly more organisms than an Ekman, the latter was considered an adequate dredge for this study. Further, the Ponar was inconvenient to operate in the reservoirs because it tended to bite firmly onto submerged debris and was difficult to retrieve.

Drift

A diurnal collection of drifting organisms was made at sites PC-1 and PC-B4 in Poplar Creek on June 23-24.

The drift net apparatus was identical to that used in 1975 and consisted of a wedge-shaped, clear-plastic frame with a long tapering net attached to it. Eyebolts, attached to the frame and slipped over two metal rods driven firmly into the stream substrate, enabled the apparatus to be positioned in the stream. The inside dimensions of the frame were 5 cm x 20 cm (0.01 m^2) at the leading upstream opening and 10 cm x 20 cm at the downstream end; the frames were 10 cm from front to rear. The nets were made of nylon (pore size 250 microns) and were 130 cm long. They tapered from a circumference of 60 cm at the frame to 36 cm at the downstream end.

At each site two nets were placed in the main flow of the stream. The nets at PC-1 were in the regular sampling riffle, but at PC-B4 they were about 10 cm upstream of the regular sampling riffle. At PC-1 the nets were in about 60 cm of water and were positioned as in 1975 with one net about 5 cm above the substrate and the other about 5 cm below the surface. At PC-B4 there was insufficient depth to allow positioning one net above the other so the nets were placed side by side in about 30 cm of water.

It had been found in 1975 that taking consecutive 2 hour samples over the 24 hour period produced more samples than could be processed within study limitations. Therefore, in the 1977 study the nets were left in the stream for two hours, emptied, and then left out for two hours before being returned to the stream for another two hour collection. There was no evidence of clogging or backflow during the collections. Samples were washed into plastic bottles and preserved in 10% formalin. In the laboratory organisms in the samples were identified and counted by order or family.

Current velocity in front of the nets was measured with a Price Model AA Current Meter. Water temperature and dissolved oxygen were recorded at the beginning of each set at each site.

Fish

Fish were collected from all the water bodies of the diversion system through a variety of methods. Test gang gill nets (15.2 m each of 1½ (38), 2½ (64), 3½ (88), 4½ (114), and 5½ (140) inch (mm) stretched mesh) and a beach seine (about 6 m by 1.3 m, mesh opening 2 mm) were used to capture fish in the lakes. Smaller gill nets (about 10 m each of 2½ and 3½ inch mesh), a seine, electrofishers (Type VII, Smith-Root Inc.) and occasional angling were employed to collect fish in upper Beaver Creek and Poplar Creek. Sampling regimes are detailed in the sections on each water body.

The larger fish that were collected were weighed, measured, and a sample scale taken from them. A thorough investigation of appropriate ageing techniques for each species was not possible during the study, consequently not all specimens were assigned ages. Stomachs dissected from selected individuals were preserved in 10% formalin for an assessment of food consumption. For suckers, the first 4-5 cm of stomach were examined in detail, the remainder being checked to ensure that its contents were not markedly different. For other species, the whole stomach was examined.

UPPER BEAVER CREEK

METHODS

Upper Beaver Creek was sampled at station UBC (Figure 3) on March 31 and at approximately four week intervals from May 4 to November 20, 1977. Temperature and oxygen were measured on each occasion, and a water sample collected for analysis of regular parameters. Samples for seasonal water analysis were taken on May 4, July 28, and October 16, and substrate samples were collected for analysis on July 28.

Twelve bottom samples were collected at site UBC with a pole-mounted Ekman dredge on May 4, July 28, and October 16. They were washed through a screen-bottom pail (aperture 0.6 mm), bottled, and preserved in the field with 70% ethanol, then sorted and identified in the laboratory. The samples were taken in midstream (water depth 1.5 to 2.0 m) along a 5 m length of the creek at the sampling station.

To investigate the occurrence of fish in the stream, fish collections were made in the 1.5 km of Beaver Creek just above the reservoir on July 27 and 28, 1977. The slow current allowed 10 m each of 2½ inch (64 mm) and 3½ inch (89 mm) mesh gill net to be stretched across the stream overnight at two locations (Figure 3). Seine hauls were taken at 3 locations and electrofishing (203 seconds) was carried out in the creek at various accessible locations.

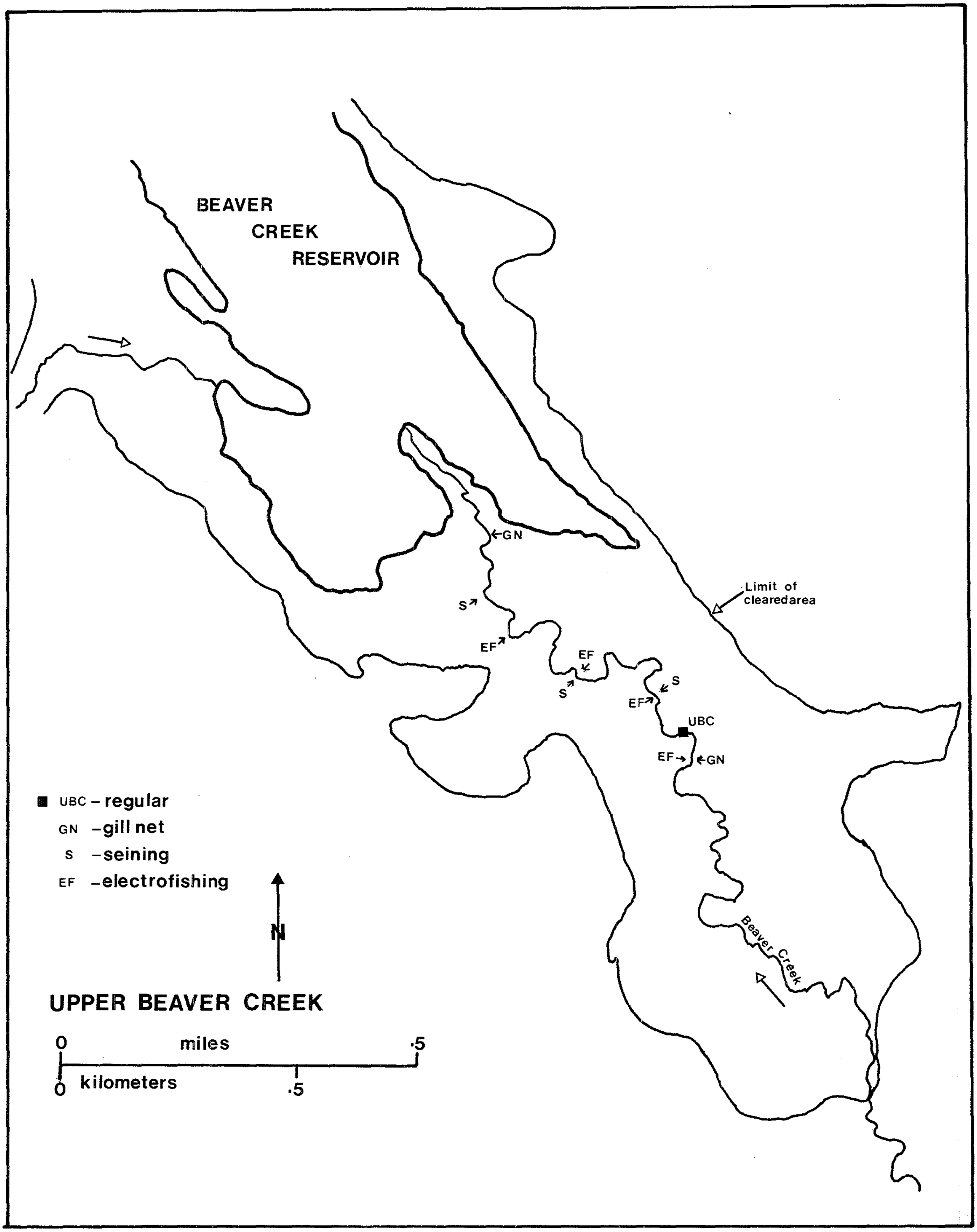


Figure 3. Sampling locations on Upper Beaver Creek, 1977.

RESULTS AND DISCUSSION

For some distance upstream of the reservoir, Beaver Creek is a slow-flowing, meandering stream contained by mud banks (Plate 1). Beaver dams are common, and the creek is about 2 m deep in midstream. The substrate is predominantly sand-silt with occasional accumulations of debris and deadwood: gravel and rubble riffles are absent. Stream water is brown coloured and is always at least moderately turbid. Sampling station UBC was located approximately 1 km upstream of the reservoir at a site typical of these conditions.

Physical and chemical parameters

Recorded temperature and oxygen values are presented in Figure 4. Oxygen saturation was greater than 80% during the open water season but lower than that under ice cover. The lowest saturation values during the open season occurred in midsummer (Figure 4). Somewhat higher oxygen concentrations were recorded for the creek in 1975 (Noton and Chymko, 1977), but it is unlikely that differences between the years reflect anything other than normal variability. The highest temperature recorded in 1977 was 19°C, a value in accord with maxima observed in other streams in the area (RRCS, 1975; Noton and Chymko, 1977; McCart *et al.*, 1977).

Streamflow is summarized in Table 5. Highest discharge occurred in April, May and June, and flow generally declined thereafter. Flow in 1977 was probably below normal and was only about half that of 1976.

The results of regular water analyses are contained in Table 6. The water quality of upper Beaver Creek was typical of a brown-water stream and was similar to that observed in 1975 (Noton and Chymko, 1977). During the open-water season,pH of the stream ranged only from 7.7 to 7.9 although it was 7.3 under the ice cover in March. Total alkalinity at 359 mg/l and dissolved solids at 520 mg/l were highest in March. As is typical for streams (Wetzel, 1975), both these parameters tended to fluctuate in concentration in an inverse manner to streamflow. Mean alkalinity during open water sampling was 158 mg/l, and dissolved solids averaged 224 mg/l. As expected, turbidity and suspended solids were generally highest when streamflow was highest, although both showed comparatively high values under ice cover (Table 6). The cause of these latter high values is not known. Total organic carbon concentrations measured during the study ranged from 6 to 41 mg/l with a mean value of 31 mg/l during the open season. Levels under ice cover were somewhat lower.

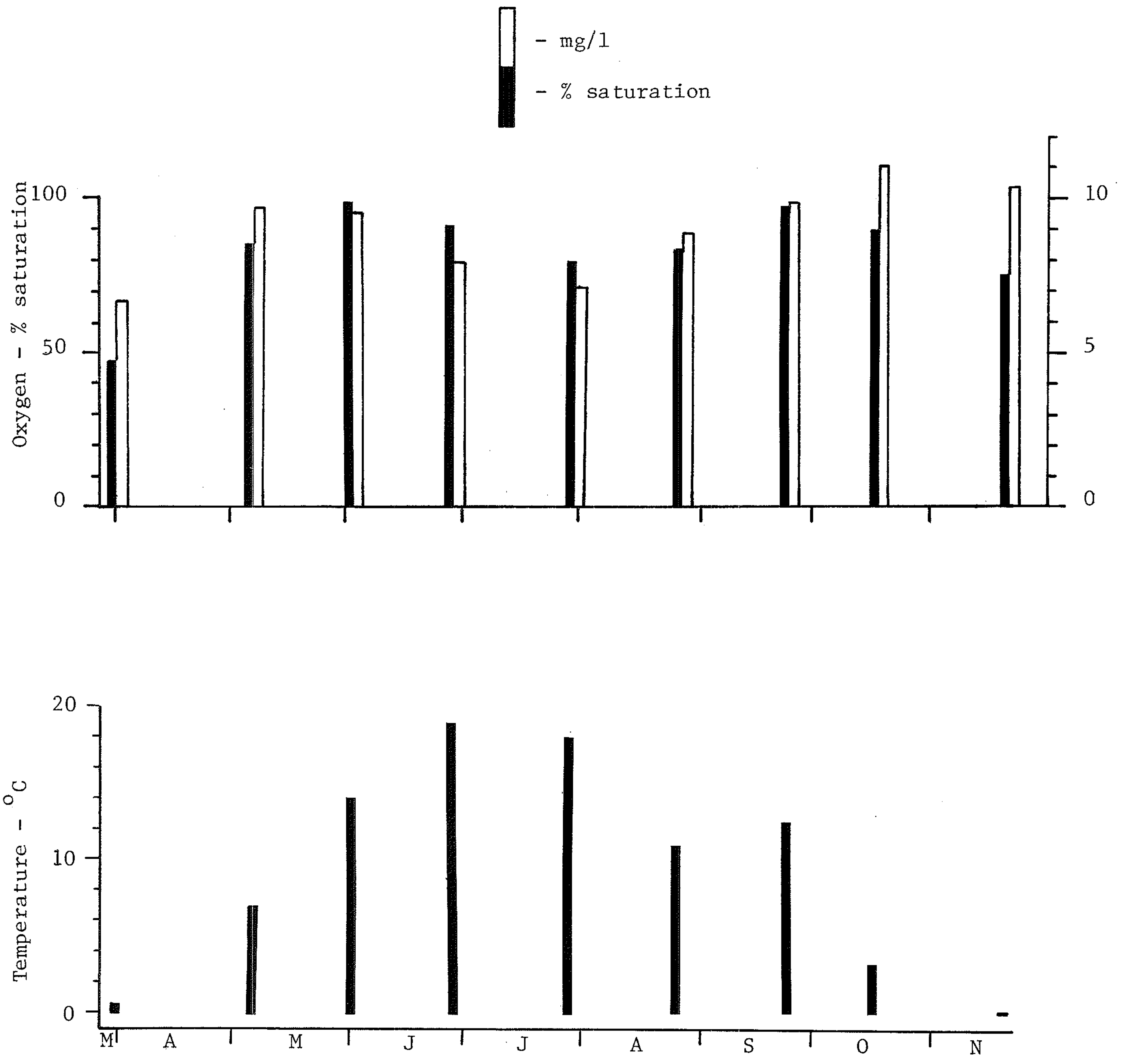


Figure 4. Temperature and oxygen content of Upper Beaver Creek, 1977.

Table 5 . Flows in Upper Beaver Creek, 1976-77.

1977	Mean daily discharge cfs	Mean daily discharge m^3/sec	Total discharge Acre feet	Total discharge m^3
Jan.	0	0	0	0
Feb.	0	0	0	0
March	0.27	0.008	16.7	206×10^2
April	28.9	0.82	1720	212×10^4
May	39.5	1.12	2430	300×10^4
June	34.7	0.98	2070	255×10^4
July	16.2	0.46	998	123×10^4
Aug.	14.4	0.41	887	109×10^4
Sept.	8.2	0.23	488	602×10^3
Oct.	11.4	0.32	701	865×10^3

Annual Summaries	1976	1977 (Jan. to Oct.)
Mean discharge m^3/sec (cfs)	0.72 (25.4)	0.44 (15.4)
Total discharge m^3 (ac.ft.)	227×10^5 (18,400)	115×10^5 (9310)
Max. daily discharge m^3/sec (cfs)	18.51 (654) on 28/8	2.60 (92) on 18/4

Data courtesy Water Survey of Canada, for station # 07DA018.

Table 6 Chemical characteristics of Upper Beaver Creek, 1977.

	March 31	May 4	June 1	June 27	July 28	Aug. 25	Sept. 23	Oct. 16	Nov. 20
pH	7.3	7.7	7.7	7.8	7.7	7.9	7.9	7.7	
Total alkalinity	359	108	84	134	161	213	219	184	
Turbidity (NTU)	8.5	14	18	3.8	3.2	12	8.7	5.4	22
Suspended solids	22.6	10	38	9	1.5	9	1.6	1.6	6.8
Total organic carbon	6	20	26	41	34	38	36	19	27
$NO_3 + NO_2 - N$	1.4	0.27	0.035	0.046	<0.03	<0.03	<0.016	<0.016	0.111
Total Kjeldahl - N	2.6	6	0.2	0.2	0.2	0.1		0.7	0.3
Ortho $PO_4 - P$	0.180	0.051	0.045	0.044	0.042	0.071	0.042	0.036	0.079
Total - P	0.199	0.062	0.062	0.112	0.096	0.096	0.064	0.071	0.081
Reactive SiO_2	7.8	7.2	4.8	5.3	5.5	6.3	6.9	10.1	2.6
Filtrable residue	520	214	196	202	204	248	312	194	388
Ignition loss	145	72	60	62	46	66	128	74	174

Results in mg/l, except pH and turbidity. Alkalinity as $CaCO_3$.

Both organic (Kjeldahl) and inorganic ($NO_2 + NO_3$) nitrogen concentrations were higher in spring and lower during summer. $NO_2 + NO_3$ - N values ranged from less than 0.016 to 0.27 mg/l, and total Kjeldahl nitrogen values ranged from 0.1 to 6 mg/l during the study. The two forms of phosphorus that were analyzed, orthophosphate and total, generally paralleled each other in concentration and were highest under ice cover. Both were fairly constant during the open season, with ortho-PO_4 phosphorus averaging 0.046 mg/l and total phosphorus 0.080 mg/l. Concentrations of reactive silicate ranged from 2.6 to 10.1 mg/l, and, as has been observed in other stream studies (Wetzel, 1975), levels were not obviously related to discharge.

Table 7 contains the results of analysis performed for seasonal parameters and substrate samples. Much of this analysis was not performed in the previous baseline studies, although there have not been major changes in those parameters (colour, COD, hardness) that were. Analysis of the ionic content of upper Beaver Creek indicates that sodium and calcium are the principal cations, and bicarbonate is the main anion. However, the relative proportions of these components may change seasonally. Iron concentrations in the creek were rather high compared to those found in Poplar Creek in 1975 (Noton and Chymko, 1977), but concentrations of other metals did not differ markedly between the two streams. The composite sample of substrate collected at Site UBC in July contained only 4% organics, by weight of the air-dried sample.

Benthic macroinvertebrates

Seasonal benthic sampling at Site UBC in upper Beaver Creek was intended to characterize the macrozoobenthos of the stream in that area. Past experience in Poplar Creek (RRCS, 1975; Noton and Chymko, 1977) had shown that sand-silt substrates there contained low numbers of invertebrates. Twelve Ekman dredge samples were collected at Site UBC on each date to give an adequate sample size. Variability among samples was high: for the 6 samples collected in October (each composed of 2 dredge samples), mean abundance per sample was 654 organisms; the range was 167-1376; the standard deviation, 435; and the coefficient of variation of the mean was 67%. This was similar to the variability found for Surber samples taken in 1974 in Poplar Creek (58% - Noton and Chymko, 1977). The abundance of organisms was not stable, however, being more than an order of magnitude higher in October than in May or July (Table 8). The May and July samples contained 772 and 553 organisms/m^2 respectively, but in October more than 14,000/m^2 were encountered. Oligochaetes and molluscs dominated the collected benthos in May; chironomids were of lesser importance;

Table 7 . Results of seasonal water analysis and substrate analysis, Upper Beaver Creek, 1977.

	Water			Substrate
	May 4	July 28	Oct. 16	July 28
True colour (APHA)	110	75	90	
Oil and grease	22.6	15.8	13.4	
Phenols	<0.001	0.006	<0.001	
C.O.D.	113	68	83	
Ca & Mg hardness, as $CaCO_3$	70	107	106	
% organic				4
% inorganic				96
Na	2.2	33.8	39.4	
Mg	6.3	9.0	9.8	
Ca	17.5	28.0	26.4	
K	2.6	0.6	1.4	
Cl	14.0	1	1	
SO_4	7	8	7	
Fe	1.16	1.61	2.04	15817
Cu	0.005	0.012	0.020	12.4
Cr	0.02	<0.01	0.09	81.3
Pb	<0.02	<0.02	0.05	240.3
Zn	0.015	0.008	0.208	23.1
Ni	<0.02	<0.02	0.02	19.0
Co	<0.01	<0.01	<0.01	35.4
Al	0.2	0.2	0.2	38001
Cd	<0.01	<0.01	<0.01	20.2
B	0.212	0.210	0.200	

Water results as mg/l, unless noted. Substrate metals as ppm. Substrate results refer to air dried samples.

Table 8 . Abundance and composition of benthic macroinvertebrates from station UBC, upper Beaver Creek, 1977.

	Number collected			% of total numbers		
	May 4	July 28	October 16	May 4	July 28	October 16
Ephemeroptera	-	10	920	-	6	23
Trichoptera	-	-	30	-	-	1
Ceratopogonidae	7	17	116	3	11	3
Chironomidae	20	42	2416	9	27	61
Other Diptera	4	7	29	2	5	1
Elmidae	1	47	171	<1	31	4
Hydracarina	2	-	129	1	-	3
Oligochaeta	83	18	64	39	12	2
Mollusca	98	10	28	46	6	1
Others*	-	3	23	-	2	1
Total	215	154	3921	100%	100%	100%
Mean per Ekman	18	13	327			
Mean per m^2	772	553	14,084			

* Includes Odonata (Anisoptera), Megaloptera, Crustacea, and Hirudinea.
12 Ekman dredges (0.023 m^2 each) taken each date.

and all other groups comprised only 7% of total numbers. The chironomids increased in both number and numerical dominance in the July samples and, together with Elmidae beetle larvae, dominated the benthos. Oligochaeta and Ceratopogonidae were secondary in importance in July while other individual groups comprised 6% or less of the total numbers. In October, collected samples contained a predominance of Chironomidae with mayfly nymphs being the second most abundant taxon (Table 8). No other group contributed more than 4% to the total collected.

Table 9 contains a complete list of the benthic macroinvertebrates collected from the creek. Ephemeroptera, absent from the samples in May, were low in number in July but very abundant in October when *Caenis* was the predominant mayfly (*Leptophlebia* occurred in smaller amounts). Trichopterans were only collected in October when *Limnephilus* was the most common genus of this group. Ceratopogonidae generally increased in numbers but not importance through the study. The Chironomidae, well represented by the groups Chironomini, Tanytarsini, Orthocladiinae, and Tanypodinae, increased in both numbers and importance and dominated the benthos collected in October. Other dipterans were of minor importance numerically. *Dubiraphia* (Coleoptera: Elmidae) was the most common organism in the July samples, and although it was more abundant in October, it comprised a lower percentage of the community in fall. Oligochaetes did not vary much in overall abundance in the three sets of samples and thus declined in dominance as other organisms increased through the study. The molluscs *Pisidium* and *Sphaerium* comprised almost half the collected benthos in spring, but had declined in number by fall. Among the minor groups, fifteen specimens of the Megalopteran *Sialis* were collected in October. This genus had not been collected in other work on Beaver Creek (RRCS, 1974a), Poplar Creek (RRCS, 1975; Noton and Chymko, 1977) or the Athabasca River (McCart *et al.*, 1977) but is reported in the area in similar slow-flowing stream habitat on the upper Muskeg and upper Steepbank Rivers (D. Barton, pers. comm.).

The salient feature of the collected benthic data is the tremendous increase in abundance that had occurred by October. The low density in May and July was what would be expected of unstable sand-silt substrates (Hynes, 1970). The most likely explanation for the increase is that with reduced flows in October (Table 5) substrate stability increased, and this, accompanied by the accumulation of organic debris observed in the October samples (taken after leaf-fall), provided a favorable habitat for benthic

Table 9 . Organisms in Ekman dredge samples from station UBC, upper Beaver Creek, 1977.

	May 4			July 28			Oct. 16					
	1	2	3	1	2	3	1	2	3	4	5	6
Ephemeroptera												
Caenis					2		598	30	177	1	4	66
Ephemerella				7		1						
Leptophlebia							31		12			
Metretopus										1		
Trichoptera												
Brachycentrus							2					
Cheumatopsyche							1					
Limnephilus							4		19			
Oecetis									1			2
Ptilostomis											1	
Odonata-Anisoptera				1								
Diptera												
Ceratopogonidae		3	4	10	4	3	53	35	10			18
Chironomidae												
Chironomini	2	2	5	6	5	4	42	108	121	18	63	170
Tanytarsini	1	1		15		1	193	338	121	40	105	45
Tanypodinae	4	2		5	1	2	56	17	21	35	24	5
Orthocladiinae			1	3			230	297	101	53	135	73
Diamesinae	1		1				2	3				
Empididae							1	3	3			
Simuliidae						2						
Tabanidae	2			2		3			3	1		2
Tipulidae	1		1					4	1		1	5
Coleoptera-Elmidae												
Dubiraphia		1		35	6	6	132	22	2	1	7	7
Megaloptera												
Sialis							15					
Hydracarina		1	1				9	16	43		6	55
Ostracoda												1
Amphipoda												
Hyalella azteca									1			
HIRUDINEA							3		1	1	1	
Helobdella stagnalis				1		1						
OLIGOCHAETA	10	15	58	14	1	3	2	28	1	11	20	2
GASTROPODA - Unid. -				1								
Ferrissia rivularis							2		1			
Gyraulus								1	1			
Helisoma				1								
Physa												1
PELECYPODA												
Pisidium	30	3	10	2		2		4	1	3	2	3
Sphaerium	11	17	27		3	1		5	1	2		1
Total	62	45	108	103	22	29	1376	911	642	167	369	456

12 Ekman dredges (0.023 m^2 each) taken each date, composited 4/sample in May and June, 2/sample in October.

macroinvertebrates. Benthos that increased in October were primarily immature aquatic insects. Abundance in fall was not typical of that observed in previous studies for sand-silt substrates in Poplar Creek (50-250/m^2). The conclusion is that although the slow-flowing, meandering portions of upper Beaver Creek may have a mud and silt substrate that is subject to scour and deposition at least during high flows, there also exists habitat of higher stability and organic content at certain times and locations that may contain an abundant benthos. The proportion of such habitat that occurs in upper Beaver Creek cannot be estimated here, but to the extent it occurs, the abundance of zoobenthos will be proportionately enhanced. It can be said, therefore, that at certain locations and times upper Beaver Creek contains habitat of high suitability for benthic macroinvertebrates.

Fish

Six species of fish were collected this year (Table 10) in the creek above the reservoir, and a seventh, northern pike, is considered likely to be present since it occurred immediately downstream in the reservoir. Of these species, only fathead minnows have not been recorded previously in Beaver Creek. Most likely, they have only recently gained access to the creek in abundance from Ruth Lake and Beaver Creek Reservoir. They were fairly common in most habitats in the region sampled. Previous work on the creek was concentrated in downstream areas where the fish fauna would probably be richer because of higher mean flows and proximity to the Athabasca River. Consequently, the absence of species such as walleye, trout-perch and lake whitefish from this year's collections is not surprising.

Only one Arctic grayling (a juvenile) was collected in July although some have been angled in 1977 about 2 km upstream of the reservoir (G. MacLaughlan, pers. comm.). This species still occurs in the upper creek even though the Beaver Creek dam was closed in fall of 1975.

Lake chub were common in all habitats sampled this summer and have been commonly collected in the creek in past studies (Table 10). They have now established in Beaver Creek Reservoir. Brook sticklebacks were abundant in the sampled areas, especially where there was some aquatic vegetation.

White and longnose suckers were both collected in the area (8 white suckers in the gill nets and 1 longnose sucker by seine). The white suckers ranged in length from 280 to 370 mm and in weight from 340 to 539 g. These

Table 10. Species of fish reported from Beaver Creek by various investigators, 1970 to present.

Species	Robertson 1970	RRCS 1971	RRCS 1973	RRCS 1974a	This Study[1]
Arctic grayling - *Thymallus arcticus*	+	+	+	+	+
Lake whitefish - *Coregonus clupeaformis*			+		
Mountain whitefish - *Prosopium williamsoni*	+				
Lake chub - *Couesius plumbeus*	+	+	+	+	+
Fathead minnow - *Pimephales promelas*					+
White sucker - *Catostomus commersoni*	+	+	+	+	+
Longnose sucker - *C. catostomus*			+	+	+
Burbot - *Lota lota*	+	+	+		
Slimy sculpin - *Cottus cognatus*	+	+		+	
Brook stickleback - *Culaea inconstans*			+	+	+
Trout-perch - *Percopsis omiscomaycus*			+		
Walleye - *Stizostedion vitreum*			+[2]		
Northern pike - *Esox lucius*	+	+	+	+	+[3]

[1] Upper Beaver Creek only

[2] Only at mouth

[3] Probably occurs

two species, especially the white sucker, are probably common in upper Beaver Creek. Length-weight information for the larger fish collected are in Appendix 1.

BEAVER CREEK RESERVOIR

METHODS

Beaver Creek Reservoir was sampled for all regular parameters at Sites BCR-1 and BCR-2 (Figure 5) on March 31 and at 4 week intervals from May 4 to November 20, 1977. Temperature and oxygen were measured on each occasion, and samples were collected for analysis of regular water quality parameters. Samples for seasonal water analysis were taken on May 4, July 28 and October 16. At BCR-1, regular and seasonal water samples and phytoplankton samples were collected by combining samples from two evenly spaced depths. When stratification or greater than normal depths were encountered, separate bottom samples were also collected. The high irregularity of the bottom of the reservoir resulted in up to 1 m depth difference wtihin a small area, with the result that different depths were often encountered between dates at a site. At BCR-2 these parameters were sampled from the midpoint of the water column (about 1.5 m). Samples for conductivity analysis were collected at the top, middle, and bottom of the water column on each date. Substrate samples were collected on July 28. Water samples taken in July and August for chemical analysis were filtered through a plankton net to remove the abundant, colonial blue-green algae.

Six vertical net hauls for zooplankton and three Ekman dredge samples for benthos were taken at each station on each date. A vertical series (every 2 m) of Schindler-Patalas trap samples for zooplankton was collected at BCR-1 on August 6. Collections of littoral zooplankton were made at two sites (Figure 5) in spring, summer and fall. Ten sites along a transect (Figure 5) in the north portion of the reservoir were sampled on August 6 to assess the colonization and distribution of the zoobenthos. Three Ekman dredge samples were collected at each of the ten points.

A survey of the submergent, floating-leafed and emergent macrophytes in Beaver Creek Reservoir was conducted on August 5 and 6. Composition, approximate abundance and distribution of these plants were assessed when travelling the shorelines by boat. Because macrophyte growth was confined to the shallow areas, sampling transects covering the entire reservoir were not required.

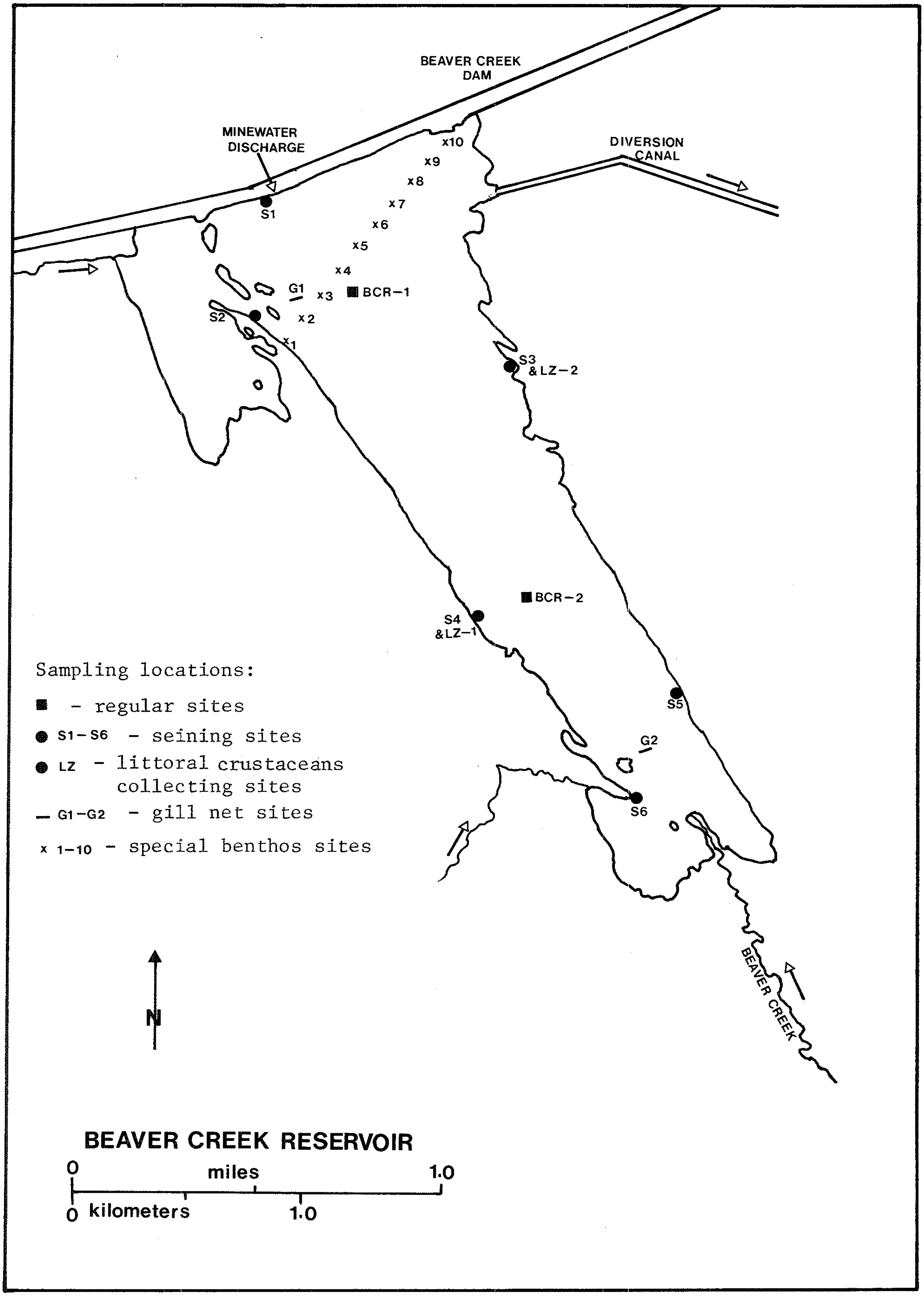


Figure 5. Sampling locations in Beaver Creek Reservoir, 1977.

To determine the species present, and their relative abundance, fish were collected with beach seines and test gang gill nets on June 25-26 and August 22-23, 1977. Six sites in the reservoir were sampled at depths up to one metre with a seine (Figure 5). Sampled habitat included open sand-gravel substrates along the dam, as well as a range of mud and organic substrates at other sites with variable amounts and species of submergent plants. Organic debris was common at these sites.

A test gang gill net was set overnight at two sites in the reservoir (Figure 5) during each of the two fish collections. Site G2 was in a shallow area; water depths were about 1 to 2 metres and some forest debris and macrophytes were present. Site G1 was deeper, (1 to 4m) with no macrophytes present.

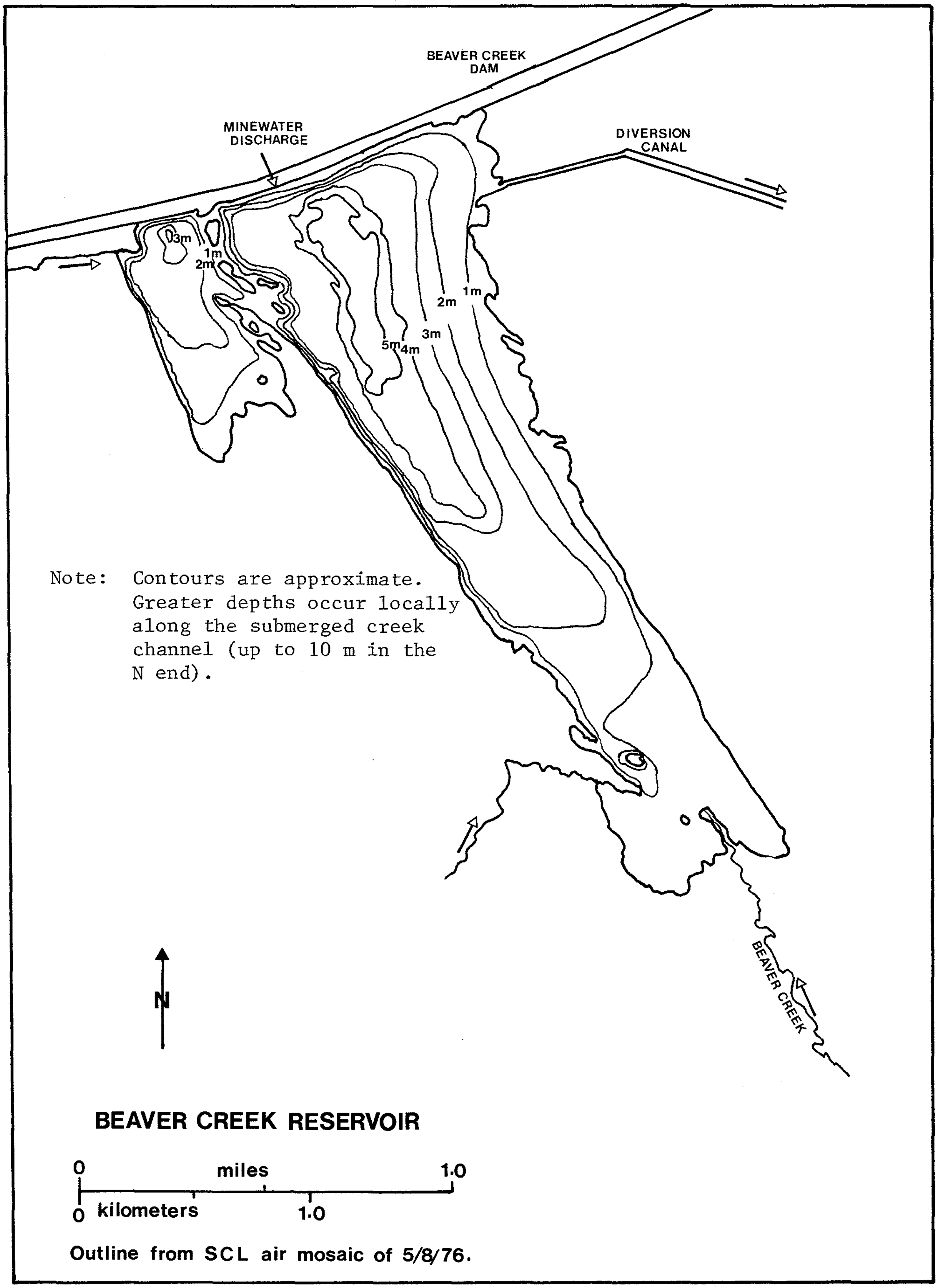
RESULTS AND DISCUSSION

Beaver Creek Reservoir is situated in the broad, shallow valley of Beaver Creek and overlies land of low relief, formerly covered by forests and muskegs. Consequently, the reservoir is not deep (Figure 6) and has gently sloping shorelines with extensive shallow littoral areas (Plate 2). Lakewater was brown coloured and fairly turbid (Secchi disc visibility averaged 1.0 m during the open season). The substrate was quite variable in composition since flooding covered stream beds and banks, sand and gravel knolls, muskeg, and forest floor. Much organic debris occurred in the substrate. Floating, stationary mats of muskeg were common in the reservoir in 1977, especially in the bay in the northwest corner of the lake and along the east shore. These rafts, of a turf-like peaty material, apparently are pieces of original substrate of the area that has simply floated to the surface after flooding. The turf remains partially attached to the bottom and, consequently, does not drift away.

Physical and chemical parameters

Preliminary depth contours of the reservoir are shown in Figure 6. Until a comprehensive sounding of the reservoir is carried out, these contours give an approximation of the depth of the lake, and from them a reservoir volume of 7×10^6 m^3 was estimated. This indicates the magnitude of lake volume although actual volume will vary somewhat from this because of the uncertainties of the depth estimates and also because of fluctuations in reservoir water level (Figure 7). In this shallow reservoir a change in water level of 1 m would produce a considerable change in the total volume of the reservoir.

Water levels of Beaver Creek Reservoir recorded by Syncrude Canada Ltd. are shown in Figure 7. The Beaver Creek dam was closed in fall, 1975, and water impounded in the reservoir reached the level of the diversion canal near the end of April, 1976, at approximately 310.3 m ASL. Canal excavation in winter (1976-77) resulted in a fall in water level in March, 1977. A further decline occurred in summer. Low rainfall in 1977 contributed to the latter decline, and a year of normal rainfall would probably result in higher water levels. Correspondingly, discharge from Upper Beaver Creek was not great (Table 5), and therefore, the flushing rate in the reservoir even at maximum discharge (May) was not high in 1977 (about once in two months).



Note: Contours are approximate. Greater depths occur locally along the submerged creek channel (up to 10 m in the N end).

Figure 6. Approximate depth contours of Beaver Creek Reservoir.

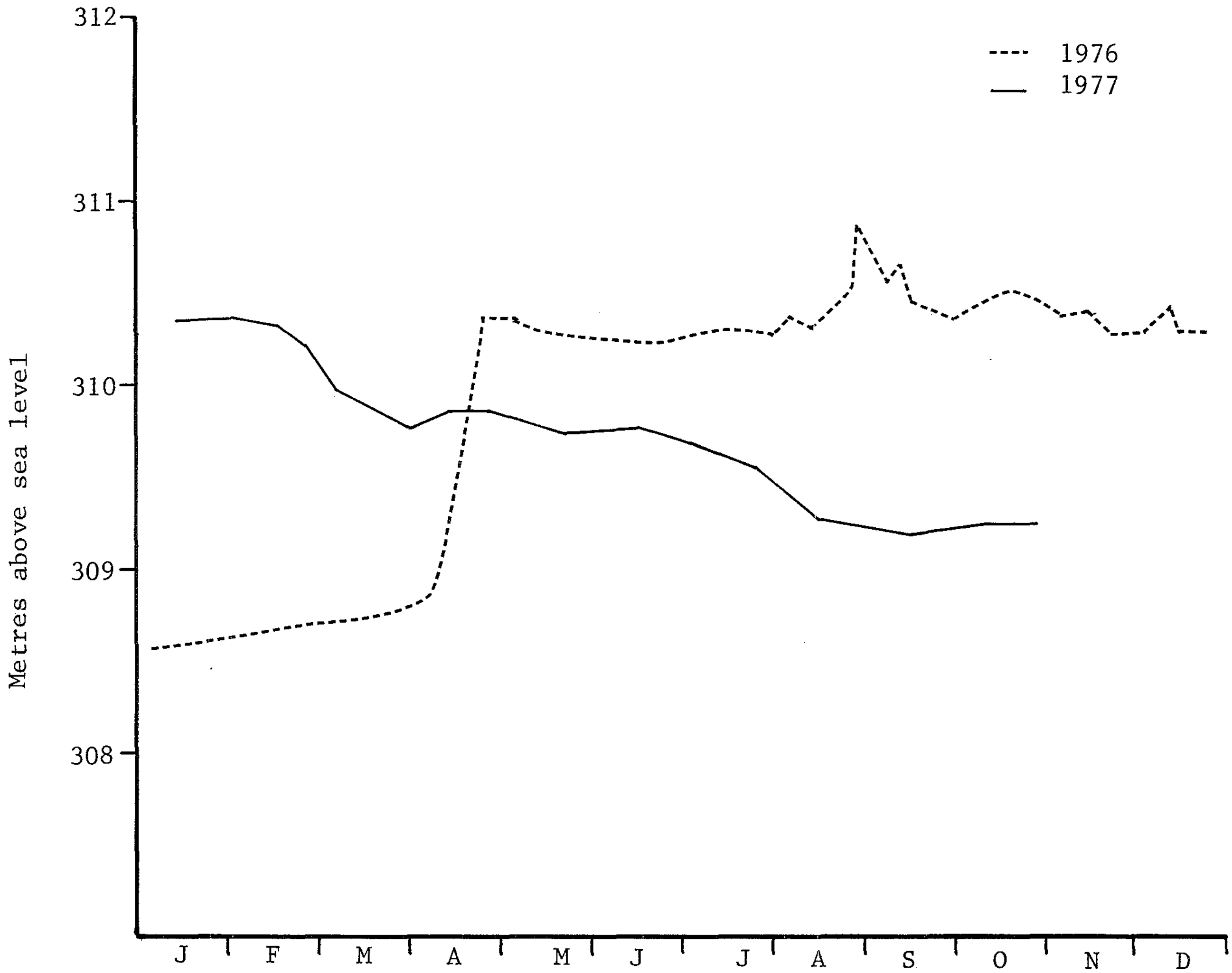


Figure 7. Water levels in Beaver Creek Reservoir, 1976-77.

Temperature and oxygen saturation data recorded at the main stations are presented in Figure 8 and Table 11. Table 12 contains the oxygen concentrations measured at both stations. A maximum temperature of 22.5°C was recorded on July 28 at BCR-2. This station was the shallower of the two and was usually slightly warmer than BCR-1. The reservoir was ice-free by the first week of May and froze around the end of October. Ice was 60-65 cm thick on March 31, 1977 and 18 cm thick on November 20, 1977.

Thermal stratification was not well developed in Beaver Creek Reservoir in 1977 even at the deeper site, BCR-1. Although a small temperature discontinuity occurred at that site between 4 and 6 m in May and June (Figure 8), it was never more than 3°C and did not persist beyond June. Site BCR-2 showed even less thermal stratification. Although temperature gradients between surface and bottom waters were commonly encountered, the reservoir is too shallow and exposed to wind action for a persistent thermocline to occur. Profiles, recorded in March at both stations, showed maximum temperatures at depths of 2 to 4 m and lower temperatures below these depths (Figure 8 and Table 11). At that time of year temperatures would normally increase with depth, therefore, other density factors such as solute concentration may have been affecting stratification of the water column. Solute concentrations are discussed below in connection with minewater discharges.

Oxygen saturation in Beaver Creek Reservoir was similar at the two sampling stations and indicates a considerable oxygen demand in the water column. Saturation was close to zero under the ice in March (Figure 8 and Table 11) but rose to 60-80% saturation in early May. Recorded oxygen saturation reached its highest levels on July 28 during a blue-green algal bloom when levels of 99% and 161% saturation were found at the surface at stations BCR-1 and BCR-2 respectively. Otherwise, saturation was consistently less than 100% in the reservoir, even at the water surface, a condition not normally found in most lakes during the open season (Wetzel, 1975). Ruth Lake for example, was at or near 100% saturation during most of its open season in 1974-75 (Noton and Chymko, 1977). After the bloom of blue-green algae in July, oxygen saturation in Beaver Creek Reservoir fell to its lowest summer values, less than 60%.

Stratification of oxygen appeared to be closely related to temperature gradients (Figure 8 and Table 11). Oxygen levels approached zero in bottom waters at BCR-1 when temperature gradients occurred (May through July) but little difference between surface and bottom waters was evident when the water

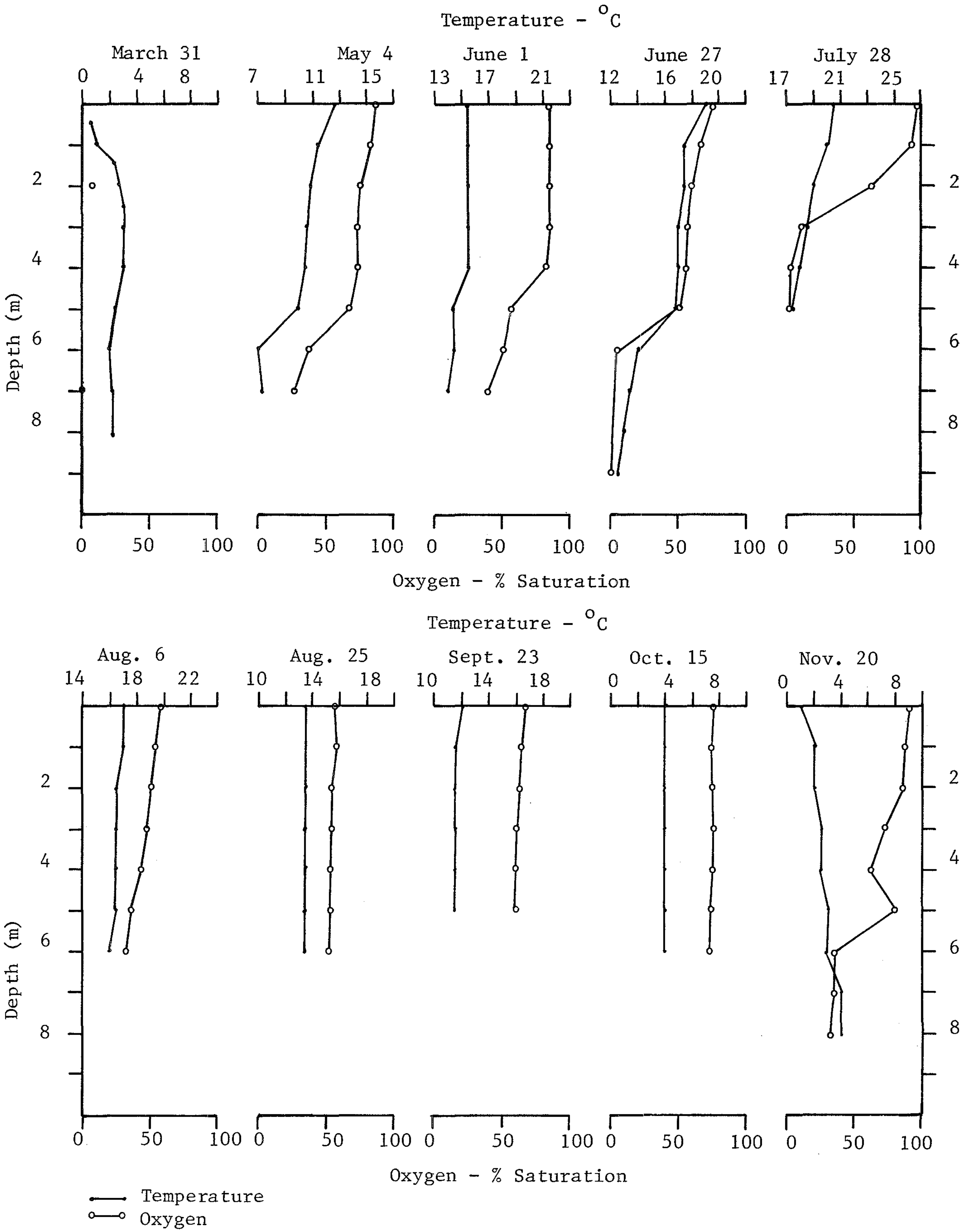


Figure 8. Temperature and oxygen saturation profile for Station BCR-1, Beaver Creek Reservoir, 1977.

Table 11. Temperature and oxygen saturation at Station BCR-2, Beaver Creek Reservoir, 1977.

					Temperature °C/Oxygen - % Saturation				
Depth (m)	*March 31	May 4	June 1	*June 27	July 28	Aug. 25	Sept. 23	Oct. 15	Nov. 20
0		12.5/67	16.0/80	22.0	22.5/161	13.0/39	12.0/71	4.5/78	1.0/90
0.5	0	10.5/63		20.0	22.5/>161				2.0/94
1.0	1.5	9.5/62	16.0/79	20.0	22.0/124	13.0/39	11.5/66	4.5/77	2.0/90
1.5		9.5/67		19.5/69	21.0/69				2.5/77
2.0	2.0/0	9.0/71	16.0/79	19.5	20.0/54	13.0/39	11.5/55	4.5/76	3.0/56
2.5		8.5/62		19.0	20.0/47		11.5/55	4.5/76	3.0/34
3.0	1.0	8.0/51	15.0/60			13.0/37			
3.5			15.0/60						
4.0	1.0					13.0/35			
4.5	/2					13.0/35			
5.0	1.0								
5.5									
6.0	1.5								
6.5	1.5								
7.0									

Measurements with dissolved oxygen - temperature meter, unless noted otherwise.
* Measurements with azide - Winkler method.

Table 12. Oxygen concentration at stations BCR-1 and BCR-2, Beaver Creek Reservoir, 1977.

Depth (m)	March 31	May 4	June 1	June 27	July 28	Aug. 6	Aug. 25	Sept. 23	Oct. 15	Nov. 20
					Oxygen concentration - mg/l BCR-1/BCR-2					
0		8.7/6.7	7.8/7.3	6.4	8.2/13.0	5.4	5.6/3.8	6.8/7.1	9.2/9.4	12.0/12.0
0.5		/6.6			/13.2		/3.8			/12.2
1.0		8.4/6.6	7.8/7.2	5.8	7.8/10.1	4.9	5.4/3.8	6.5/6.6	9.2/9.3	11.4/11.8
1.5		/7.1		/5.9*	/5.8		/3.8			/9.7
2.0	<0.1/0*	7.8/7.6	7.8/7.2	5.4	5.4/4.6	4.6	5.3/3.8	6.4/5.6	9.2/9.2	11.0/7.0
2.5		/6.9			/4.0		/3.8	/5.6	/9.2	/4.3
3.0		7.6/5.6	7.8/5.6	5.2	0.6	4.1	5.3/3.7	6.2	9.2	9.0
3.5			/5.6				/3.6			
4.0		7.8	7.6	5.0	0.2	3.7	5.3/3.5	6.1	9.2	7.8
4.5							/3.5			
5.0		7.0	5.6	4.6	0.2	3.2	5.3	6.0	9.1	10.0
6.0		4.1	4.9	0.3		2.8	5.2		9.1	4.3
7.0		2.9	3.8	0.2						4.3
8.0				0.2						4.0
9.0				0.2						

Measurements with dissolved oxygen - temperature meter, unless noted otherwise.

* Measurements with azide-Winkler method.

column was essentially isothermal (August through October). This indicates that when bottom waters are isolated for any length of time, oxygen is rapidly depleted, and implies that a considerable oxygen demand exists in the reservoir. Further supporting this implication, saturation at the 6 m depth at site BCR-1 fell from 75% to 35% from October 15 to November 20, despite the fact that low water temperatures then ($4^{o}C$) would be expected to slow decomposition.

The results of regular chemical analyses are in Table 13. Differences in water quality between the two stations were not pronounced. Beaver Creek Reservoir had a quality of water similar to that of Upper Beaver Creek. The inflowing water apparently determined the general chemical characteristics of the reservoir although some change in quality was detectable within the lake. Apparently the water retention time in the reservoir is not great enough for large changes to occur. Both the stream and the reservoir showed a general increase in solute concentration through the summer, likely as a result of generally declining stream flow over the same period.

Reservoir pH was similar to that of Upper Beaver Creek, being 7.6 to 7.9 during the open season but somewhat lower under ice in March. Bottom samples collected at BCR-1 usually had a slightly lower pH than samples from the top of the water column. On July 28, both stations had an elevated pH (8.3-8.5) associated with a bloom of blue-green algae. Total alkalinity did not fluctuate in the reservoir as much as in Beaver Creek. From highs of 186-347 mg/l in March, it declined to lows of 119-131 mg/l in early June then rose through the open season to about 200 mg/l in November. Filtrable residue showed trends parallel to those of alkalinity, although it was generally a bit higher at Site BCR-1 than Site BCR-2, and reservoir concentrations were somewhat higher than those in Beaver Creek. Values in March were greater than 500 mg/l, but concentrations fell to 208-218 mg/l in early June. Values reached a plateau of 360-390 mg/l in late August. Total organic carbon (TOC) was highest in late August (45 mg/l), but was usually around 20-40 mg/l, similar to levels in Beaver Creek. Ignition loss tended to parallel filtrable residue and was generally somewhat higher in the reservoir than in the creek. Values were highest in March (240-325 mg/l) and lowest in early June (62-75 mg/l).

Both turbidity and suspended solids were lower in the reservoir than in the creek since sediment carried by the creek would settle when it entered the reservoir. Nitrogen values (both $NO_3 + NO_2$ - N and total Kjeldahl nitrogen) were similar in the creek and reservoir and were highest in spring. TKN

Table 13. Chemical characteristics of Beaver Creek Reservoir, 1977.

	March 31	May 4	June 1	June 27	July 28	Aug. 25	Sept. 23	Oct. 15	Nov. 20
				BCR-1 - Top					
pH	7.0	7.5	7.9	7.7	8.3	7.8	7.8	7.7	7.9
pp alkalinity	0	0	0	0	0	0	0	0	0
Total alkalinity	186	153	127	137	150	170	178	181	196
Turbidity (NTU)	7.0	8.5	1.6	2.7	3.5	8.7	3.9	2.5	2.4
Suspended solids	16.6	14.0	5.0		0.5	8.0	3.6	3.2	<0.5
Total organic carbon	23	40	24	34	35	45	40	20	28
$NO_3 + NO_2$ - N	0.53	0.12	0.035	0.248	<0.03	<0.03	0.023	0.085	0.144
Total Kjeldahl - N	10.3	13.4	0.3	0.2	0.4	0.5	0.8	0.3	<0.1
Ortho PO_4 - P	0.460	0.060	0.036	0.077	0.031	0.034	<0.016	<0.016	<0.016
Total P	0.603	0.102	0.064	0.116	0.100	0.061	0.082	0.052	0.052
Reactive SiO_2	13.6	7.5	3.5	4.1	3.4	3.3	2.4	5.4	4.7
Filtrable residue	520	254	218	306	296	372	396	210	385
Ignition loss	325	76	62	98	118	82	200	88	135
				BCR-1 - Bottom					
pH	7.3	7.5	7.6	7.4	7.6	-	-	-	-
pp alkalinity	0	0	0	0	0	-	-	-	-
Total alkalinity	347	160	131	131	156	-	-	-	-
Turbidity (NTU)	8.0	10	5.8	3.9	2.7	-	-	-	9.9
Suspended solids	19.6	10.4	2.7	2.0	1.5	-	-	-	4.4
Total organic carbon	15	19	24	33	32	-	-	-	36
$NO_3 + NO_2$ - N	0.61	0.14	<0.03	0.340	0.035	-	-	-	0.133
Total Kjeldahl - N	10.9	9.5	0.2	0.2	0.4	-	-	-	<0.1
Ortho PO_4 - P	0.490	0.056	0.030	0.149	0.026	-	-	-	<0.016
Total P	0.510	0.076	0.104	0.202	0.08	-	-	-	0.052
Reactive SiO_2	15.6	12.4	3.4	3.9	3.6	-	-	-	2.7
Filtrable residue	550	342	238	334	334	-	-	-	442
Ignition loss	240	160	72	106	130	-	-	-	226
				BCR-2					
pH	7.0	7.4	7.7	7.8	8.5	7.6	7.8	6.8	7.9
pp alkalinity	0	0	0	0	2	0	0	0	0
Total alkalinity	260	146	119	127	150	173	179	180	202
Turbidity (NTU)	12.0	8.0	5.8	4.0	3.6	4.5	3.4	2.9	3.1
Suspended solids	7.8	7.6	5.5	0.5	1.5	1.0	4.4	1.2	2.0
Total organic carbon	31	20	24	36	32	46	37	26	34
$NO_3 + NO_2$ - N	1.42	0.15	<0.03	0.084	0.070	<0.03	<0.016	0.129	0.110
Total Kjeldahl - N	12.5	12.6	0.1	0.2	0.3	0.4	0.3	0.4	<0.1
Ortho PO_4 - P	0.350	0.066	0.050	0.091	0.025	0.034	<0.016	<0.016	<0.016
Total P	0.647	0.122	0.064	0.142	0.092	0.064	0.061	0.066	0.054
Reactive SiO_2	13.4	10.4	3.6	3.8	3.3	3.2	2.9	1.6	3.6
Filtrable residue	550	246	208	236	266	350	362	346	362
Ignition loss	240	76	74	50	136	82	176	134	98

Results in mg/l except pH and turbidity. Alkalinities as $CaCO_3$.

dropped sharply thereafter and was fairly constant for most of the rest of the sampling period but nitrate nitrogen declined steadily through the open season. Total and orthophosphate phosphorus showed parallel trends in the reservoir, being highest in March, then dropping abruptly by May and declining gradually through the open season. This contrasts with fairly stable concentrations which occurred in upper Beaver Creek over the same time period. Reactive silicate was highest in spring but dropped to levels of about 2-5 mg/l for the rest of the study. It was generally lower in the reservoir than in the creek in summer but showed spring peaks not evident in the creek.

The results of spring, summer and fall analyses for major ions, metals and other parameters are placed in Table 14. Levels of these parameters also reflected the input of water from upper Beaver Creek. The coloured nature of both water bodies is evident. Hardness and most ions were similar in level between the two as well, with the important exception of sodium and chloride. Although calcium and bicarbonate were the major ions in spring, sodium became the most important cation in summer and fall (Table 14), and chloride increased to significant levels (40-60 mg/l) then as well. In Beaver Creek, sodium also increased, but not as much, and chloride actually decreased over the same period. The significance of these changes will be discussed below in conjunction with the conductivity data.

Concentrations of phenols were quite low in Beaver Creek Reservoir (Table 14), but oil and grease ranged up to 65 mg/l, levels considerably higher than in upper Beaver Creek. Chemical oxygen demand (COD) was higher in concentration in the reservoir than in the creek, reaching levels up to 200 mg/l in July. Both parameters may have been influenced by biological activity within the reservoir.

Iron and aluminum were the only metals that showed noticeably different values from those of Beaver Creek (Table 14); both were higher in the creek perhaps because of the higher suspended solids in the creek. A stratification of metal concentrations at Site BCR-1 was not evident form the data.

Organic compounds constituted 6-13% of the dry weight of the substrate samples collected in Beaver Creek Reservoir this year (Table 15). Results of substrate metal analyses indicate samples from Site BCR-1 generally have higher metal concentrations than those from BCR-2. Considering the limited level of substrate sampling, however, these results should be considered preliminary until the degree of normal variability in substrate parameters in

Table 14. Results of seasonal water analysis, Beaver Creek Reservoir, 1977.

	BCR-1 - Top			BCR-1 - Bottom			BCR-2		
	May 4	July 28	Oct. 15	May 4	July 28	Oct. 15	May 4	July 28	Oct. 15
True colour (APHA)	170	110	70	130	85		140	95	70
Oil and grease	16.6	12	40.2	19.6	11.4		7.8	5.6	65.0
Phenols	0.013	<0.001	0.012	<0.001	<0.001		0.005	<0.001	<0.001
C.O.D.	67	123	25	68	165		66	200	12
Hardness[1]	127	116	89	109	118		97	115	97
Na	3.63	64.6	58.5	3.37	71.6		2.90	40.9	60.9
Mg	11.5	9.9	7.8	9.5	10.1		8.5	9.2	7.6
Ca	32.1	30.2	22.7	28.2	30.7		25.3	30.9	26.1
K	2.6	1.5	1.5	2.2	1.6		2.1	1.9	1.7
Cl	24	59	44	35	51		9	41	59
SO_4	13	6	6	14	8		10	7	10
Fe	1.04	0.63	0.53	0.65	0.51		0.95	0.37	0.58
Cu	0.022	0.014	0.013	0.009	0.018		0.011	0.017	0.022
Cr	0.02	<0.01	0.03	0.02	<0.01		0.02	<0.01	0.03
Pb	0.02	<0.02	0.05	0.02	<0.02		0.04	<0.02	0.05
Zn	0.019	0.008	0.105	0.021	0.011		0.015	0.012	0.076
Ni	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	0.03
Co	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01
Al	0.1	0.1	<0.1	0.1	0.1		0.2	0.2	0.2
Cd	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01
B	0.261	0.176	0.206	0.202	0.156		0.291	0.196	0.227

Results as mg/l unless noted.

[1] Ca & Mg hardness, as $CaCO_3$.

Table 15. Results of substrate analysis, Beaver Creek Reservoir, July 28, 1977.

	BCR-1	BCR-2
% organic	13	6
% inorganic	87	94
Fe	30868	18102
Cu	24.5	13.5
Cr	121	82.8
Pb	300	283
Zn	87.5	24.4
Ni	31.3	33.0
Co	46.0	41.6
Al	52393	29283
Cd	32.0	25.8

Results are by weight of air dried samples.
Metals as ppm.

the reservoir can be assessed. The reservoir substrate is presently quite heterogeneous in gross features (texture, organic debris), and it seems reasonable to assume that concentrations of metals would also vary considerably from site to site.

From the information in Table 16, it can be seen that stratification of conductivity occurred on occasion in Beaver Creek Reservoir. Conductivity was measured as a means of monitoring changes in salinity due to minewater discharges to the reservoir. Notable conductivity gradients occurred mainly at Site BCR-1 (closest to the discharge), but also in March at BCR-2. The differences between top and bottom samples at BCR-1, were not great, however, being only 385 μmhos/cm in March, and 365 μmhos/cm in November. July samples showed a differential of 135 μmhos. All stratifications occurred under conditions of moderate thermal stability (Figure 8) and may represent either pooling of denser, more saline minewater or solution of compounds from sediments, or some combination of the two. Since minewater discharge to the reservoir did not occur before April, 1977, (J. Retallack, pers. comm.), March stratification cannot be related to the minewater discharge. Analyses of water samples for major ions (discussed previously) showed that sodium and chloride increased in concentration during the summer in the reservoir, an occurrence that may be related to the discharge of saline minewater. The increased concentration of electrolytes, observed on occasion near the bottom at these sampling stations, is not likely, in itself, to adversely affect biota. It is possible, however, that concentrations high enough to affect the biota did occur at other times and locations.

Phytoplankton

Complete cell counts for Beaver Creek Reservoir phytoplankton samples are placed in Appendix 2. Figure 9 portrays the abundance and overall composition of the sampled phytoplankton in the reservoir in 1977 at the two sampling stations. Cell counts were slightly higher at Site BCR-1, except during blue-green algal blooms in June and July (Figure 9). Site BCR-2 was closer to the mouth of Beaver Creek, in a portion of the reservoir that is narrower and shallower in cross section so that the flushing effect of the creek was probably more pronounced there. Such higher flushing may have suppressed populations of phytoplankton at that station; however, for the reservoir as a whole, not even the maximum calculated flushing rate (approximately once in 2 months at 1977 peak flows) was an important factor affecting

Table 16. Specific conductance at the top, middle and bottom of the water column in Beaver Creek Reservoir, 1977.

	SPECIFIC CONDUCTANCE - μmhos/cm @ 25°C								
	March 31	May 4	June 1	June 27	July 28	Aug. 25	Sept. 23	Oct. 15	Nov. 20
					BCR-1				
Top	340	350	205	280	445	475	520	620	500
Middle	460	360	215	270	450	485	530	610	575
Bottom	725	410	215	310	580	475	500	630	865
					BCR-2				
Top	340	320	195	270	405	450	540	555	580
Middle	340	320	195	270	390	450	540	560	570
Bottom	600	320	200	270	380	460	500	545	570

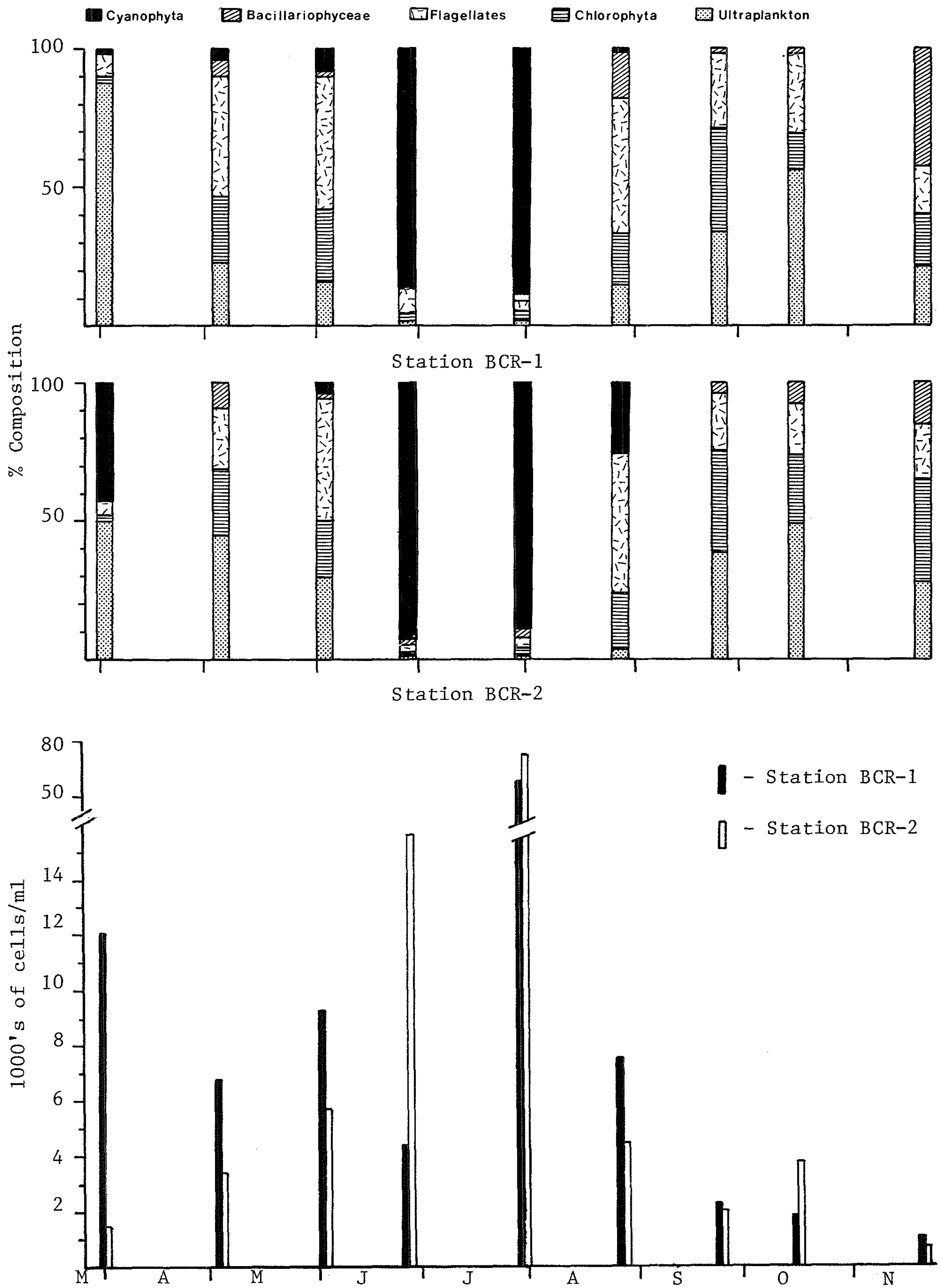


Figure 9. Abundance and composition of phytoplankton in Beaver Creek Reservoir, 1977.

the plankton community since algal composition and abundance was observed to change markedly by itself in less than half that time.

Phytoplankton abundance was variable in spring, ranging from 2000 to 12,000 cells/ml. Blue-green algae became dominant in June and July when total cell numbers were as high as 70,000 cells/ml. Blue-green algae, at that time, were concentrated near the water surface, and on July 28 at Site BCR-2, this group alone was in excess of 100,000 cells/ml at the top of the water column. By late August, blue-greens were no longer the dominant algae, and total algal numbers had declined to around 4000 to 7500 cells/ml. Numbers continued to decline through the rest of the season to 1000/ml or less in November (Figure 9).

The phytoplankton community of Beaver Creek Reservoir was a diverse assemblage of algal types. Ultraplankton were numerically dominant in March but in May-June flagellated algae were equally as abundant as ultraplankton with green algae third in importance. Cyanophyta (blue-greens) bloomed in late June and through July and strongly dominated the community. By late August blue-greens were replaced by flagellates as the dominant algae, and then from September through November a mixed assemblage of flagellates, greens and ultraplankton dominated. Diatoms were an important component of the community under the ice in November. Flagellated algae, ultraplankton and, to a lesser extent, green algae generally dominated the phytoplankton community except during the bloom of blue-green algae in June and July. Non blue-green algae (graphed in Figure 10) fluctuated in abundance at about 2000 to 8000 cells/ml except in late June when populations of Cyanophyta were first observed. *Aphanizomenon flos-aquae* and *Anabaena flos-aquae* were the two blue-green species that formed the bloom in June and July. Although they persisted through to September, the bloom had essentially subsided by late August.

Diatoms were represented in the phytoplankton by a number of species. *Cyclotella* and *Synedra* were the most abundant and recurrent, but *Melosira* was common in late summer and fall. Diatom periodicity was irregular, there generally being a few hundred cells/ml present, but abundance ranged from zero to 1265 cells/ml.

Flagellated algae were from diverse taxonomic groups, *Cryptomonas*, *Rhodomonas*, and *Trachelomonas* being the three most abundant genera. Numbers of flagellates were generally highest from May through August, although they were rather variable (about 400 to 4500 cells/ml) during the ice-free season. The common occurrence of three species of Euglenoids (*Trachelomonas*,

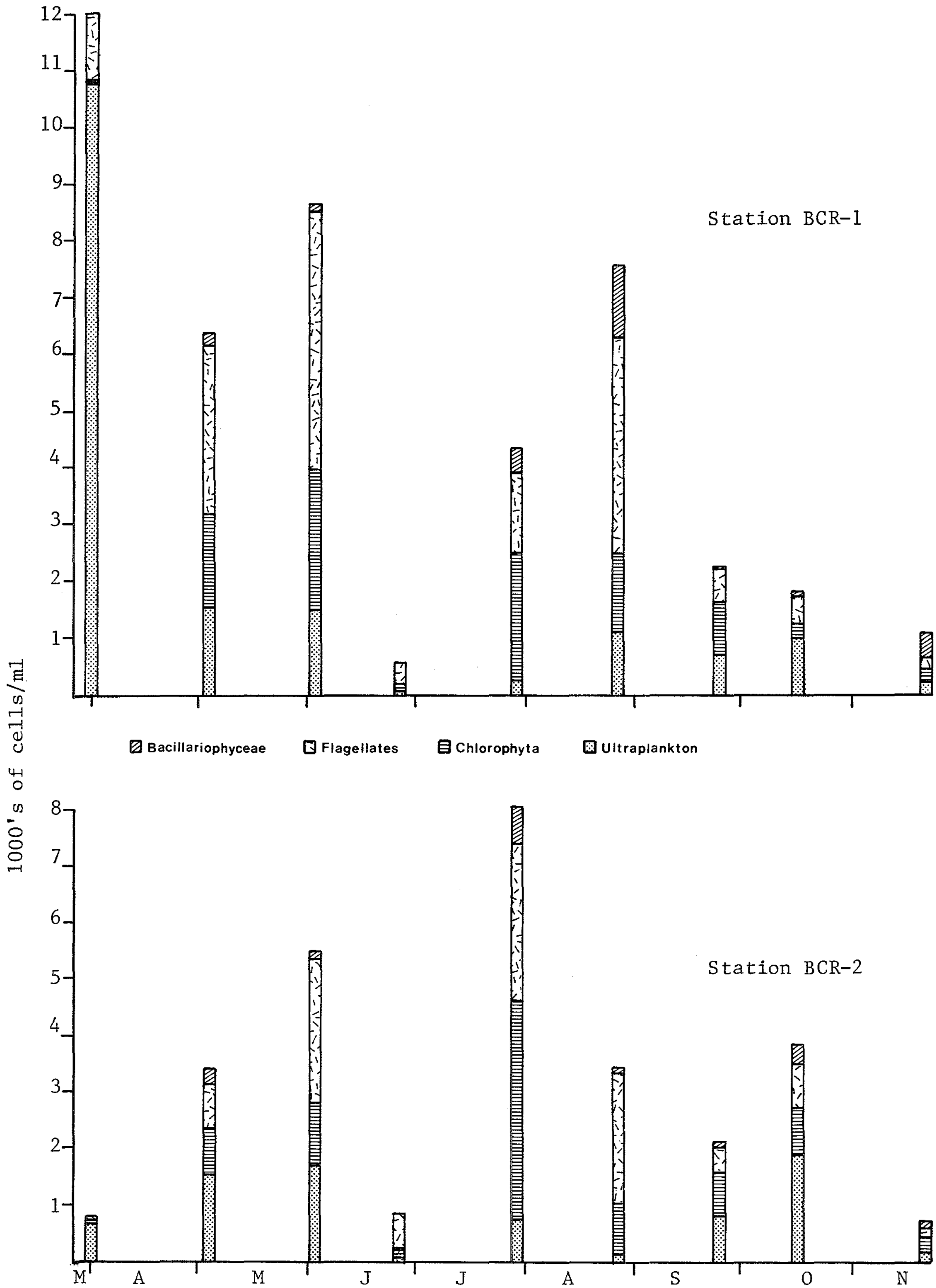


Figure 10. Abundance and composition of non-blue-green phytoplankton in Beaver Creek Reservoir, 1977.

Euglena, Phacus) may reflect high levels of organic compounds in the reservoir since this group is known to be common where organics are high (Round, 1965).

Ankistrodesmus, Dictyosphaerium and *Scenedesmus* were the three most common green algae encountered in the reservoir. *Ankistrodesmus* was fairly widespread in time but the other two genera were concentrated in the summer, as was the occurrence of green algae generally. This group ranged in abundance from 14 to 3855 cells/ml but was usually in the range 200 to 2000 cells/ml.

The Beaver Creek Reservoir phytoplankton community appears to reflect the high nutrient and organically rich nature of the water body. Spring concentrations of macronutrients (N, P, Si) were well in excess of those regarded as minimal in eutrophic situations (Wetzel, 1975), and accordingly, the bloom of blue-green algae in June and July was not unexpected. The amount of other algae (generally about 2000 to 8000 cells/ml), however, was perhaps lower than might have been expected considering nutrient levels alone. Populations of these other algae may be suppressed by the turbidity of the reservoir (mean Secchi disc visibility was about 1 m) which probably limits the trophogenic zone to the top half of the water column. According to Vollenweider's (1969) generalization that the trophogenic zone is approximately twice the Secchi disc depth, the reservoir would only have net photosynthesis in the top 2 m of water. Much of the reservoir volume lies below this depth, and since thermal stratification is poorly developed, phytoplankton would be regularly circulated out of the photogenic surface waters, and some suppression of algal growth would result. Because of their ability to regulate buoyancy, the blue-green algae may have been able to resist this circulation and thereby grow to the high abundances observed.

Aquatic macrophytes

Beaver Creek Reservoir is a moderately shallow body of water with a gently sloping shoreline of muskeg, sand, and some gravel substrates. These shallow shorelines are conducive to aquatic plant growth. Floating rafts of muskeg provide protection from wave action along much of the eastern and northwestern shores, further enhancing conditions for aquatic macrophytes. When surveyed in August, the second summer that the reservoir contained water, seventeen species of aquatic plants were identified (Table 17) and an abundant population of submerged macrophytes was found.

Table 17. Aquatic macrophytes observed in Beaver Creek Reservoir, 1977.

Submergents:

Ceratophyllum demersum L. - abundant and widespread

Lemna trisulca L. - occasionally collected in seine hauls

Myriophyllum exalbescens Fernald - abundant and widespread

Potamogeton alpinus Balb. - common and widespread

P. berchtoldii Fieb. - very abundant and widespread

[1]*P. obtusifolius* Mert. & Koch - occasional

P. richardsonii (Benn.) Rydb. - one specimen seen, on dam shoreline

P. zosteriformis Fernald - one specimen seen, in NE corner of reservoir

Utricularia vulgaris L. - abundant, concentrated in NW corner of reservoir

Floating-leafed:

Polygonum natans A. Eaton - abundant, mostly in S end of reservoir

Potamogeton natans L. - locally common, in NW corner of reservoir

Sparganium - common and widespread

Emergents:

Carex - common and widespread, often growing on muskeg rafts

Equisetum - common in stands on E shore

[2]*Hippuris vulgaris* L. - one bunch seen, in NW corner of reservoir

Sagittaria - a few specimens seen, in NW corner of reservoir

Typha latifolia L. - occasional stands throughout reservoir

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[1] Second recorded occurrence in Alberta (Dr. J.G. Packer, pers. comm.)

[2] Has both emergent and submergent leaves

Submergent and floating-leafed plants

At the time of the survey, these aquatic macrophytes were found throughout most areas of the reservoir. Plant growth was most profuse at depths of less than 0.75 m but did occur in decreasing densities out to 1.5 m. These depths, however, were measured after reservoir water levels had already declined 0.5 m since spring. Macrophyte growth was better developed in sheltered areas such as the east shore of the reservoir in the lee of rafts of muskeg. Exposed shores, especially if they consisted of gravel such as the dam face and some of the small islands, supported less plant growth. Many of the floating rafts of muskeg were located in depths greater than 1.5 m and no submergent plants were associated with them.

Potamogeton berchtoldii was by far the most abundant submergent plant. It occurred throughout the littoral zones and was the prevalent species except along the dam face. *Ceratophyllum demersum*, *Myriophyllum exalbescens* and *Utricularia vulgaris* were also abundant and widely distributed in the reservoir. All four of these species apparently have excellent colonization mechanisms since they have become widespread throughout the reservoir in less than two years since it began to fill. *Sparganium* sp. was the most abundant floating-leafed plant, occurring as single plants scattered throughout the littoral zone. *Polygonum natans* was also common, being abundant in patches in the south end of the reservoir but scarce in other areas.

Five types of submergent and floating-leafed plant assemblages were distinguished around the shore of the reservoir, based on the most abundant species, the number of species, and the overall abundance of the submergents (Figure 11). *Potamogeton berchtoldii* was the most abundant species in all but one area, but the species associated with it and their abundance varied from type to type. The areas occupied by these types are plotted in Figure 11. They have been estimated visually in the field and should be considered approximate. Extent of the zones along the shoreline has been estimated more accurately than width of the zones into the lake, although relative widths of the different areas are considered fairly accurate. The five types of submergent and floating-leafed plant assemblages and their characteristics are:

I High coverage of mostly *P. berchtoldii*

Ceratophyllum demersum and *Myriophyllum exalbescens* were scattered through this type, but other species were rare. Coverage of the substrate was as high as 50% in places but more often was about 10-20%.

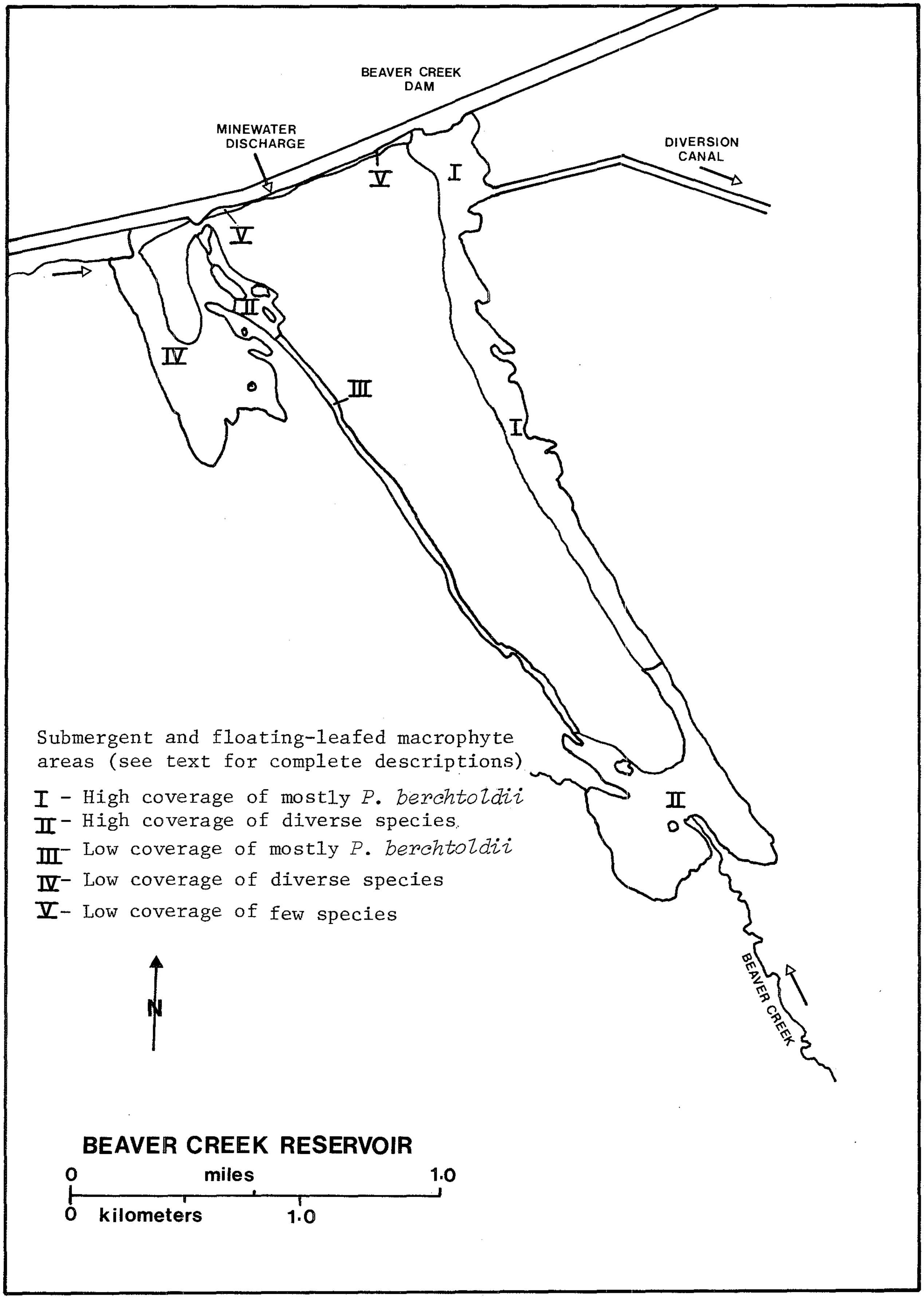


Figure 11. Occurrence of submergent and floating-leafed plants in Beaver Creek Reservoir, 1977.

This type occurred along the east shore where the bottom contained much organic material and wave exposure was low.

II High coverage of a diverse group

P. berchtoldii accounted for 50% or more of the plants in this type but *C. demersum* and *M. exalbescens* were common throughout. *Polygonum natans* was locally abundant in areas of this type and *Sparganium* and *Utricularia vulgaris* occasionally occurred as well. This type was found in the south end of the reservoir and on a portion of the northwest shore (Figure 11). Both areas had mud and/or organic substrates.

III Low coverage of mostly *P. berchtoldii*

C. demersum, M. exalbescens, and *Sparganium* sp. were scattered throughout this type but total coverage was low. This type was found mostly along the west shore where the bottom was sandy and the slope was steeper.

IV Low coverage of a diverse group

P. berchtoldii was again the most common species although a quite diverse group was found in this type. *C. demersum, M. exalbescens, U. vulgaris* and *Sparganium* were common, and *Potamogeton alpinus, P. obtusifolius, P. natans* and *Polygonum natans* were occasionally encountered. The northwest bay of Beaver Creek Reservoir was occupied by this type.

V Low coverage of few species

Potamogeton alpinus and *P. berchtoldii* were most common with scattered individuals of *C. demersum* and *M. exalbescens* as well. Coverage was low in this type, which was found on the gravel and sand substrates along the dam face.

Emergent plants

The emergent plant community in Beaver Creek Reservoir was largely confined to the floating rafts of muskeg where *Carex* was quite abundant and dominant. Very few emergents occurred around the shoreline itself, perhaps partly as a result of fluctuating water levels in the reservoir. Only scattered individuals of *Sagittaria* were seen, and *Equisetum* sp. was largely restricted to two stands on the east central shore. These two stands extended back from the shore a considerable distance in low terrain, and they probably occurred there prior to reservoir filling. Only about half a dozen stands of *Typha latifolia* were found growing around the reservoir, and *Hippuris vulgaris* was seen only in one location. *Carex* occurred occasionally around the main shoreline, but as previously mentioned, it was most abundant on the fixed muskeg rafts where it grew in the water-saturated turf. Because these turfs were floating, the water level experienced by plants growing on them was quite stable. These muskeg rafts were quite common along the east shore and in the north bay.

Beaver Creek Reservoir, with its low relief and soft substrates, supported a fairly abundant macrophyte population comprised of a limited number of species. This reflects a colonization pattern that is common to new habitats wherein a few species with efficient dispersal mechanisms quickly appear and dominate an area. Over a period of years other species will arrive and slowly establish in the habitat as well. The reservoir contained 12 species of submergent and floating-leafed plants while 20 such species occurred in Ruth Lake where colonization and plant succession have been taking place presumably since de-glaciation. More species will likely appear in the reservoir over time, and there will probably be changes in the dominant species as well. Development of the emergent plant community is difficult to predict since fluctuating water levels will be deleterious to the community, and the future pattern of water levels is not certain. Present low abundances of emergent plants may reflect both adverse water level changes and the short time since creation of the reservoir.

<u>Zooplankton</u>

The species of zooplankton collected at the two regular sampling stations and in the shallow water sampling sites in Beaver Creek Reservoir are listed in Table 18. At the regular stations the number of common[1] species in the major zooplankton groups were as follows: Rotifera - 10, Cyclopoida - 4, Calanoida - 1, Cladocera - 5. Nauplii of *Lynceus brachyurus* (Conchostraca) were observed in low numbers on May 4, but no adults were collected. The composition and abundance of the zooplankton at the two main stations are given in Appendices 3 and 4 and are discussed in the following.

[1]common refers to species that (1) were consistently observed during the study, or (2) were present on a few occasions in high numbers. Species observed in very low numbers on a few occasions were considered uncommon or rare. Species consistently occurring in low numbers were considered common but low in abundance.

Table 18. Beaver Creek Reservoir Zooplankton. The letter "L" denotes species collected in littoral tows that can be considered littoral in lifestyle.

	Open Water	Shallow Water
AMPHIPODA		
Hyalella azteca (Saussure)		X(L)
OSTRACODA		X(L)
CONCHOSTRACA		
Lynceus brachyurus Muller	X[1]	X(L)
CLADOCERA		
Alona retangula Sars		X(L)
Bosmina longirostris (Muller)	X	X
Ceriodaphnia affinis Lilljeborg	X	
C. reticulata (Jurine)	X[1]	
Chydorus sphaericus (Muller)[2]	X	X(L)
Daphnia magna Straus	X	
D. pulicaria Forbes	X[1]	X
D. rosea Sars	X	
Diaphanosoma leuchtenbergianum Fischer	X	X
Pleuroxus denticulatus Birge		X(L)
P. procurvus Birge		X(L)
Sida crystallina (Muller)		X(L)
COPEPODA		
CALANOIDA		
Diaptomus leptopus Forbes	X	X
CYCLOPOIDA		
Cyclops vernalis Fischer	X	X
Cyclops bicuspidatus thomasi Forbes	X	X
C. navus Herrick	X	X
Eucyclops agilis (Koch)		X(L)
E. speratus (Lilljeborg)		X(L)
Macrocyclops albidus (Jurine)	X[1]	X(L)
ROTIFERA[3]		
Asplanchna	*Hexarthra*	
Brachionus calyciflorus (Pallas)	*Keratella cochlearis* (Gosse)	
Brachionus	*K. quadrata* (Muller)	
Conochilus unicornis (Rousselet)	*Polyarthra*	
Filinia longiseta (Ehrenberg)	*Synchaeta*	

[1] denotes very rare species (i.e. only a few individuals ever observed).
[2] *Chydorus sphaericus* can occupy both littoral and open water (limnetic) zone.
[3] only documented at the regular sampling stations.

Rotifera

Total numbers of rotifers, as well as the dominant taxa, are presented in Figure 12. The two stations were similar in terms of abundance and dominants. Maximum numbers observed were 1 to 1.5 million/m^3 and occurred in the late July to late September period. Abundance on the other sampling dates was lower and generally in the 50,000 to 200,000/m^3 range. As mentioned in the methods, these figures should only be treated as a general indication of abundance. *Filinia longiseta* was the only rotifer collected in late March when oxygen concentrations were low (less than 0.2 ppm). *Keratella cochlearis* and *K. quadrata* were the important rotifers during the summer, and *Polyarthra* was the dominant rotifer during the fall.

Cyclopoida

Cyclopoid copepods showed a spring pulse in the May-June period with an abundance of about 70,000 to 90,000/m^3 at the time of sampling (Figure 13). Numbers were low in late June but higher from late July to late September (10,000-18,000/m^3). Seasonal abundance was similar at the two stations, and unidentified early copepodite stages usually were dominant. The numbers of *Cyclops vernalis* adults and *C. vernalis-Cyclops navus* late stage copepodites[1] on May 4 suggests that *C. vernalis* was the most abundant cyclopoid in early spring. Other cyclopoid species were very low in abundance.

Calanoida

Diaptomus leptopus was the only calanoid copepod collected in Beaver Creek Reservoir. A distinct pulse occurred in the June-July period but abundance of nauplii, copepodites and adults was generally low on the sampling dates (less then 8,000/m^3, Figure 14). The occurrence of only one apparent pulse for nauplii, copepodites and adults suggests the population is univoltine (one generation per year).

Cladocera

Three of the eight cladoceran species, *Ceriodaphnia reticulata, Chydorus sphaericus* and *Daphnia magna*, occurred sporadically and in low numbers (Appendices 3 and 4). The other five species had large populations at certain times

[1]It was not possible to distinguish between the late stage copepodites of these two species during counting procedures.

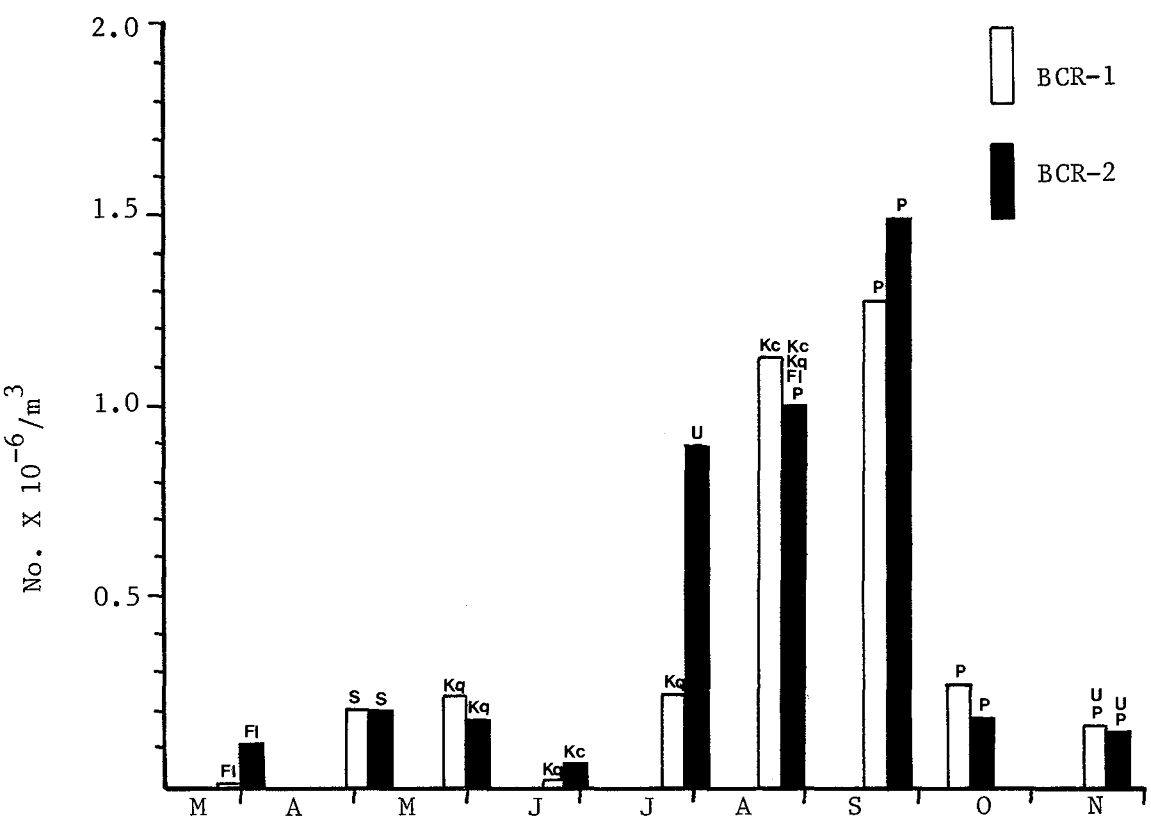


Figure 12. Abundance of Rotifera in Beaver Creek Reservoir in 1977. Letters above the bars indicate dominant types. Fl = *Filinia longiseta*, Kc = *Keratella cochlearis*, Kq = *K. quadrata*, P = *Polyarthra*, S = *Synchaeta*, U = unidentified.

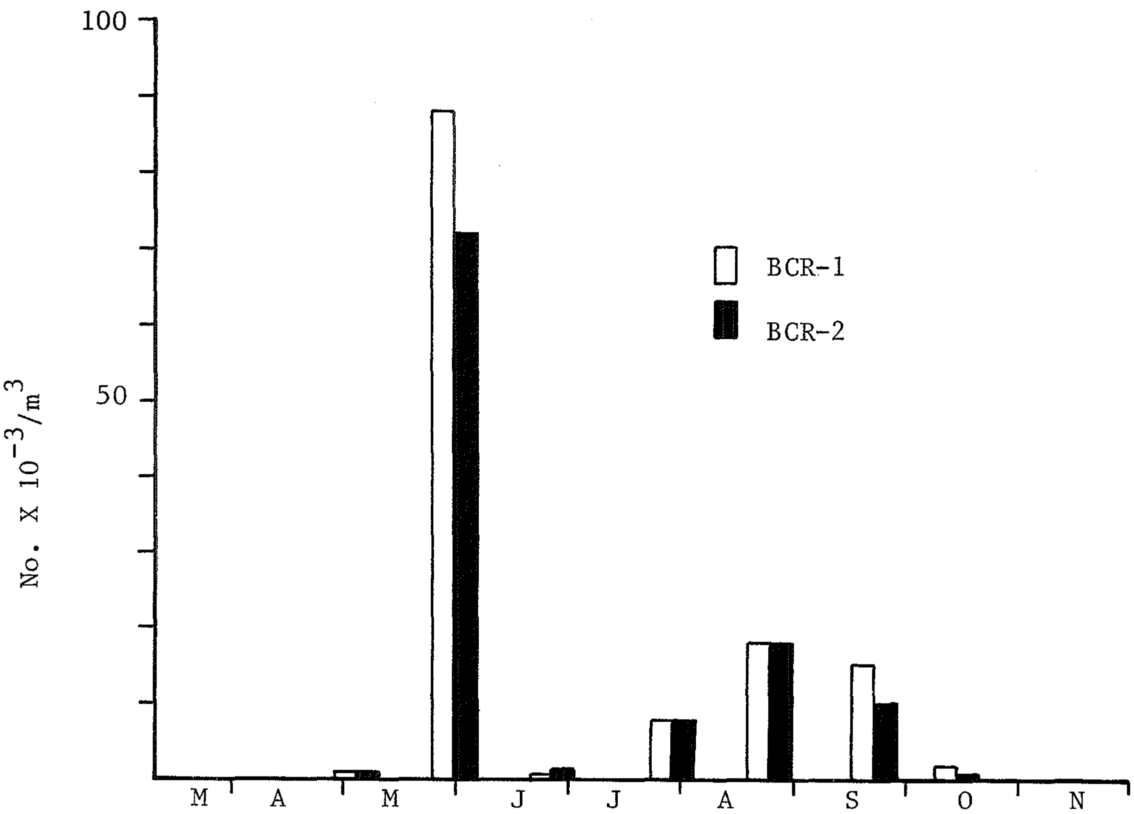


Figure 13. Abundance of Cyclopoida in Beaver Creek Reservoir in 1977. Values are the sum of copepodite and adult stages.

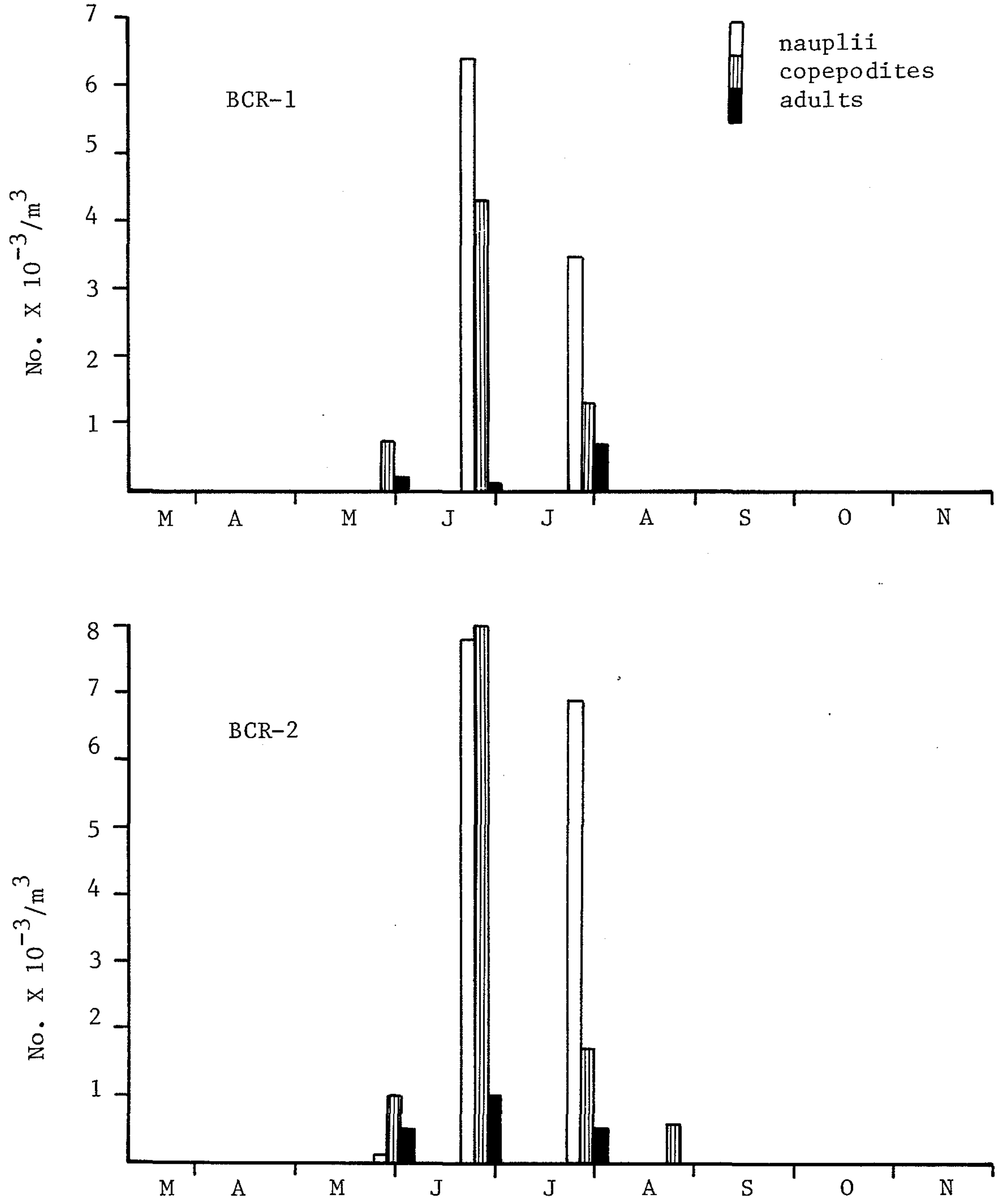


Figure 14. Abundance of *Diaptomus leptopus* in Beaver Creek Reservoir in 1977.

with *Ceriodaphnia affinis, Daphnia pulicaria* and *D. rosea* showing population peaks around June (Figure 15). *C. affinis*, for unknown reasons, was not observed at BCR-2. *Bosmina longirostris* and *Diaphanosoma leuchtenbergianum* were most abundant in the July-August period. The four-week sampling interval and the short duration of the active periods of the species preclude comparisons of abundance between stations.

Seasonal Trends

Seasonal community composition is shown in Figure 16 and this, in conjunction with individual species abundances (Figures 13 to 15), indicates the trends over the study period. On the first three sampling dates (March 31, May 4, June 1) cyclopoids were completely dominant. On the first two dates total abundance was low, but on June 1 cyclopoid numbers were relatively high. By late June cyclopoid numbers were low again. From late June to late July cladocerans were completely dominant. *Daphnia pulicaria* and *D. rosea* had population peaks in this period; *Bosmina longirostris* and *Diaphanosoma leuchtenbergianum* were most abundant in the July-August period. After late July cladocerans decreased. Cyclopoids began to dominate the community again and showed a shallow pulse in the August-September period. After September they were completely dominant even though their abundance was very low.

Total Numbers and Biomass

Total numbers and biomass of crustacean zooplankton are presented in Figure 17. Both parameters were low on the first two sampling dates but had increased by June 1 due to the pulse of cyclopoid copepods. Total numbers were lower on June 27, but biomass was at a maximum due to the presence of large zooplankton such as *Daphnia pulicaria, D. rosea,* and *Diaptomus leptopus*. In late July total abundance at BCR-2 was at the observed maximum due to a large pulse of *Bosmina longirostris*; however, biomass was not correspondingly high since this organism is relatively small. Considerably fewer organisms of this species were collected at BCR-1. At BCR-1, *B. longirostris* did not show as large a pulse, possibly a result of the four week sampling interval and rapid change in population size. Over the remainder of the season total numbers and biomass gradually decreased.

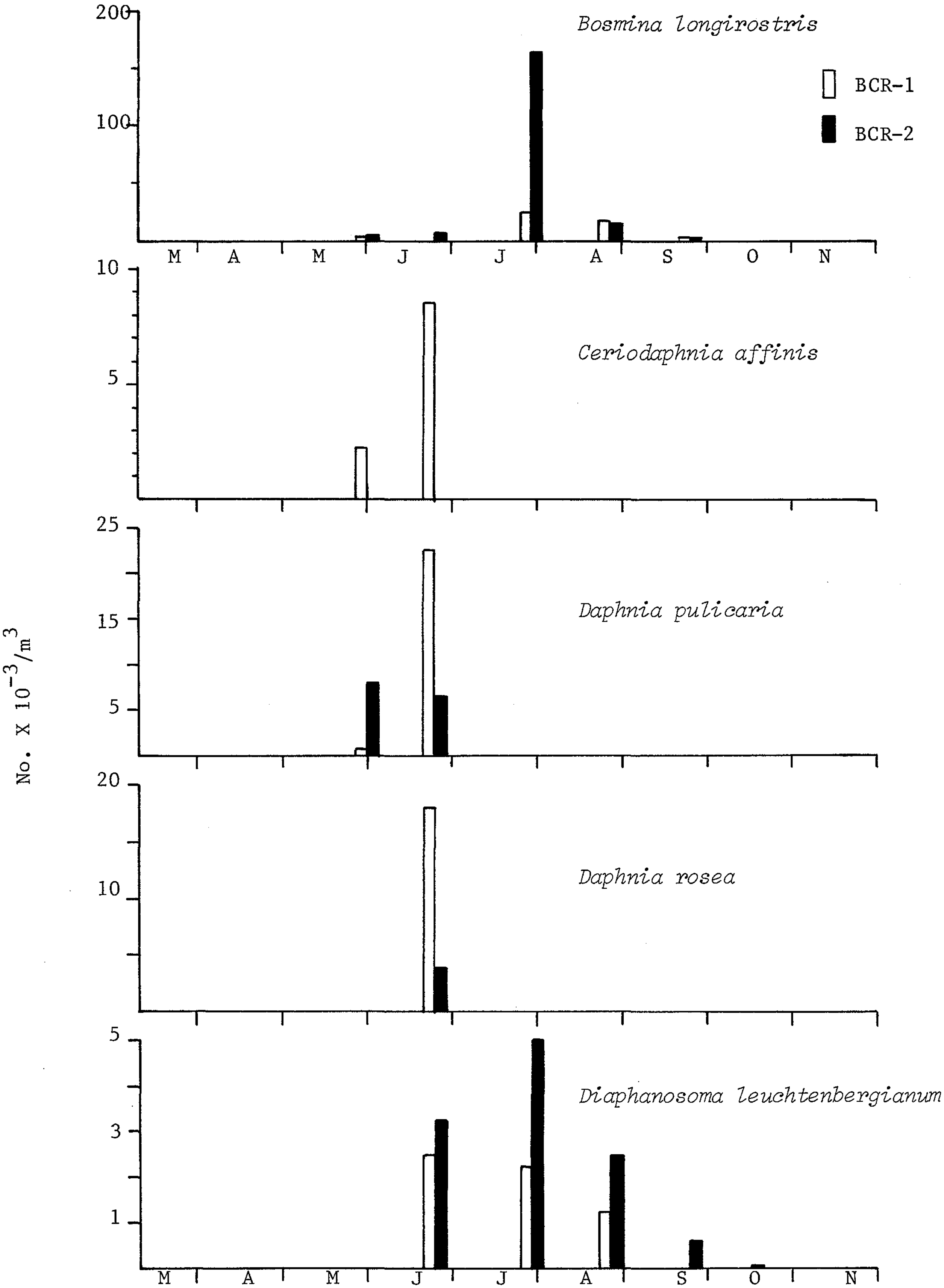


Figure 15. Abundance of the major species of Cladocera in Beaver Creek Reservoir in 1977.

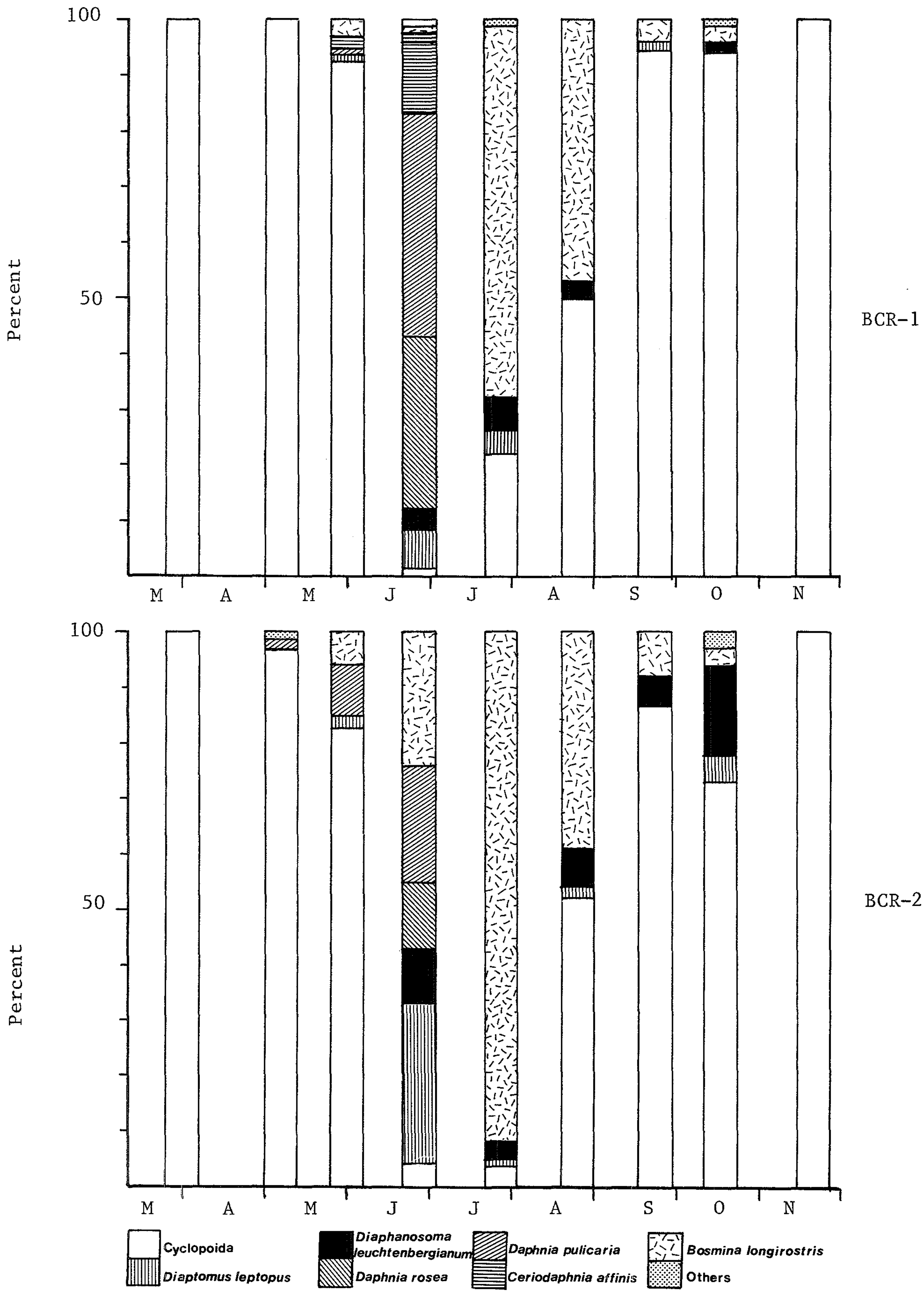


Figure 16. Numerical composition of the crustacean zooplankton in Beaver Creek Reservoir in 1977.

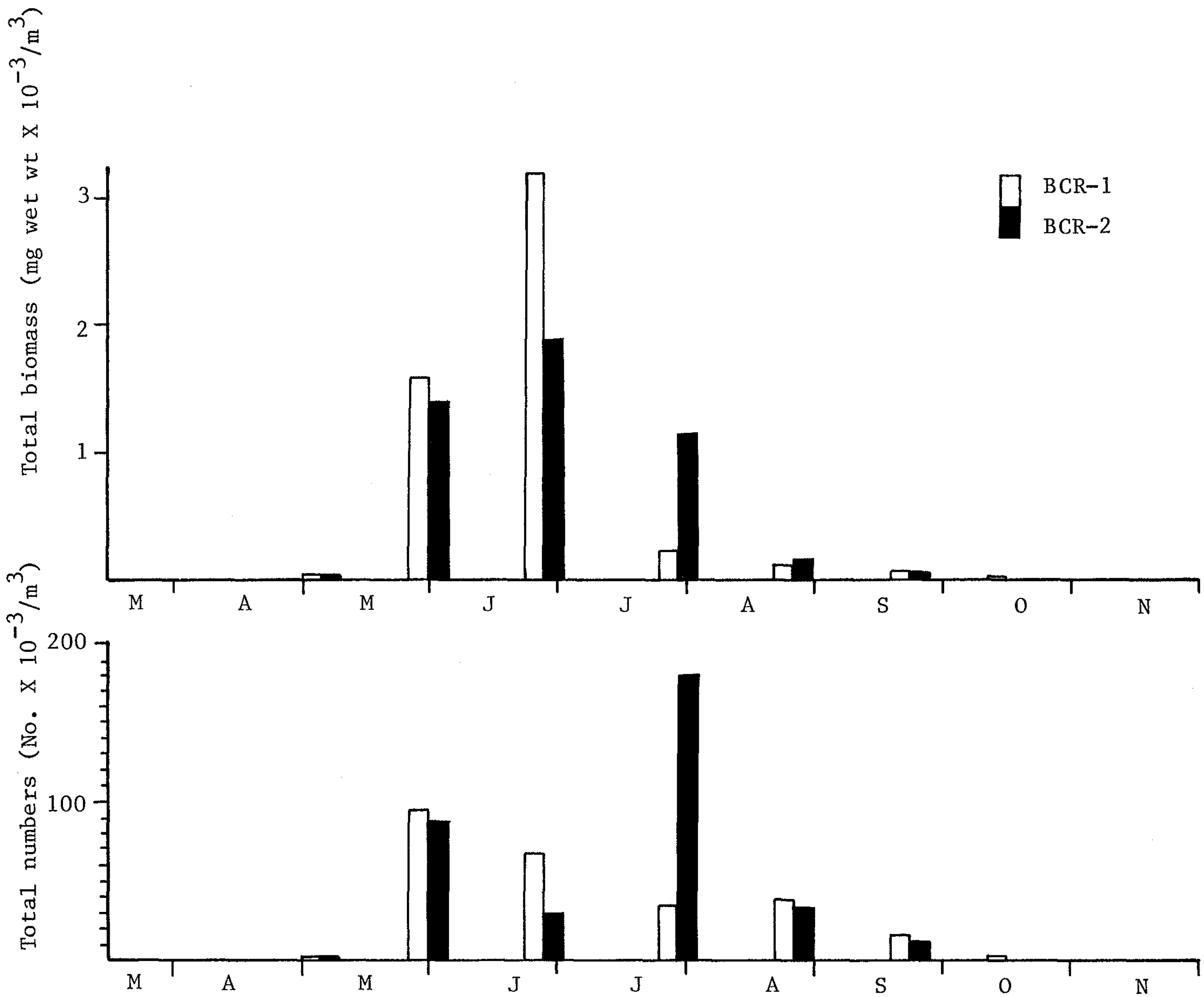


Figure 17. Total abundance and biomass of crustacean zooplankton in Beaver Creek Reservoir in 1977.

Littoral Crustaceans[1]

Counts of crustaceans collected in the shallow-water sampling are presented in Table 19, and sampling locations are given in Figure 5. The values are approximate because net tow lengths were estimated visually, and some debris blockage of the net occurred. Limnetic species were collected in the tows as well, since the collecting method did not exclusively sample the weeds. Since the purpose of the sampling was to document the presence and estimate the abundance of littoral species, the limnetic species collected will not be discussed.

Eleven taxa were collected that can be considered littoral in lifestyle[2]. Cyclopoid copepodites could not be accurately identified at the species level, consequently it is not known if this group contained additional species, or what portion of it belonged to littoral species. The number of species and abundance of littoral cladocerans and the abundance of adults of the copepod *Eucyclops agilis* tended to be highest in the late July collections. This was probably due to the association of these littoral species with the well-developed plant communities that occurred then. Macrophyte abundance was much lower at the sampling sites in the spring and fall.

Vertical Distribution

The vertical distribution of crustacean zooplankton was examined in Beaver Creek Reservoir since it could be affected by the saline minewater discharge. Samples were collected at 2 m intervals at BCR-1 on August 6. Oxygen concentration and temperature were measured as well. Figure 18 shows the vertical distribution of the major crustacean zooplankton as well as the temperature and oxygen data.

At the time of sampling *Bosmina longirostris* showed a preference for surface regions although it was abundant throughout the water column.

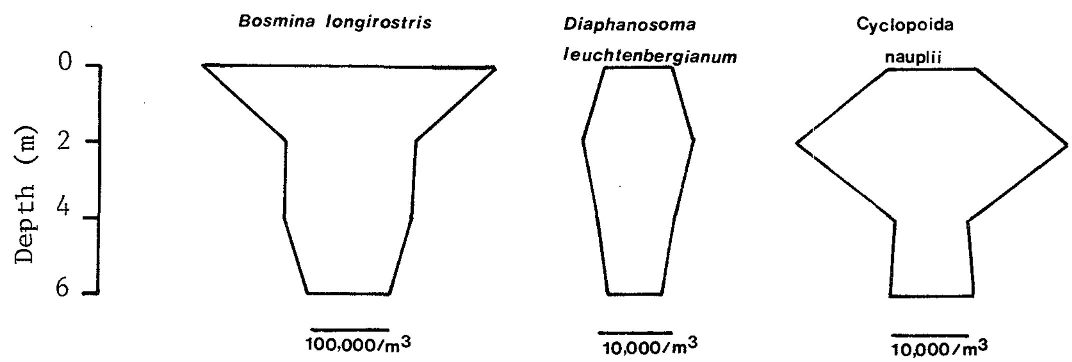
[1] In accordance with Ruttner (1963) and Hutchinson (1967), the littoral zone is defined as the benthic zone occupied by rooted plants. Littoral crustaceans are here defined as small crustaceans that live among the plants, are not found in large numbers in the open water, and are not found far from the weedy zone. *Chydorus sphaericus* is an exception to this rule; it can thrive in open water zones as well as littoral zones.

[2] The assignment of a species to a littoral or limnetic category is based on a review of the literature, mainly Edmondson (1959), Hutchinson (1967) and Anderson (1974).

Table 19. Summary of crustaceans collected in shallow water sampling in Beaver Creek Reservoir in 1977. Values expressed as number/m^3.

	Site LZ-1			Site LZ-2		
	May 4	July 29	Oct. 16	May 4	July 29	Oct. 16
AMPHIPODA						
**Hyalella azteca*			10			
CONCHOSTRACA						
**Lynceus brachyurus*						
nauplii	10					
*OSTRACODA	130	40	10	60		
CLADOCERA						
**Alona rectangula*					150	
Bosmina longirostris		1800	10		18000	20
**Chydorus sphaericus*		80			2000	160
Daphnia pulicaria	30					20
Diaphanosoma leuchtenbergianum		260	30		8000	20
**Pleuroxus denticulatus*		80			600	
**P. procurvus*		80			300	
**Sida crystallina*		110			1800	20
COPEPODA						
CALANOIDA						
Diaptomus leptopus						
copepodites		230	20			
adults					300	
CYCLOPOIDA						
copepodites	20000	2200	1260	90	21000	320
adults						
Cyclops vernalis	410	40	100	200		100
Cyclops bicuspidatus thomasi			80			40
Cyclops navus		40		20		
**Eucyclops agilis*	50	760	10		6100	
**E. speratus*				90		40
**Macrocyclops albidus*	10			20		
TOTAL	20,640	5,720	1,530	300	58,550	740
NUMBER OF LITTORAL TAXA	4	6	3	3	6	3

* denotes taxa considered to be littoral in lifestyle.



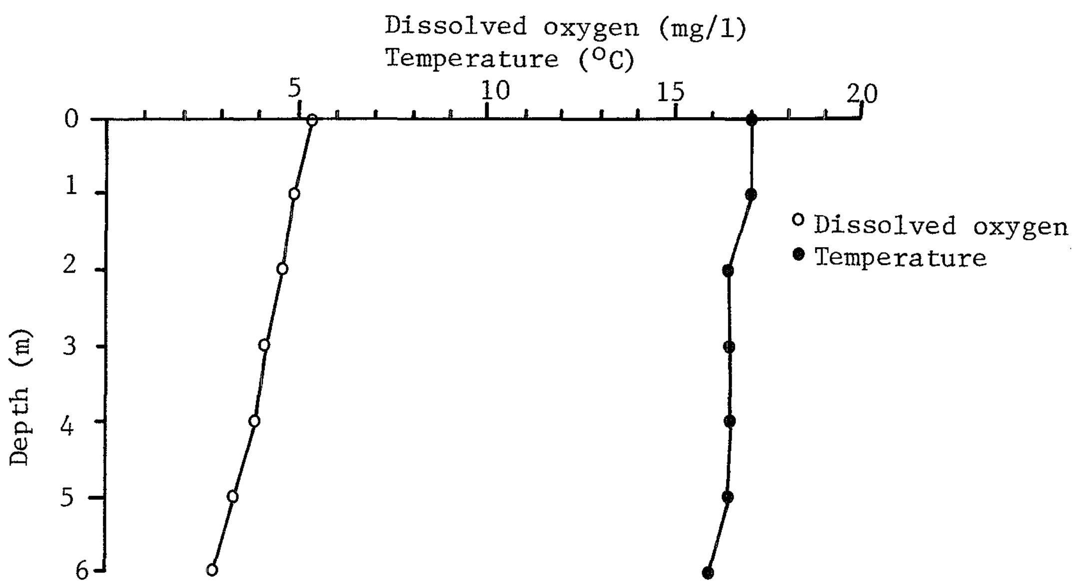


Figure 18. The vertical distribution of temperature, oxygen and major crustacean zooplankton, at BCR-1, August 7, 1977.

Diaphanosoma leuchtenbergianum showed little preference for a particular depth, but abundance was slightly higher at 2 m. Cyclopoid nauplii were distinctly more abundant at 2 m and were the only group with a strong preference for a particular depth; however, they were also relatively abundant in deeper waters. In essence, the major zooplankton were abundant throughout the water column but did show a preference for the 0 to 2 m range. This preference probably involved conditions in the trophogenic zone[1] which, on the basis of Vollenweider's (1969) generalization[2], would have been about 2 m deep in Beaver Creek Reservoir. Dissolved oxygen decreased with depth and below the zone was 4 ppm or less. Light intensity has been well documented as a factor in zooplankton distribution, and decreasing light levels with depth would serve to keep the zooplankton in the upper layers. The fact that zooplankton did occur through the water column was probably a result of turbulence. Temperature showed little stratification and would be an unlikely factor in the vertical distribution of zooplankton. The small amount of stratification of conductivity observed in Beaver Creek Reservoir in this study (discussed previously) would also be an unlikely factor.

Benthic macroinvertebrates

The counts of the benthic organisms collected at the two sampling sites are presented in Tables 20 and 21. Figure 19 shows total abundance and composition of the macrobenthos. Considerable variability occurred in the numbers collected per sample (Figure 19), therefore discussions must be general.

Chironomid larvae were the dominant group, and the trends in total numbers of benthos largely followed the abundance of this group. *Chironomus* was the dominant genus of chironomid, although *Glyptotendipes* was well represented at BCR-2. The only other significant major group of benthos was the Oligochaeta. The phantom midge, *Chaoborus flavicans*, was usually observed in low numbers, although 4th instar larvae were very abundant at BCR-1 in November.

[1]the zone of net photosynthesis; generally considered to be above the 1% light level (the compensation point).

[2]This states that the trophogenic zone is about twice the Secchi disc visibility.

Table 20. Organisms in Ekman dredge samples from station BCR-1, Beaver Creek Reservoir, 1977.

	March 31			May 4			June 1			June 27			July 28			Aug. 25			Sept. 23			Oct. 15			Nov. 20		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																											
Diptera																											
Chironomidae																											
Chironomini	5	1	4	13	6	21	4	9	1	5	1	9	2	1	14	16	11	18	49	25	30	58	66	115	2	4	5
Tanytarsini								1															1				
Tanypodinae								1									1			1		2		3			1
Orthocladiinae																		1							1		
Culicidae																											
Chaoborus	2	1	1						5	1	1	1	2	2	2		1					3	1	6	51	82	144
Hemiptera																											
Corixidae																	1										
Coleoptera																											
Haliplus													1														
ARACHNOIDEA																											
Hydracarina																							1				1
CRUSTACEA																											
Ostracoda																											
OLIGOCHAETA	1					9	3	30	1	1					3	1	4	2	23	10	33	24	9	144			
GASTROPODA																											
Gyraulus																											
Helisoma																											
Valvata sincera sincera																											
TOTAL	8	2	5	13	6	30	7	41	7	7	2	10	5	3	19	17	18	21	72	36	63	87	78	268	54	86	151
Mean per sample		5			16			18			6			9			18			57			144			97	
Mean per m^2		215			702			788			271			388			805			2454			6214			4177	

Three dredges (0.023 m^2 each) taken on each date.

Table 21. Organisms in Ekman dredge samples from station BCR-2, Beaver Creek Reservoir, 1977.

	March 31			May 4			June 1			June 27			July 28			Aug. 25			Sept. 23			Oct. 15			Nov. 20		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																											
Diptera																											
Chironomidae																											
Chironomini	5	10	5	19	15	21	32	8	11	20	81	62	65	8	41	28	138	120	50	88	111	50	42	48	60	20	28
Tanytarsini							1					5	1		1		1		2	1		3		3		1	
Tanypodinae													1		1	1	5	1	2	5	3	1	1	6	1	1	1
Orthocladiinae																	3										
Culicidae																											
Chaoborus		2								1		3															
Hemiptera																											
Corixidae																											
Coleoptera																											
Haliplus																											
ARACHNOIDEA																											
Hydracarina																					2						
CRUSTACEA																											
Ostracoda																	2	1	1	1	2	4			1		
OLIGOCHAETA	3	2	1		2		20		27	2	12	4	22		49	1	36	20	11	7	22	1		2		1	
GASTROPODA																											
Gyraulus																		1									
Helisoma																		1									
Valvata sincera sincera																		1									
TOTAL	8	14	6	19	17	21	53	8	38	23	93	74	89	8	92	30	185	145	66	102	141	59	43	59	62	23	29
Mean per sample		9			19			33			63			63			120			103			54			38	
Mean per m^2		401			818			1421			2726			2713			5167			4435			2312			1636	

Three dredges (0.023 m^2 each) taken on each date.

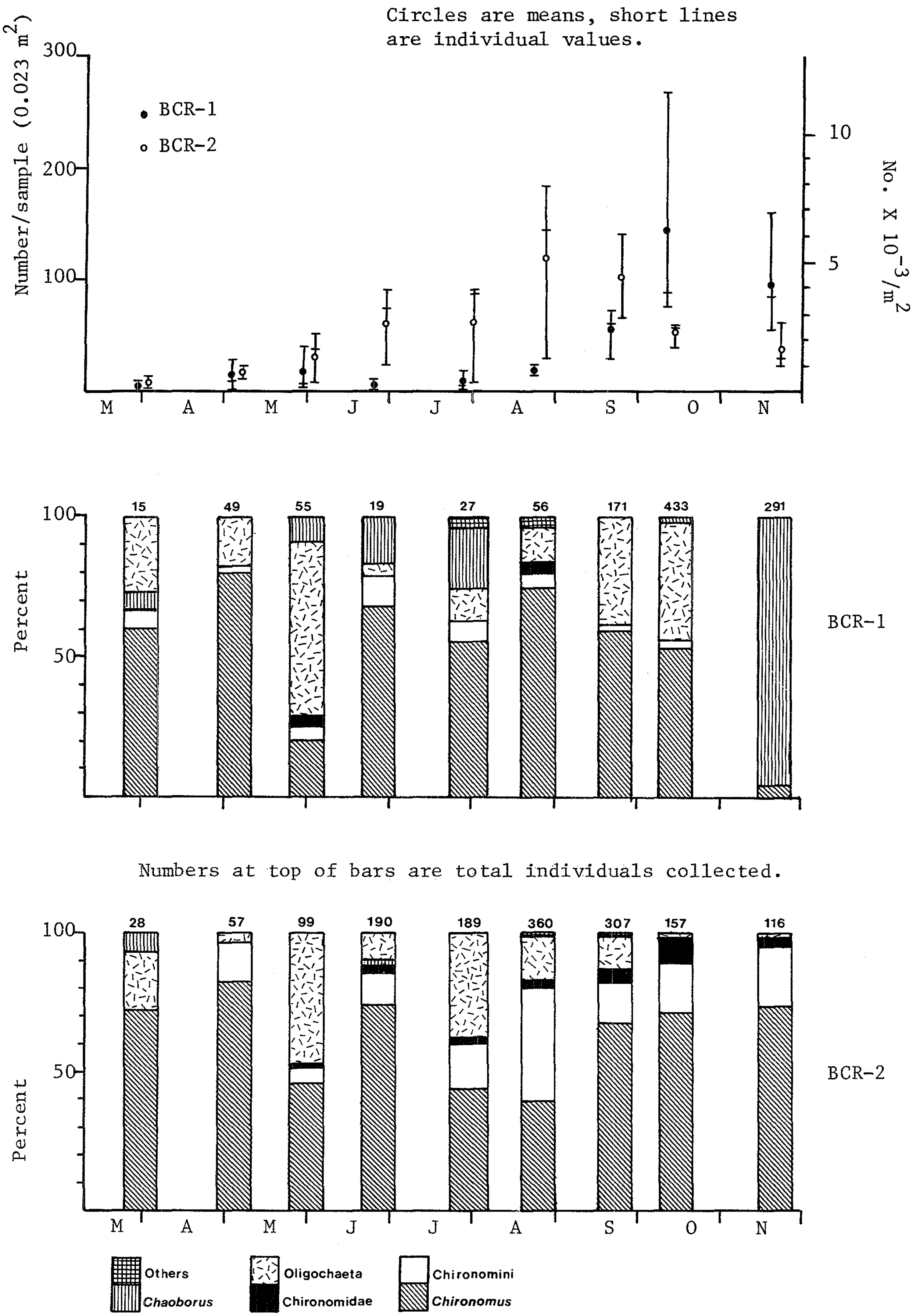


Figure 19. Total abundance and numerical composition of the benthos in Beaver Creek Reservoir in 1977.

Total abundance was low at both stations in late winter and early spring (about 25 organisms/sample or less). At BCR-2 numbers increased during the summer and fall, mainly in response to the increase of *Chironomus* and *Glyptotendipes* (Table 22). The data indicate a tendency towards maximum abundance at this site in the August-September period. At BCR-1 numbers remained low throughout the summer but increased in September-October because of increased numbers of *Chironomus*. In November the abundance of *Chironomus* was very low, but total abundance remained fairly high because of the abundance of the phantom midge, *Chaoborus flavicans*. It is not known what caused the decrease in number of *Chironomus*. At BCR-2 there was no drastic decrease in the abundance of *Chironomus* in November, although it declined somewhat during fall.

The general increase of *Chironomus* in the late summer-fall period was also observed in Ruth Lake and at Site PCR-2 in Poplar Creek Reservoir. The increase in numbers may be related to the mesh size used in washing samples. The 0.6 mm mesh would miss most smaller 1^{st} and 2^{nd} instar larvae, and what was actually detected was probably the growth of the larvae into the larger 3^{rd} and 4^{th} instars. The larvae overwinter in the fourth instar, with most of the population pupating and emerging in the spring or early summer (J. Rasmusson, pers. comm.).

As mentioned previously, 4^{th} instar larvae of *Chaoborus flavicans* were generally observed in low numbers but were abundant at BCR-1 in November, at which time they accounted for 95% of the bottom fauna. Late instar larvae develop in late summer and fall, and these stages generally show the strongest migrations between bottom sediments in the day (an inactive period) and the water column at night (an active feeding period). It is possible the high abundance observed was due to sampling variability, but this seems unlikely since a similar phenomenon of high abundance in fall was observed at PCR-1 in Poplar Creek Reservoir. Also, in several central Alberta lakes, 4^{th} instar larvae of *C. flavicans* have been found to be most abundant in the benthos in late fall and winter (P. Mitchell, J. Rasmusson, pers. comm.). Therefore, it seems that in some regions of Beaver Creek Reservoir, *C. flavicans* larvae are associating with the bottom in the fall.

Conductivity, as an indicator of the influence of the saline minewater discharge, was considered as a factor that could affect the benthos. Conductivity gradually increased over the season, and BCR-1 tended to have higher values, as well as more noticeable vertical gradients, than BCR-2 (Table 16;

Table 22. Abundance of Chironomidae at BCR-1 and BCR-2 in Beaver Creek Reservoir, 1977. Three Ekman samples were collected on each date (area of one sample = $0.023\ m^2$)

STATION BCR-1

	March			May			June			June			July			Aug.			Sept.			Oct.			Nov.		
	31			4			1			27			28			25			23			15			19		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Subfamily Chironominae																											
Tribe Chironomini																											
Chironomus	4	1	4	13	6	20	2	9		5	1	7	2	1	12	16	11	18	48	25	30	57	66	108	2	4	5
Einfeldia	1							1																			
Glyptotendipes						1	2					2			2				1					7			
unidentified																						1					
Tribe Tanytarsini								1															1				
Subfamily Orthocladiinae																		1							1		
Subfamily Tanypodinae																											
Procladius								1									1			1		2		3			1
TOTAL	5	1	4	13	6	21	4	12		5	1	9	2	1	14	16	12	19	49	26	30	60	67	118	3	4	6
Mean per sample		3			13			5			5			5			16			35			82			4	
Mean per m^2		130			565			217			217			217			695			1522			3565			174	

STATION BCR-2

	March			May			June			June			July			Aug.			Sept.			Oct.			Nov.		
	31			4			1			27			28			25			23			15			20		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Subfamily Chironominae																											
Tribe Chironomini																											
Chironomus	5	10	5	17	14	16	31	8	9	17	75	49	35	8	41	18	79	43	41	70	97	40	42	32	46	15	22
Einfeldia						2				3	6	13															
Glyptotendipes				2	1	3	1		2				30			10	59	76	9	16	12	10		15	14	5	6
unidentified																		1		2	3			1			
Tribe Tanytarsini							1					5	1		1		1		2	1		3		3		1	
Subfamily Orthocladiinae																	3										
Subfamily Tanypodinae																											
Procladius													1		1	1	5	1	2	5	3	1	1	6	1	1	1
TOTAL	5	10	15	19	15	21	33	8	11	20	81	67	67	8	43	29	147	121	54	94	115	54	43	57	60	22	29
Mean per sample		10			18			17			56			39			99			88			51			37	
Mean per m^2		435			783			739			2435			1696			4304			3826			2217			1609	

see chemistry section for detailed discussion). This may have been related to the minewater discharge, but the data from this study alone do not enable an assessment of the situation. Although BCR-1 tended to have lower numbers of benthic organisms during the summer than BCR-2, conductivity differences between the stations were usually relatively small and are an unlikely factor in abundance differences. In addition, maximum numbers of the important organism *Chironomus* were similar at the two stations.

Benthic Colonization

To examine benthic colonization, ten sites were established along a transect in the north part of the reservoir (Figure 5). The conditions at each site are described in Table 23, and the detailed results of the collections are presented in Table 24. Figure 20 shows total abundance and percent composition of the benthic macroinvertebrates at the sites.

Site 1, in a shallow vegetated region on the west shore, was the most productive site - total abundance averaging about 1000 individuals/dredge. Chironomid larvae, mostly *Glyptotendipes*, were dominant, but snails, amphipods, mites and oligochaetes were well represented. At the remaining sites abundance was lower, with most of the total numbers being in the range of about 20-60 individuals/dredge. There may have been a trend of decreasing abundance of benthos with increasing depth, but high variability between samples precludes a firm conclusion.

Chironomids, of which *Chironomus* and *Glyptotendipes* were the major genera, were the most abundant group collected along the transect. *Chironomus* became more dominant as depth increased due to decreasing numbers of *Glyptotendipes*. The reasons for the decrease of the latter genus were not obvious but could involve the physical-chemical nature of the water and substrate.

The colonization data showed that benthic organisms, mainly chironomid larvae, occupied the various regions along the transect. Mean total abundance of the three transect sites nearest BCR-1, which were also the transect sites most comparable in depth to the main station, was in the range of 14-26 individuals/dredge. Mean abundance at BCR-1 in late July and late August was 9 and 18 individuals/dredge respectively, similar to that found at the three adjacent transect sites. As mentioned earlier, total abundance at the transect sites (excluding the littoral Site 1) was in the range of 20-60 individuals/dredge, and, taking into account the variability within samples at a given site, the general area prescribed by BCR-1 and the transect appeared rather uniformly

Table 23. Description of benthic colonization sampling sites in Beaver Creek Reservoir, August 6, 1977.

Site	Depth (m)	Dissolved Oxygen (mg/l)	T (°C)	Substrate
1	0.3	6.0	19.0	sand-silt; abundant plant debris[1], twigs and branches, macrophytes present
2	5.0	3.2	17.0	some clay; abundant twigs and branches
3	3.0	3.5	17.0	some clay; abundant twigs and branches
4	6.0	1.5	16.5	plant debris[1]
5	2.8	3.2	16.5	plant debris[1]
6	1.9	3.9	17.0	lots of moss and plant debris[1]
7	1.9	3.8	17.0	lots of moss and plant debris[1]
8	1.5	3.4	17.0	gravel; plant debris[1]
9	1.2	3.6	17.0	plant debris[1]
10	1.0	6.5	17.0	sand-mud, some gravel; small amount of macrophytes and plant debris[1]

[1] plant debris refers to dead vegetation arising from flooded forest litter, flooded terrestrial plants, and/or dead aquatic macrophytes; sticks, twigs, and branches are not included in this category.

Table 24 . Organisms in Ekman dredge samples from benthic colonization survey in Beaver Creek Reservoir, 1977. Area of each sample = 0.023 m^2. Three samples taken at each station.

	STN-1			STN-2			STN-3			STN-4		
	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA	51	80	363			1	1	2		5		
NEMATA	1		2									
HIRUDINEA	16	14	20			1						
CRUSTACEA												
AMPHIPODA												
Gammarus lacustris			1									
Hyalella azteca	19	11	179									
OSTRACODA	4	8	110									
ARACHNOIDEA-Hydracarina	103	94	60									
INSECTA												
DIPTERA												
Ceratopogonidae	1		2									
Chironomidae												
Chironomini												
Chironomus	77	39	69	26	21	12	30	21	18	22	3	2
Glyptotendipes	598	53	619	1			3	1		3		
unidentified	5	3	16	1						1		
Diamesinae												
Orthocladiinae	2	2	4									
Tanypodinae												
Ablabesmyia	2	1	8									
Procladius	2	2	2				1			1		
Tanytarsini	37	26	162	1						1		
Culicidae												
Chaoborus				1	1	5					2	1
COLEOPTERA												
Haliplus			3									
EPHEMEROPTERA												
Caenis		2	2									
HEMIPTERA	4											
Corixidae												
TRICHOPTERA												
Agraylea		1										
MOLLUSCA												
Gastropoda												
Gyraulus deflectus		61	2									
Helisoma												
Menetus cooperi	16	44	4									
Physa		128										
Promenetus exacuous												
TOTAL	938	569	1628	30	22	19	35	24	18	33	5	3
MEAN TOTAL/SAMPLE		1045			24			26			14	

Table 24 . Continued

	STN-5			STN-6			STN-7			STN-8		
	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA	10		10	3	4	1					3	11
NEMATA												
HIRUDINEA												
CRUSTACEA												
AMPHIPODA												
Gammarus lacustris												
Hyalella azteca			1									
OSTRACODA			1									
ARACHNOIDEA-Hydracarina												
INSECTA												
DIPTERA												
Ceratopogonidae												
Chironomidae												
Chironomini												
Chironomus	21	9	29		20	21	13	6	15			2
Glyptotendipes	9	6	5	8	25	2	35		27	23	3	24
unidentified	1						1	1				2
Diamesinae										2		1
Orthocladiinae												
Tanypodinae												
Ablabesmyia												
Procladius	13		2	4	8	1	5		1	6	11	7
Tanytarsini		1		9	1		7			11	1	40
Culicidae												
Chaoborus	1							1	1			
COLEOPTERA												
Haliplus												
EPHEMEROPTERA											1	
Caenis												
HEMIPTERA												
Corixidae												
TRICHOPTERA												
Agraylea												
MOLLUSCA												
Gastropoda												
Gyraulus deflectus	1				5	2			1		2	
Helisoma												
Menetus cooperi												
Physa												
Promenetus exacuous												
TOTAL	56	16	47	24	63	27	61	8	45	42	21	87
MEAN TOTAL/SAMPLE		40			38			38			50	

Table 24. Continued

	STN-9			STN-10		
	1	2	3	1	2	3
OLIGOCHAETA	7			3	2	
NEMATA					1	
HIRUDINEA						
CRUSTACEA						
AMPHIPODA						
Gammarus lacustris						
Hyalella azteca						
OSTRACODA				1		1
ARACHNOIDEA-Hydracarina				3		2
INSECTA						
DIPTERA						
Ceratopogonidae						
Chironomidae						
Chironomini						
Chironomus	1	28	6	6	5	2
Glyptotendipes	276	17	12	89	24	41
unidentified	2	3		8	3	2
Diamesinae						
Orthocladiinae	5			4		1
Tanypodinae						
Ablabesmyia						
Procladius	5	2		8	1	7
Tanytarsini	24	1	4	22	4	
Culicidae						
Chaoborus						
COLEOPTERA						
Haliplus						
EPHEMEROPTERA						
Caenis						
HEMIPTERA						
Corixidae						
TRICHOPTERA						
Agraylea						
MOLLUSCA						
Gastropoda						
Gyraulus deflectus		1				3
Helisoma				4		
Menetus cooperi						
Physa						
Promenetus exacuous			1			
TOTAL	320	52	23	148	40	59
MEAN TOTAL/SAMPLE		132			82	

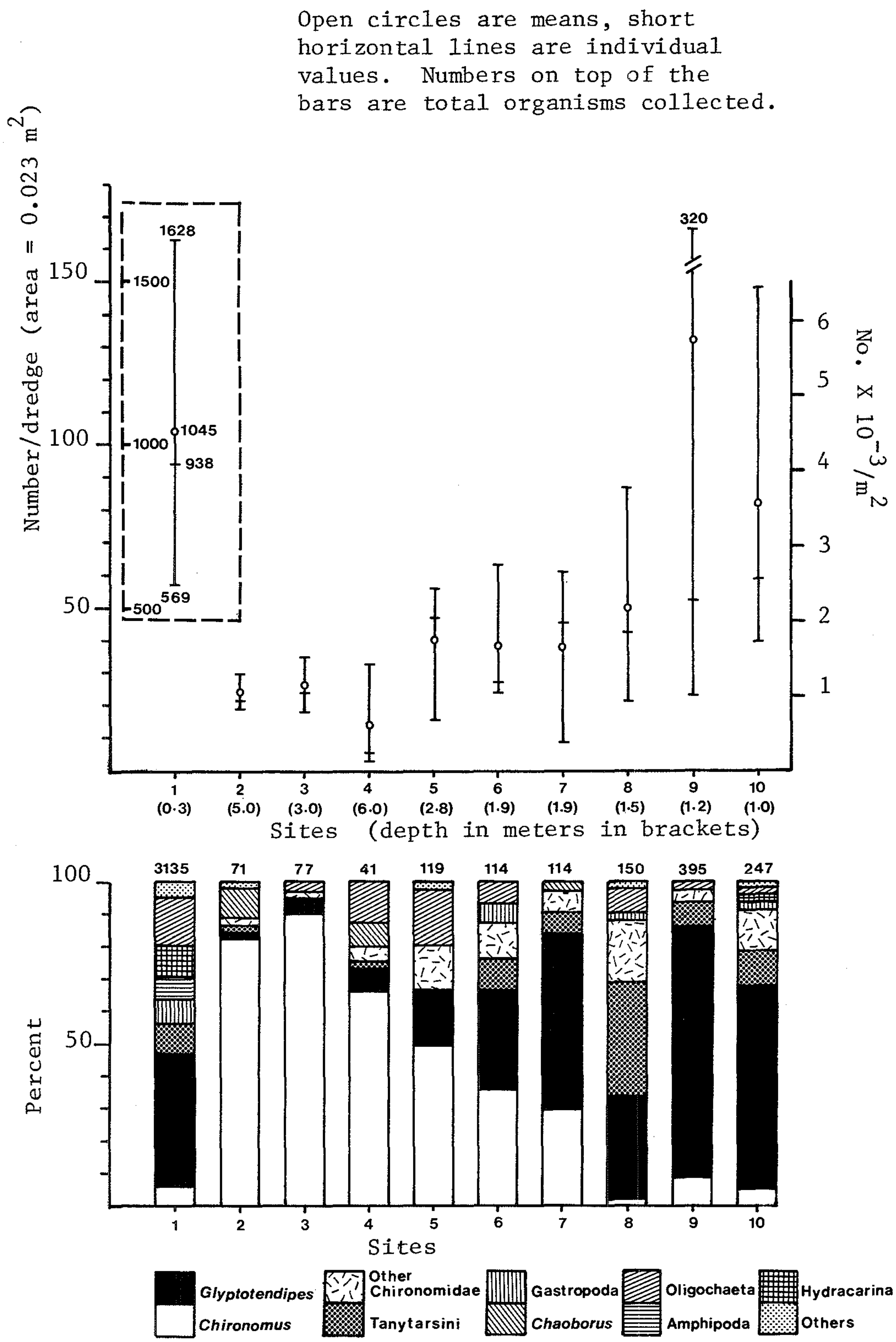


Figure 20. Abundance and numerical composition of the benthos at the benthic colonization sample sites in Beaver Creek Reservoir, August, 1977.

colonized in terms of abundance of benthos. Thus, BCR-1 was representative of the benthos in the northern region of the reservoir. As already noted, there were compositional differences in the benthos at the transect sites.

The benthos data demonstrated that through much of the season BCR-2 had a higher abundance of benthos than BCR-1. It is not known if this represents only a local situation at BCR-2 or whether there is a tendency towards higher numbers in the general region of this site. As previously mentioned, there may have been a trend of higher abundance with decreasing depth so that shallower BCR-2 may have supported higher standing crops. Oxygen depletion in bottom regions was more severe at BCR-1, and this may limit the distribution, growth and survival of the benthos at that site and at deeper locations in general. More detailed information would be needed to assess this situation.

It should be noted that as the physical-chemical nature of the reservoir evolves, the types of benthos present, and their distributions, will change. In a two year study of a newly flooded reservoir in Saskatchewan, McMillan (1971) noted major changes in the species composition and depth distribution of the benthos.

Fish

Six species of fish were collected in Beaver Creek Reservoir in 1977. Their relative abundances are indicated in Table 25. Appendix 5 contains length-weight information on gill-netted fish. Brook sticklebacks, fathead minnows, and lake chub were collected in seine hauls (Table 26) and were common to abundant in the reservoir. All size classes of the three species were collected, indicating that these species are reproducing in the reservoir. Brook sticklebacks and fathead minnows probably colonized the reservoir from Ruth Lake where they were abundant in the past (Noton and Chymko, 1977). Lake chub did not occur in Ruth Lake and must have originated in Beaver Creek.

White suckers were abundant in the impoundment (Table 27) and were reproducing there as evidenced by the occurrence of young of the year in seine hauls taken in August. Suitable spawning substrates for this species (shallow water with gravel bottoms - Scott and Crossman, 1973) exist in the northeast corner of the reservoir. Individuals were collected in gill nets and seine hauls, and many of those in the gill nets were around 300 mm fork length. This size of

Table 25. Species and relative abundance of fish collected in Beaver Creek Reservoir, 1977.

Species	Relative abundance
Brook stickleback - *Culaea inconstans*	++++
Fathead minnow - *Pimephales promelas*	++++
Lake chub - *Couesius plumbeus*	+++
White sucker - *Catostomus commersoni*	++++
Longnose sucker - *C. catostomus*	+++
Northern pike - *Esox lucius*	++

++++ Very abundant

+++ Common to abundant

++ Occasional

Table 26. Fish collected in seine hauls in Beaver Creek Reservoir, 1977.

	Site S1	S2	S3	S4	S5	S6
June 25						
Brook stickleback	+++	+++	++	++	+++	+++
Fathead minnow	+++	++	++	++		
Lake chub	++	+	+			
White sucker		++				
unidentified suckers	+++	+++	++	+		+++
August 23						
Brook stickleback	+++	+++	++	+++	+++	+++
Fathead minnow	+++	++	++	++	+++	+++
Lake chub	+++	++	+	+		
White sucker	+++	++	+		+	++
unidentified suckers						++

++++ Very abundant

+++ Common to abundant

++ Occasional

+ Rare

Table 27. Numbers of fish collected in gill nets in Beaver Creek Reservoir, 1977.

	Site G1	Site G2
June 25-26		
White sucker	29	18
Longnose sucker	4	2
Northern pike	__	4
Total	33	24
August 22-23		
White sucker	98	88
Longnose sucker	13	24
Northern pike	4	5
Total	115	117

One test gang gill net set overnight at each site on each occasion.

individual appeared to be quite common in the reservoir and seemed to encompass fish of ages 5 to 9 years, although firm ages could not be determined from scales. Nonetheless, it is clear these larger fish were too old to have been spawned within the reservoir and must have existed in upper Beaver Creek prior to closure of the dam in fall of 1975. Considering the abundance of this size group of fish, plus the fact that this size group was equally abundant in Ruth Lake in 1977 and must also have reached there from upper Beaver Creek after dam closure, pre-diversion populations of white suckers in Beaver Creek must have been high in numbers.

Stomachs of a representative sample of fish, gill netted in June, were examined to obtain an indication of the type of foods being consumed (Table 28). Cladoceran crustaceans and larval Chironomidae were the major food items of both white and longnose suckers (Table 28). Corixidae and Coleoptera were the only other groups of aquatic invertebrates that occurred with any regularity in the examined stomachs. Cladocerans were the most abundant zooplankters in the reservoir at the time, and Scott and Crossman (1973) report that white suckers are known to consume large amounts of cladocerans on occasion. Sucker stomachs from Ruth Lake, examined at the same time, contained predominantly chironomids and amphipods. Cladocerans were much less abundant in the zooplankton there than in Beaver Creek Reservoir, and it appeared that benthic invertebrates were more abundant in Ruth Lake than the reservoir. This suggests that the suckers were opportunistic, feeding on whatever was most abundant at the time and that they are capable of adapting their food habits to exploit new situations, such as occurred in this reservoir.

Longnose suckers were not as abundant as white suckers in the reservoir but were common in gill net catches. Of the small fish collected in seine hauls, none could be positively identified as longnose suckers. Therefore, whether or not this species was reproducing in the reservoir is not known, although the gravel substrates in the northeast corner and adjacent diversion canal are suitable for spawning. Longnose suckers will probably establish a population in the impoundment.

Thirteen northern pike were collected in gill nets in 1977 (Table 27), but no small pike occurred in the seine hauls. Therefore, there was no evidence of successful reproduction, but habitat suitable for pike spawning will probably be present since submergent macrophytes were establishing in the

Table 28. Composition of food of fish collected in gill nets in Beaver Creek Reservoir, June 25-26, 1977.

Food Items	Mean percent (by numbers) of total items in stomachs White sucker (n=16) (265 - 345 mm FL)	Longnose sucker (n=6) (255 - 305 mm FL)	Northern pike (n=4) (395 - 480 mm FL)
Coleoptera (larvae)	<1	-	-
Chironomidae (larvae)	11	<1	-
(pupae)	<1	-	-
Corixidae	1	-	-
Ostracoda	-	<1	-
Copepoda	-	<1	-
Isopoda	<1	-	-
Cladocera	87	99	-
Gastropoda	<1	-	-
Brook stickleback	-	-	60
Lake chub	-	-	40
Eggs	1	-	-
No. of Empty stomachs	-	-	1

impoundment and should provide at least some areas of suitable spawning habitat. The abundant forage fish (sticklebacks, fathead minnows, lake chub, and small suckers) would provide a ready food supply for pike, and pike stomachs examined in June contained sticklebacks and chub (Table 28). No pike have ever been collected in Ruth Lake, therefore this species must have originated in Beaver Creek.

There is a possiblity that other species of fish now occur in small numbers in the reservoir or will colonize it later. Burbot have been regularly collected in Beaver Creek in the past (Table 10), and it seems likely that at least some burbot would have been upstream of the Beaver Creek dam when it was closed. If this is the case, this species may eventually establish in the reservoir. Other species collected in Beaver Creek in the past (lake whitefish, yellow walleye - Table 10) were only rarely found, or were restricted to the lower end of the creek, and are not likely to gain access to Beaver Creek Reservoir. Arctic grayling presently occur in upper Beaver Creek and, consequently, have ready access to the impoundment. It is not known if they will establish there since they are generally considered to prefer lakes with less turbid waters (Scott and Crossman, 1973). However, they can survive in the fairly turbid waters of upper Beaver Creek although it is not known if they are reproducing there. Grayling do not generally spawn in lakes, and gravel substrates are not common in upper Beaver Creek near the reservoir. Consequently, a lack of spawning habitat may inhibit this species from establishing in the reservoir.

The ability of the fish populations to overwinter in the reservoir is uncertain. Oxygen measurements taken in March, 1977, revealed almost completely anaerobic conditions at the two sampling sites. Of the fish collected from the reservoir, fathead minnows and brook sticklebacks are probably the only species capable of surviving such conditions. If the other species do not make their way back to Beaver Creek where winter oxygen saturation is considerably higher, or perhaps to an oxygenated region near the mouth of the creek, it seems that they would not survive the winter.

RUTH LAKE

METHODS

Ruth Lake was sampled at two sites, RL-2 and RL-3, which corresponded to two of the stations sampled in the previous studies in 1974 and 1975 (Figure 21). Sampling commenced on March 31 and then occurred at approximately 4-week intervals from May 4 to November 20, 1977. All regular parameters were sampled on each occasion at the two sites. Temperature and oxygen were measured, and water for chemical analysis and phytoplankton counting was collected at the mid-point of the water column. Samples for seasonal water analysis were collected on May 4, July 29 and October 15, and substrate samples were taken July 29. At each site and date, samples were taken from the top, middle and bottom of the water column (in the latter half of the study, only at top and bottom at shallow site RL-3) for measurement of conductivity. Water samples taken in July and August for chemical analysis were filtered through a plankton net to remove the abundant colonial blue-green algae.

Six vertical net hauls for zooplankton were taken at each station on each date, and three Ekman dredge samples were collected at the same times and locations. Shallow water sampling for littoral crustaceans was also conducted at two inshore locations in spring, summer and fall (Figure 21).

On August 4, 1977, the macrophyte community of Ruth Lake was surveyed using the same methods as in the 1974 and 1975 studies (RRCS, 1975; Noton and Chymko, 1977). Points on transects were sampled for abundance and composition of submergent and floating-leafed plants, and shorelines were inspected for composition, abundance and distribution of floating-leafed and emergent plants. Transects and sampling points are illustrated in Figure 26. The transects were placed at the same locations, and the same number of points were sampled on them as in previous years.

Fish were collected with a beach seine at three shore sites on Ruth Lake on June 26 and with a test gang gill net at two sites on June 26-27 and August 23-24 (Figure 21). An overnight set was made at each site on each occasion. Site G1 was about 2 m deep with scattered individuals of *Nuphar variegatum* nearby, and site G2 was 1 to 1.5 m deep with scattered submergent plants in the vicinity. All seining sites had moderate submergent macrophyte densities and soft muddy substrate. *N. variegatum* and emergent plants occurred occasionally at these sites.

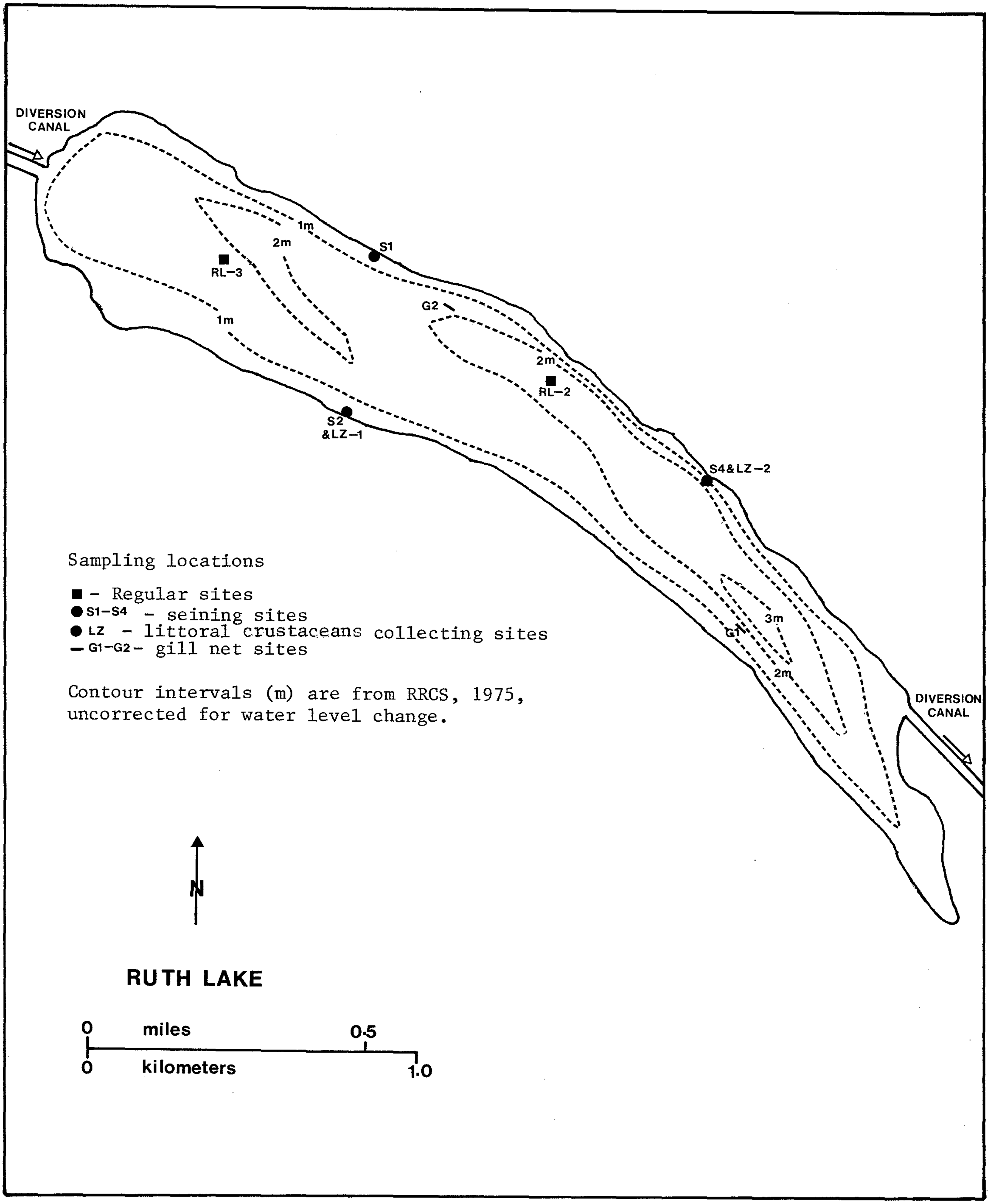


Figure 21. Sampling locations in Ruth Lake, 1977.

RESULTS AND DISCUSSION

Ruth Lake is a shallow littoral body of water, with soft mud and organic substrates. In past years it had a fairly stable water level; clear, alkaline, well-oxygenated waters (in summer); and moderate to low levels of phytoplankton (Noton and Chymko, 1977). Aquatic macrophytes were profuse throughout the lake, and zooplankton and zoobenthos abundances were typical of a moderately eutrophic lake. These conditions existed during the two previous studies (1974 and 1975), but re-examination of the lake this year under post-diversion conditions revealed considerable change, particularly in water quality and plankton populations. Other components of the lake ecosystem have also been modified.

Physical and chemical parameters

During the open season of 1974 and 1975, very little fluctuation in the water level of Ruth Lake was noticed, despite considerable fluctuation of summer rainfall during those years (RRCS, 1975; Noton and Chymko, 1977). Figure 22 portrays Ruth Lake water levels in 1976-77 and shows that more than one metre of fluctuation occurred. Highs in August-October, 1976, were associated with heavy rains, but highs in March-June, 1977, coincided with upstream canal excavation (from Beaver Creek Reservoir) and spring run-off. Declining levels from June to September, 1977, were coincident with low flows in Beaver Creek and declining water levels in Beaver Creek Reservoir. These water level fluctuations can be expected to continue since Ruth Lake has effectively acquired a much larger watershed with the diversion of flow from Beaver Creek into the lake. Flushing rate of the lake is difficult to estimate precisely since increases in flow will be offset by increased water levels and lake volume. In 1977, the maximum monthly discharge of Beaver Creek (3×10^6 m^3 in May) would have flushed Ruth Lake (at pre-diversion levels and 2×10^6 m^3 in volume) in about 20 days.

Temperature and oxygen measurements taken in Ruth Lake are placed in Tables 29 and 30. The recorded temperatures were within the range observed in 1974-75, and there has been no apparent change subsequent to diversion. A maximum temperature of 20^oC was recorded at Site RL-3 on July 29, and thermal stratification was not observed in the lake. Ice break-up occurred around the end of April and freeze-up, around the end of October. Ice cover on March 31, 1977, was 60 cm and on November 19 was 18 cm. It is possible

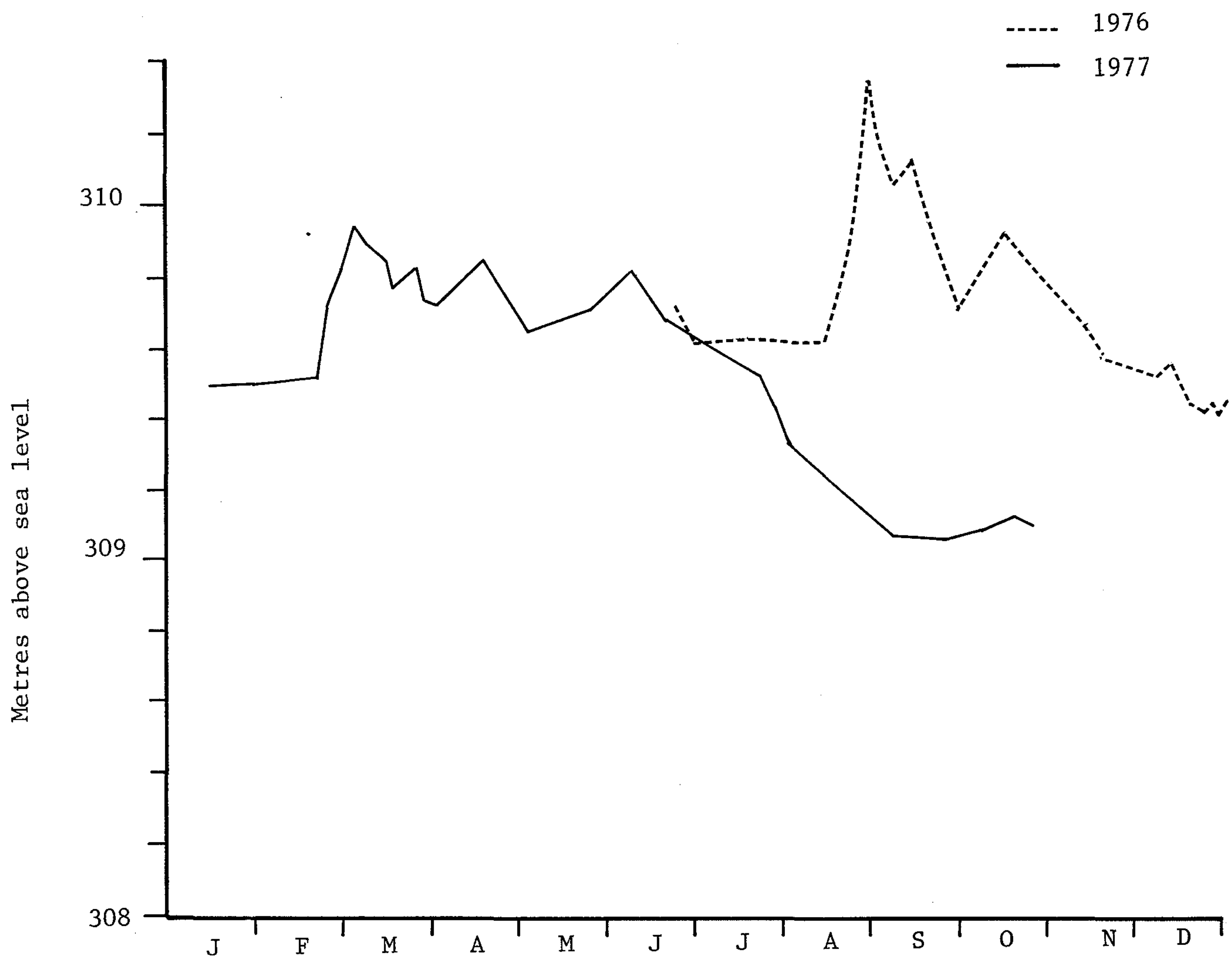


Figure 22. Water levels in Ruth Lake, 1976-77.

Table 29. Temperature and oxygen saturation in Ruth Lake, 1977.

Depth (m)	March 31*	May 4	June 1	June 26*	July 29	Aug. 6	Aug. 24	Sept. 23	Oct. 15	Nov. 19-20
				Temperature °C/Oxygen % saturation						
				Station RL-2						
0	0.5	11.0/88	12.0/78	20.0	20.0/133	17.5/122	13.5/68	12.0/59	5.0.81	1.0/60
0.5	0.5	11.0/88	12.0/78	19.5	20.0/135	16.0/97	13.5/67	12.0/59	4.0/79	2.0/55
1.0	1.0/5	9.5/86	12.0/78	19.5/99	20.0/136	16.0/74	13.5/67	12.0/58	4.0/79	2.5/52
1.5	2.0	9.0/84	12.0/78	19.5	20.0/105	16.0/59	13.5/65	12.0/57	4.0/79	2.5/42
2.0	3.0/<1	8.0/78	12.0/77	19.5	19.5/79					
2.5	3.8									
Mean	1.8/(5)	9.7/84	12.0/78	19.6/(99)	19.9/118	16.4/88	13.5/67	12.0/58	4.3/80	2.0/52
				Station RL-3						
0		11.0/93	12.0/62	20.0	20.0/136		13.0/84	12.0/89	5.0/88	1.0/88
0.5	1.0/3	11.0/89	12.0/62	20.0/113	20.0/139		13.0/83	12.0/89	5.0/88	2.5/86
1.0	1.3	10.5/88	12.0/62	19.5	20.0/133		12.5/82	12.0/89	4.5/87	2.5/71
1.5	2.5/3	10.0/73	11.5/60	19.5	20.0/115					
2.0	3.0									
Mean	2.0/3	10.6/86	11.5/61.5	19.8/113	20.0/131		12.8/83	12.0/89	4.8/88	2.0/82

Measurements with dissolved oxygen - temperature meter, unless noted otherwise.
* Measurements with azide - Winkler method.

Table 30. Oxygen concentrations in Ruth Lake, 1977.

	Oxygen - mg/1									
Depth (m)	March *31	May 4	June 1	June *26	July 29	Aug. 6	Aug. 24	Sept. 23	Oct. 15	Nov. 19-20
					RL-2					
0		9.4	7.8		11.2	10.8	6.6	6.0	9.7	8.0
0.5		9.4	7.8		11.4	8.8	6.5	6.0	9.7	7.0
1.0	0.7	9.2	7.8	8.5	11.6	6.8	6.5	5.9	9.7	6.6
1.5		9.1	7.8		9.0	5.5	6.4	5.8	9.7	5.3
2.0	0.1	8.0	7.7		6.8					
					RL-3					
0		9.5	6.3		11.6		8.3	8.0	10.6	11.8
0.5	0.5	9.2	6.3	9.6	11.8		8.2	8.0	10.6	11.1
1.0		9.2	6.3		11.3		8.2	8.0	10.6	9.0
1.5	0.4	7.7	6.2		9.8					

Measurements with dissolved oxygen - temperature meter unless noted otherwise.

* Measurements with azide - Winkler method.

that water inflow from the diversion canal may hasten spring break-up on Ruth Lake; however, no information was gathered concerning this in 1977.

The mean water column oxygen saturation values from Table 29 are presented in Figure 23 along with similar data from 1975. In 1977, oxygen saturation at the sampling stations was usually in the 60-90% range with the exception of late June and July when mean values surpassed 100% during a bloom of blue-green algae (an individual, high reading of 139% occurred at RL-3). Site RL-3 generally had higher saturation than RL-2 in both surface and mean values, but the reason for this is not clear. In general, oxygen saturation was lower than in 1974-75 (Figure 23) when values in the open season oscillated around 100% and only after a spell of very hot, sunny weather were levels less than 80% observed. Apparently an increased oxygen demand in Ruth Lake in 1977 depressed oxygen levels. Although it is not possible to delineate the exact combination of factors responsible for this, events associated with the diversion that could have increased oxygen demand in Ruth Lake include the entry of organically rich water from Beaver Creek Reservoir; exposure of fresh organic sediments in the diversion canal and their partial flushing into Ruth Lake; and periodic decomposition of high populations of Ruth Lake phytoplankton.

Results of the regular chemical analyses are presented in Table 31. In 1977, Ruth Lake water quality was fairly similar to that of Beaver Creek Reservoir and thus differed noticeably from water quality in the lake in 1975 (Noton and Chymko, 1977). Differences in water chemical parameters between the reservoir and Ruth Lake were not as great as differences between upper Beaver Creek and the reservoir. Water quality generally exhibited more variability in the lake during this year than in 1975; at the same time, the water became slightly less alkaline, more turbid and brown coloured and higher in dissolved organic compounds and nutrients. During the open season this year, pH averaged 8.0, excluding July 29 when a blue-green algal bloom apparently raised the pH to 9.3. In 1975, mean, open-season pH levels of 8.3 were never interrupted by similar peak values. Measurements in late March revealed a winter pH of 6.9-7.0. Total alkalinity has decreased and become more variable since 1975, when it was never less than 175 mg/l and averaged 190 mg/l. In 1977, high levels in March (183-213 mg/l) declined after break-up to lows around 130 mg/l and then rose through summer to about 190 mg/l at freeze-up.

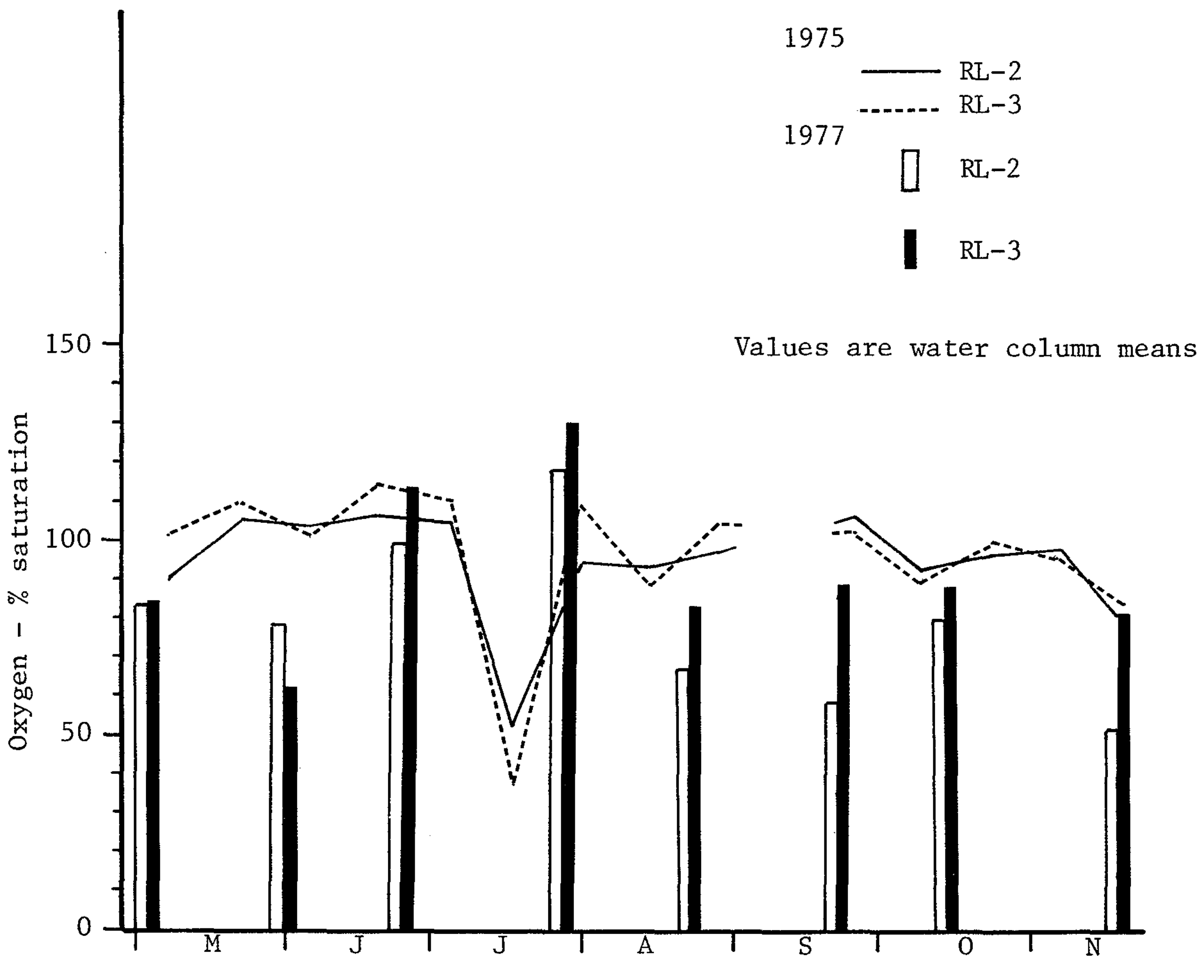


Figure 23. Oxygen saturation in Ruth Lake, 1975 and 1977.

Table 31. Chemical characteristics of Ruth Lake, 1977.

	March 31	May 4	June 1	June 26	July 29	Aug. 24	Sept. 23	Oct. 15	Nov. 19-20
RL-2									
pH	7.0	7.8	8.1	8.2	9.3	7.9	8.0	7.9	7.8
pp alkalinity	0	0	0	0	25	0	0	0	0
Total alkalinity	201	131	148	145	149	173	186	190	212
Turbidity (NTU)	9.0	4.6	2.4	1.5	4.1	2.3	1.5	2.2	1.5
Suspended solids	12.2	10.4	32.0	<0.5	2.0	3.0	<0.5	<0.5	<0.5
Total organic carbon	32	34	24	46	43	40	41	27	35
$NO_3 + NO_2 - N$	0.37	0.09	<0.03	0.084	0.047	<0.03	0.044	0.376	0.130
Total Kjeldahl - N	20.4	8.2	0.6	0.3	0.3	0.2	0.4	0.9	0.4
Ortho $PO_4 - P$	0.330	0.054	0.048	<0.016	0.022	0.031	<0.016	<0.016	<0.016
Total P	0.384	0.760	0.062	0.112	0.100	0.051	0.051	0.046	0.049
Reactive SiO_2	12.9	6.7	2.8	4.7	4.6	3.0	9.3	6.6	8.8
Filtrable residue	310		258	248	254	332	356	304	338
Ignition loss	185		72	68	108	76	100	82	44
RL-3									
pH	6.9	7.8	7.9	8.4	9.2	8.2	8.0	7.8	8.0
pp alkalinity	0	0	0	3.5	20	0	0	0	0
Total alkalinity	183	150	142	156	151	176	184	184	213
Turbidity (NTU)	6.0	5.6	5.4	2.6	4.4	3.4	1.9	1.3	1.5
Suspended solids	5.2	6.0	10.0	0.5	3.5	1.0	<0.5	4.4	<0.5
Total organic carbon	30	38	23	37	32	51	38	16	35
$NO_3 + NO_2 - N$	0.28	0.09	0.04	0.095	0.038	<0.03	<0.016	0.100	0.132
Total Kjeldahl - N	15.0	10.8	0.4	0.3	1.0	0.4	0.3	0.8	0.3
Ortho $PO_4 - P$	0.340	0.064	0.046	0.024	0.023	<0.016	<0.016	<0.016	<0.016
Total P	0.357	0.064	0.062	0.094	0.108	0.05	0.051	0.052	0.048
Reactive SiO_2	9.6	7.1	3.7	3.6	4.4	2.7	2.8	3.0	3.1
Filtrable residue	290		260	264	300	372	366	154	394
Ignition loss	165		80	68	142	88	228	54	210

Results as mg/l except pH and turbidity. Alkalinities as $CaCO_3$.

Filtrable residue showed a similar pattern with highs under ice in March and November (about 290-390 mg/l) and lower levels (down to about 260 mg/l) in summer. This contrasts with somewhat lower (240 mg/l) but more stable levels in 1975 for filtrable residue (Noton and Chymko, 1977).

Turbidity, which was generally less than 1 FTU (= 1 NTU) in 1975, had increased somewhat in 1977. Values were around 9 NTU in March and subsequently declined until June when fairly stable levels of 1-4 NTU's were established. Suspended solids showed a pattern similar to turbidity this year, being highest in spring and fairly stable and lower after June. Values recorded in 1975 were quite variable and are difficult to compare with those of 1977. Total organic carbon, which averaged about 22 mg/l in 1975, had increased in 1977. Values ranged from 16 to 51 mg/l with mean values of 36 and 33 mg/l at RL-2 and RL-3 respectively. TOC levels were generally in the 30 to 40 mg/l range with occasional peak and low values, but no pattern was evident in the fluctuations. Ignition loss in Ruth Lake water samples was not closely related to TOC, and showed little discernible pattern. Levels were high in March, then generally lower but variable through the rest of the season. Peaks occurred in July and September, and values ranged from 44 to 228 mg/l (Table 31).

Nitrate-nitrogen (NO_3 + NO_2 - N) was high in March under the ice cover (0.28 - 0.37 mg/l) but from May through September fluctuated from less than 0.016 to 0.095 mg/l. It rose in October and November to slightly more than 0.1 mg/l. Although levels in the spring of 1975 were comparable to those of 1977, many values in the former year were less than 0.01 mg/l during the summer, and this nutrient has apparently increased in overall concentration. Total Kjeldahl nitrogen paralleled nitrate-nitrogen in concentration. It was high in spring at 8-20 mg/l and about 0.2 to 0.6 mg/l during the rest of the 1977 study. High concentrations of orthophosphate-phosphorus in March (0.34 mg/l) had declined sharply by May (to about 0.06 mg/l) and subsequently declined more slowly to less than 0.016 mg/l in September. These levels were considerably higher than 1975 values, which rarely exceeded 0.04 mg/l and were often 0.02 mg/l or less. Total phosphorus concentrations largely paralleled orthophosphate values but showed high levels in June and July. Reactive silicate concentrations were much higher than in 1975 when they were generally less than 1 mg/l. Values for 1977 were 10-13 mg/l in March but they declined to around 3-5 mg/l by June and stayed at this level for most of the rest of this study.

Additional water samples were collected seasonally from Ruth Lake and were analyzed for the parameters listed in Table 32. The results show the intensity of the brown colour acquired by Ruth Lake since the diversion of Beaver Creek through it. The colour was much more pronounced than in 1975 when it was 15-20 APHA units. Oil and grease ranged from 12 to 156 mg/l in 1977, somewhat higher than in Beaver Creek Reservoir, while phenol concentrations were near the detection limit and were similar to levels in both the reservoir and Beaver Creek. Chemical oxygen demand (COD) was quite variable, ranging from 28-163 mg/l, these values being similar to those of the reservoir. In 1975, COD in Ruth Lake was somewhat lower. Calcium and magnesium hardness was in the range of 61-113 mg/l, comparable to hardness in upstream water bodies but generally lower than in 1975 when levels averaged 137-144 mg/l at the 3 sampling stations in Ruth Lake.

Of the major ions (Table 32) only chloride had been analyzed in 1975, at which time it averaged 5.8 to 6.3 mg/l at the three sites (Noton and Chymko, 1977). Chloride levels had increased to about ten times that level by fall, 1977, and were similar to levels observed in Beaver Creek Reservoir in this study. Concurrently, sodium increased by roughly the same proportion in both lakes and replaced calcium as the dominant cation. This increase of sodium chloride may be related to the minewater discharge into Beaver Creek Reservoir since concomitant increases were not observed in upper Beaver Creek. Calcium and bicarbonate were the principal ions measured in the spring samples, but in summer and fall sodium became the dominant cation, and chloride became an important anion. Concentrations of metals in the seasonal analyses (Table 32) of Ruth Lake water were quite similar to those measured in Beaver Creek Reservoir samples with the exception of iron, which was somewhat higher in the reservoir. In Ruth Lake only iron and copper concentrations showed noticeable increases over levels observed in 1975, while nickel and cobalt showed decreases.

Substrate samples collected from the two sampling stations in Ruth Lake contained 40-64% organic compounds by weight (Table 33) and had lower metal concentrations than the substrate in Beaver Creek Reservoir. Most metals were higher in concentration at site RL-2 than RL-3; only chromium and lead were highest at RL-3. Regular analysis of conductivity revealed no stratification of electrolytes that might be related to minewater discharges into the diversion system (Table 34). This is not surprising since any minewaters

Table 32 . Results of seasonal water analysis, Ruth Lake, 1977.

	RL-2			RL-3		
	May 4	July 29	Oct. 15	May 4	July 29	Oct. 15
True colour (APHA)	130	65	55	110	95	55
Oil and grease	12.2	156.2	86.0	5.2	42.4	25.4
Phenols	0.005	<0.001	<0.001	0.001	<0.001	0.002
C.O.D.	52	28	66	-	163	70
Hardness[1]	84	111	61	86	113	77
Na	2.56	56.6	39.6	2.68	60.6	42.7
Mg	7.1	9.4	4.8	7.1	9.5	6.0
Ca	22.2	29.0	16.6	22.9	29.6	20.8
K	1.8	1.7	1.5	1.5	1.6	1.4
Cl	4	50	60	22	44	39
SO_4	16	6	11	10	6	6
Fe	0.38	0.40	0.25	0.39	0.76	0.36
Cu	0.010	0.013	0.015	0.015	0.093	0.020
Cr	0.02	<0.01	0.02	0.02	<0.01	0.02
Pb	0.08	<0.02	0.05	<0.02	0.10	0.07
Zn	0.011	<0.010	0.024	0.008	0.019	0.106
Ni	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Co	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al	0.1	0.1	0.2	<0.1	0.2	0.1
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B	0.105	0.168	0.114	0.136	0.225	0.107

Results as mg/l unless noted.

[1] Ca & Mg hardness, as $CaCO_3$.

Table 33. Results of substrate analysis, Ruth Lake, July 29, 1977

	RL-2	RL-3
% organic	64	40
% inorganic	36	60
Fe	43865	5426
Cu	10.8	8.3
Cr	42.6	49.9
Pb	109	119
Zn	70.2	1.3
Ni	14.5	3.2
Co	19.2	14.8
Al	16677	3828
Cd	25.1	10.2

Results are by weight of air dried samples. Metals as ppm.

Table 34. Specific conductance at the top, middle and bottom of the water column in Ruth Lake, 1977.

	SPECIFIC CONDUCTANCE - µmhos/cm @ 25°C							
	May 4	June 1	June 26	July 29	Aug. 23	Sept. 23	Oct. 15	Nov. 19-20
				RL-2				
Top	300	275	320	400	450	500	620	660
Middle	310	285	320	410	450	530	545	655
Bottom	340	265	320	400	460	530	585	660
				RL-3				
Top	360	270	310	440	485	520	555	685
Middle	360	265	310	430	-	-	-	-
Bottom	360	260	310	440	480	500	610	670

Declining water levels prevented effective sampling of all depths at RL-3 after July.

high in solutes would have to enter Ruth Lake via the shallow diversion canal in which they would become well mixed with the entire diversion canal flow. Because of the shallowness of the lake basin, flow from the canal probably would simply supplant water in the lake rather than form a subsurface density current. Furthermore, wind mixing of the shallow lake waters would tend to eliminate vertical stratification.

Phytoplankton

The cell counts for Ruth Lake phytoplankton samples are placed in Appendix 6. Figure 24 portrays the abundance and composition of the phytoplankton at the two sampling stations. Although total algal abundance varied somewhat between the two sites and most often was higher at RL-3, composition of the phytoplankton community was very similar at the two stations. Total cell counts were fairly high (7500-35,000 cells/ml) but variable in spring and increased in June and July during a bloom of blue-green algae (30,000-228,000 cells/ml). By late August, populations had declined to levels similar to those of spring and then from September through November were quite low, never exceeding 2500 cells/ml (Figure 24). Although a bloom of blue-green algae appeared in June and July and dominated the community in total numbers, other phytoplankton algae did not show any decline at that time (Table 35), maintaining the same general abundance from spring through to September.

Ultraplankton dominated the Ruth Lake phytoplankton in March and May (Figure 24), forming more than 65% of total numbers. Flagellates and green algae were present in early June in amounts similar to ultraplankton, but by the end of June, blue-green algae completely dominated the phytoplankton. They maintained this dominance through July, were only co-dominant in late August, and had almost disappeared from the phytoplankton in September. All five algal types were about equally represented in the samples in late August. In the September-November samples, flagellates, greens and ultraplankton were similar in abundance while diatoms were slightly less common.

Aphanizomenon flos-aquae and *Anabaena flos-aquae* formed the bloom of blue-green algae that occurred in June and July in Ruth Lake. Their combined abundance surpassed 200,000 cells/ml on occasion, and they were the only common blue-green species in the lake.

Among the diatoms (Bacillariophyceae), *Cyclotella* was the most common throughout the study; *Synedra* occurred regularly during the study; *Melosira*

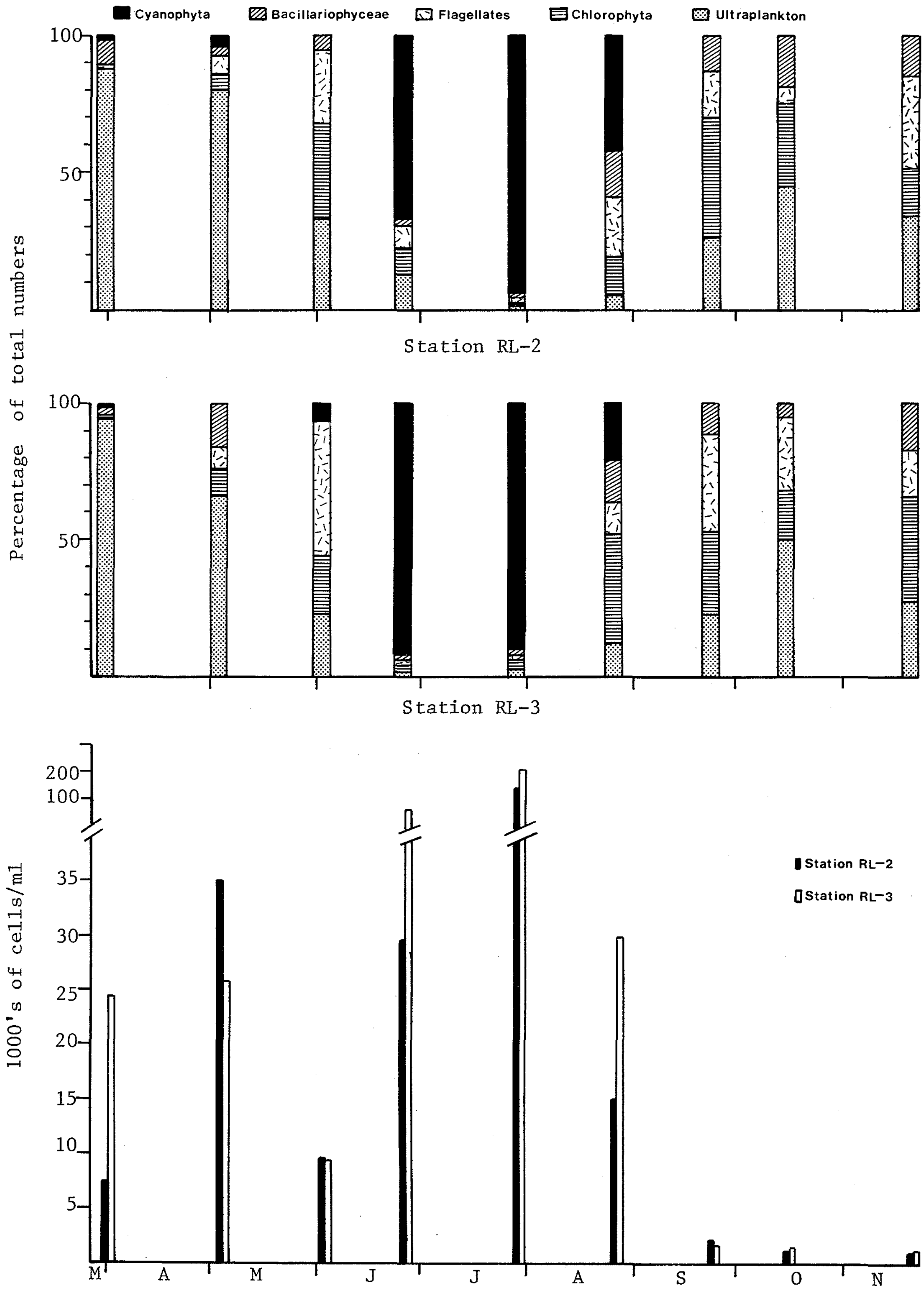


Figure 24. Abundance and composition of phytoplankton in Ruth Lake, 1977.

Table 35. Abundance and composition of non blue-green phytoplankton in Ruth Lake, 1977.

	March 31	May 4	June 1	June 26	July 29	Aug. 24	Sept. 23	Oct. 15	Nov. 19
				cells/ml					
				STATION RL-2					
Bacillariophyceae	-	1100	460	975	1518	2431	307	81	158
Flagellates	801	2598	2626	2371	381	3368	403	260	370
Chlorophyta	42	2257	3332	2556	2105	2195	1052	405	194
Ultraplankton	6368	29068	3144	3769	886	820	613	616	369
Total	7211	35023	9562	9671	4890	8814	2375	1362	1091
				STATION RL-3					
Bacillariophyceae	-	4322	115	1265	5272	4843	193	72	232
Flagellates	821	1897	4676	923	4640	3558	651	406	231
Chlorophyta	84	2988	2012	2134	12512	11961	545	264	527
Ultraplankton	23658	17571	2166	712	703	3690	422	738	401
Total	24563	26778	8969	5034	23127	24052	1811	1480	1391

was common in late summer and fall; *Tabellaria* was abundant on occasion; and various other pennate diatoms occurred throughout the season. Diatoms were most abundant during July-August (about 2000-5000 cells/ml).

Flagellated algae (containing members of the Cryptophyceae, Chrysophyceae, Dinophyceae, and Euglenophyta) were generally most abundant May through August (usually about 1000-4000 cells/ml). *Cryptomonas*, *Dinobryon*, and *Rhodomonas* were the most abundant genera. Euglenoid flagellates were fairly common and were represented by *Euglena*, *Phacus* and *Trachelomonas*.

Green algae (Chlorophyta) were the most diverse phytoplankton group in Ruth Lake (Appendix 6) and were most abundant in May through August (about 2000 to 12,000 cells/ml). *Ankistrodesmus* and *Scenedesmus* were the most ubiquitous green algae encountered while *Crucigenia* and *Dictyosphaerium* were second in abundance and occurred mostly during summer. Ultraplankton were most abundant in spring (6000-29,000 cells/ml), less abundant in summer (700-3700 cells/ml) and even lower in fall (400-700 cells/ml - Table 35).

The phytoplankton of Ruth Lake were indicative of a eutrophic system. Cell counts of both blue-green and non-blue-green algae were fairly high (Figure 24) during most of the growing season in 1977 and undoubtedly reflected the high levels of macronutrients (N, P, Si) in the lakewater (Table 31). Although nutrients in the lake were similar in concentration to Beaver Creek Reservoir, algal populations were much higher in Ruth Lake and may have been able to reach these higher abundances because of the shallower depth of the lake. As discussed previously, high turbidity (hence a shallow trophogenic zone) and vertical mixing may be suppressing algal populations in Beaver Creek Reservoir. In Ruth Lake the trophogenic zone probably occupies most of the water column (Secchi visibility varied from 0.5 m to 2.0 m), and algae would be capable of growth even if circulated to the lowest depths.

A considerable increase has occurred in phytoplankton abundance in Ruth Lake since 1974-75 (Figure 25). This was undoubtedly caused by the increase in macronutrients (N, P, Si) which have reached levels above those regarded as typical for eutrophic lakes (Wetzel, 1975). Besides a marked increase in total numbers, the composition of the community has changed. Blue-green algae have become abundant and formed a bloom in the lake in 1977, whereas formerly they had accounted for no more than about 10% of total phytoplankton numbers. Ultraplankton, previously the dominant algal type in the Ruth Lake phytoplankton (RRCS, 1975; Noton and Chymko, 1977), have been supplanted by a diverse assemblage of algae in 1977. Diatoms, greens and

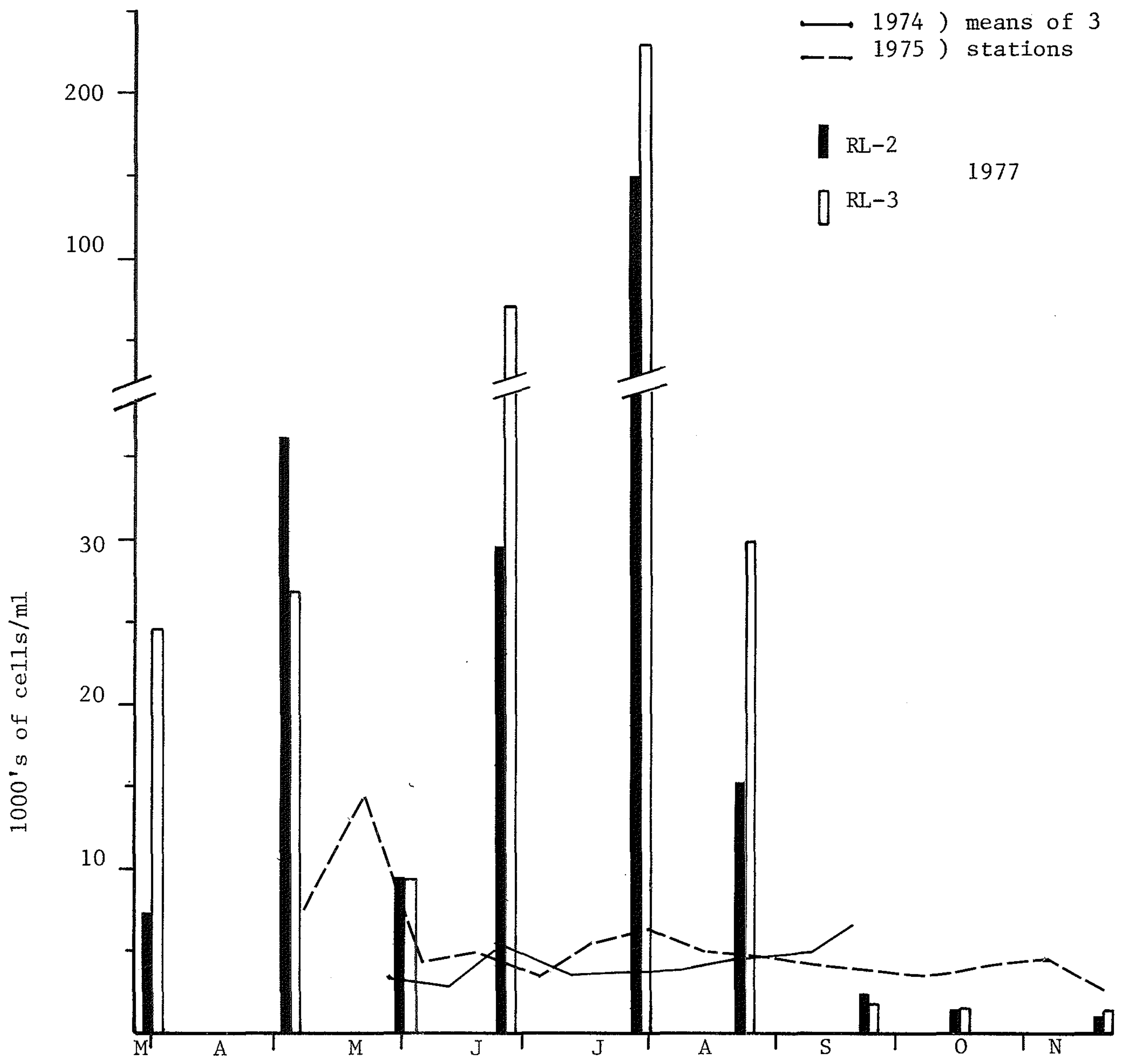


Figure 25. Abundance of phytoplankton in Ruth Lake in 1974, 1975, and 1977.

flagellates were all more abundant in 1977 and formed a greater proportion of the total crop than they had previously. *Euglena*, *Phacus* and *Trachelomonas* of the Euglenophyta were common in the phytoplankton in 1977 and may reflect the increased organic content of Ruth Lake water since they were rare or absent during the two previous studies. Euglenoid algae are known to be associated with water of high organic content (Round, 1965), and in 1977 total organic carbon concentrations averaged 50% higher than in 1975.

Aquatic macrophytes

Ruth Lake is a shallow body of water with soft mud substrates over almost all of its basin. It supported a macrophyte community that was well developed and extended over the the whole lake. Previous surveys of the macrophyte community (RRCS, 1975; Noton and Chymko, 1977) revealed little change in its general characteristics between 1974 and 1975. A similar survey this summer, however, showed that since 1975 there had been an extensive die-off of the submergent species *Chara* and that much of the emergent community was above the lowered water level of the lake. These changes are discussed more thoroughly below.

No major changes were apparent in the species of aquatic macrophytes occurring in Ruth Lake, although two species previously observed were not seen this year, and two new species were collected (Table 36). None of these four species are, or were, abundant in the lake, and they could have been easily overlooked in the field.

Submergent plants

Appendix 7 contains observations of the relative abundance and composition of submergent plants at the transect points sampled in Ruth Lake in 1977. These results were examined to see if certain plant assemblages were regularly observed over sizeable areas of the lake, and based on this and similar past analyses, a map of recognizable submergent macrophyte regions was prepared (Figure 26). As in past years, three regions could be distinguished: areas dominated by the macrophytic alga *Chara*; areas with poor cover by any submerged species (less than 50%); and areas having a fairly continuous cover of a highly diverse and spatially heterogeneous plant assemblage (a mixed type). In previous years the *Chara* assemblage occupied 25% of Ruth Lake (Table 37 and Figure 26). When surveyed in 1977, however, *Chara* had largely disappeared from the areas where it had formed extensive meadows, and colonization by

Table 36. Aquatic macrophytes collected in Ruth Lake, 1974-75 and 1977.

	Submergents		Floating-Leafed
[1](Ch)	*Chara*	(Nv)	*Nuphar variegatum* Engelm.
(F)	*Fontinalis*	[4](Pg)	*Polygonum*
[2](Hv)	*Hippuris vulgaris* L.	(Pn)	*Potamogeton natans* L.
(Lt)	*Lemna trisulca* L.	[5](Scu)	*Sagittaria cuneata* Sheldon
(Mx)	*Myriophyllum exalbescens* Fernald	[5](Sp)	*Sparganium*
(Nf)	*Najas flexilis* (Willd.) Rostk. & Schmidt		
	[3]*Potamogeton berchtoldii* Fieb.		
(Pfo)	*P. foliosus* Raf.		
(Pfr)	*P. friesii* Rupr.		
(Ppc)	*P. pectinatus* L.		
(Ppr)	*P. praelongus* Wulf.		
(Pps)	*P. pusillus* L.		
(Pr)	*P. richardsonii* (Benn.) Rydb.		**Emergents**
	[3]*P. strictifolius* Benn.	(C)	*Carex*
(Pv)	*P. vaginatus* Turcz.	(Ef)	*Equisetum fluviatile* L.
(Pz)	*P. zosteriformis* Fernald	(Sv)	*Scirpus validus* Vahl.
(Uv)	*Utricularia vulgaris* L.	(Tl)	*Typha latifolia* L.

[1] Abbreviation, used in Appendix 7.

[2] Also grows as an emergent. Not observed in 1977.

[3] First collected in 1977, perhaps confused with *P. pusillus* in previous years.

[4] Not observed in 1977.

[5] Also grows as an emergent.

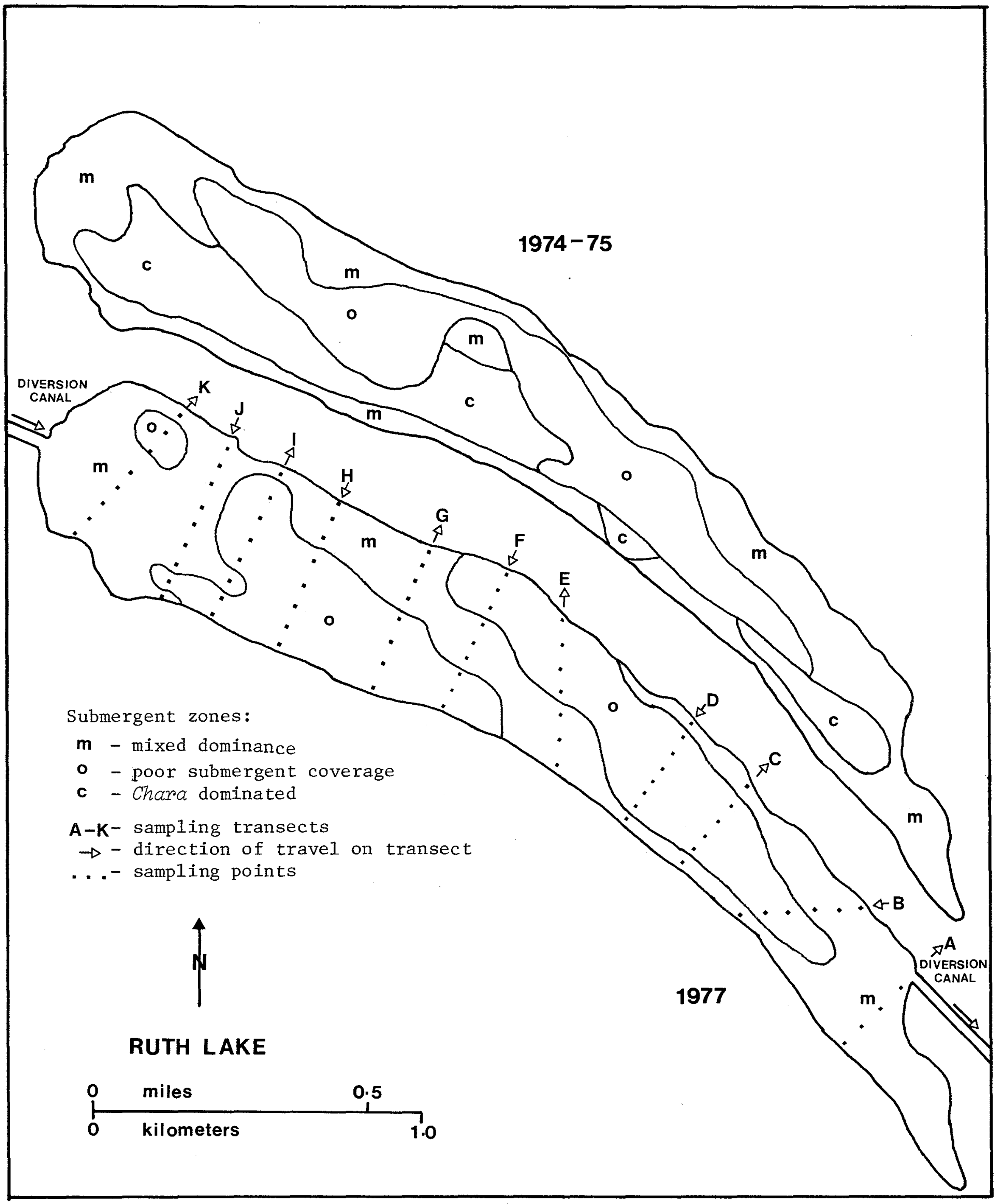


Figure 26. Distribution of submergent macrophytes in Ruth Lake in 1974-75 and 1977.

Table 37. Percent of Ruth Lake occupied by three types of submergent plant assemblages before and after diversion.

Type	Percent of total area 1974-75	1977
Chara dominated	26	0
Open areas	30	50
Mixed dominance	44	50

other macrophytes was apparently restricted to a small portion of the denuded areas. Much of these areas are now the open type (poor submergent cover) which, consequently, constituted about the same fraction of total lake area as the mixed type (Table 37). The area formerly dominated by *Chara* will probably be colonized by a mixed association of submergents. *Chara* was only found as a dominant at one sampling point in 1977 and was only common in the southeast half of the lake. Its former areas of prominence were largely in the northwest half.

The open type assemblage was found in waters deeper than 2 m where *Nuphar variegatum* was also quite abundant (Noton and Chymko, 1977; RRCS, 1975). In 1977, however, the open type included much of the shallower areas formerly occupied by extensive *Chara* beds where *Nuphar* was not abundant. This type is not so much a distinct macrophyte assemblage as it is an area low in coverage of submergent macrophytes. Scattered plants of most submergent species occurred throughout this type.

Many of the points sampled within regions classified as mixed assemblages were dominated by one species (e.g. *Potamogeton pectinatus*, *P. zosteriformis*, *P. praelongus*, *Myriophyllum exalbescens*, *Fontinalis* sp), but such dominance was very localized so that a fairly constant proportion of species was not regularly encountered over sizeable areas. Mixed assemblages formerly were observed mostly around the shorelines, but in 1977 they occupied more area in the northwest end and in a band stretching SE-NW through the central lake (Figure 26). Declining water levels have eliminated this type from some areas where it had occurred in a thin band along the shore.

The exact reason for the disappearance of much of the *Chara* from Ruth Lake is not certain. Aquatic macrophyte communities undergo succession like terrestrial plant communities (Sculthorpe, 1967; Hutchinson, 1975), and this could result in the disappearance of certain species. Such changes, however, are normally slow and induced by competition from other plant types. The rapid disappearance of the *Chara* and the scarcity of other submergents in the denuded areas would suggest that this change was not a part of normal plant succession in the lake. The implementation of the Beaver Creek Diversion has been accompanied in Ruth Lake by increased blue-green algal abundance, increased suspended solids, a change in the colour of the water, occasional high pH values, and declining water levels. The first three changes would reduce the amount of light reaching the substrate while the last change would increase light levels, so that changes in the amount of light received by *Chara* in Ruth Lake can not be readily assessed. Increased input of suspended solids (both organic and inorganic) from the diversion canal could exert a shading and oxygen-demanding effect primarily in the northwest end of the lake where settling would be greatest. This corresponds to the fact that the die-off of *Chara* was largely confined to that end of the lake. High pH values generated by blue-green algal blooms would probably occur throughout the lake.

Although it can not be completely certain that these changes in water quality relate to the die-off of *Chara* in Ruth Lake, evidence from another study in Alberta strongly supports this. In a study of aquatic macrophytes in Lake Wabamun, Allen (1973) found a die-off of *Chara* to be associated with increased turbidities over the *Chara* beds. Ancillary laboratory experiments in the study showed that *Chara globularis* had a low rate of net photosynthesis and high respiration compared to *Myriophyllum exalbescens*, *Elodea canadensis* and *Potamogeton pectinatus* and did not withstand oxygen depletion and lowered light levels as well as these 3 species. Further, at elevated pH values its net photosynthesis declined more than that of the others. These findings indicate that the high pH levels plus increased suspended solids in the northwest end of Ruth Lake are factors that could be responsible for the disappearance of *Chara* from that area of the lake.

Floating-leafed plants

Of the five species of floating-leafed plants found in past studies, only *Polygonum* sp. was not observed in Ruth Lake in 1977 (Table 36). This plant had never been common in the lake, occurring in occasional clumps along the shoreline. Declining water levels probably stranded many individuals since it formerly occurred in less than 1 m of water. It may still occur in Ruth Lake in low numbers, however.

Nuphar variegatum (yellow water lily or lily pad) remained the dominant floating-leafed plant in Ruth Lake and was one of the most prominent aquatic plants. It continued to form extensive beds in the deeper parts of the lake, covering a high percentage of the water surface in those areas. No change in its abundance was apparent in the field or in the data collected (abundance ratings are placed in Appendix 7). The areas of densest *Nuphar* growth are plotted in Figure 27.

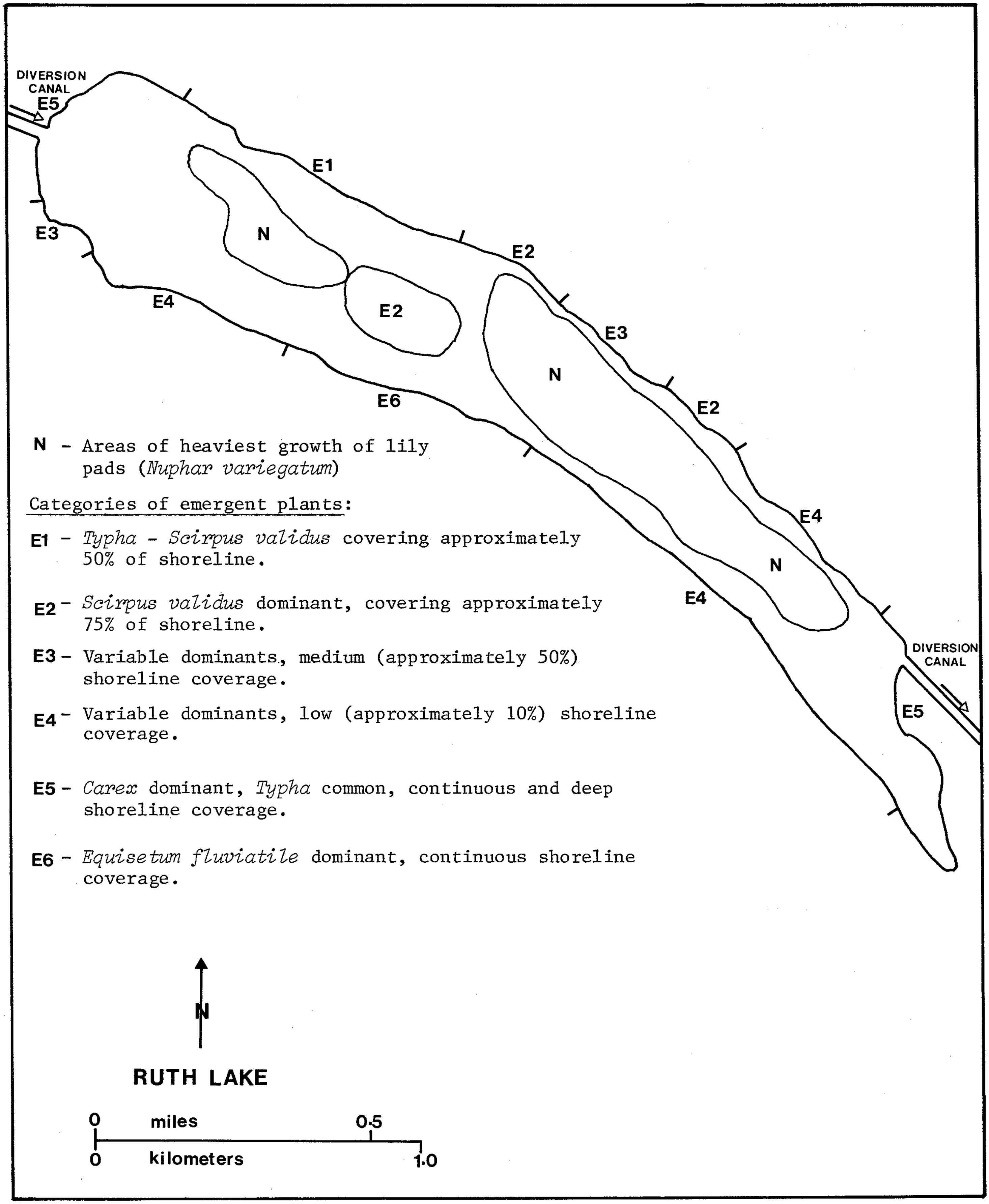


Figure 27. Areas of dense *Nuphar* growth, and sections of emergent plants discussed in text, Ruth Lake, 1977.

Emergent plants

The emergent plant community in Ruth Lake had not reacted noticeably to the lowered water levels when surveyed on August 4, 1977. Declines in water level had been greatest in the previous month and half (Figure 22), and at the time of the survey most of the emergents were stranded above water but still appeared healthy (Plate 3). Emergent stands at the northwest and southeast ends of the lake, as well as the mid-lake stands of *Scirpus* (Figure 27), were still inundated since many of them were growing in floating mats of peat which had not become stranded.

The decline in water levels presented a conceptual problem since many of the emergent plants were no longer strictly aquatic when examined this year. It was decided to survey them as normal since they appeared healthy and future water level changes could not be known. No major changes in composition, abundance or distribution of the four major emergents (*Carex, Scirpus, Typha* and *Equisetum*) were apparent. Figure 27 summarizes the six categories of emergent plant communities delineated in 1974 (RRCS, 1975). Some invasion of the uppermost level of exposed lake bottom by terrestrial plants appeared to be taking place, indicating that at least some fairly permanent decline in water level had occurred. The emergent community as a whole will undergo dramatic changes, of course, if water levels remain low.

The conditions observed in 1977 should not be considered as the final post-diversion state of the macrophyte community. The plants will continue to respond to changes in physical and chemical conditions in the lake and will take some time to reach equilibrium even after abiotic factors have stabilized. In the near future the emergent community will probably undergo a marked change in response to falling or fluctuating water levels. Also, colonization of the recently denuded *Chara* meadows by other submergents is likely to occur.

Zooplankton

The composition and abundance of the zooplankton collected at the two regular sampling stations in Ruth Lake are shown in Appendices 8 and 9, and the species collected at these stations and in the shallow water sampling are presented in Table 38. At the regular stations the number of *common*[1] species in the major zooplankton groups were as follows: Rotifers - 10, Cyclopoida - 3, Calanoida - 2, Cladocera - 6. The major groups will be discussed individually.

[1]See footnote 1, page 56.

Table 38. Ruth Lake Zooplankton. The letter "L" denotes species collected in littoral tows that can be considered littoral in life style.

	Open Water	Littoral
AMPHIPODA		
Gammarus lacustris Sars		X(L)
Hyalella azteca (Saussure)		X(L)
CONCHOSTRACA		
Lynceus brachyurus Muller	X[1]	X(L)
OSTRACODA		X(L)
CLADOCERA		
Acroperus harpae Baird		X(L)
Alona affinis (Leydig)		X(L)
A. costata Sars		X(L)
A. rectangula Sars		X(L)
Bosmina longirostris (Muller)	X	X
Ceriodaphina affinis (Lilljeborg)	X	
Chydorus sphaericus (Muller)[2]	X	X(L)
Daphnia pulicaria Forbes	X	
D. rosea Sars	X	
Diaphanosoma leuchtenbergianum Fischer	X	X
Ilyocryptus spinifer Herrick		X(L)
Leydigia leydigii (Schoedler)		X(L)
Pleuroxus denticulatus Birge		X(L)
P. procurvus Birge		X(L)
Sida crystallina (Muller)		X(L)
Simocephalus vetulus (Muller)		X(L)
COPEPODA		
CALANOIDA		
Diaptomus leptopus Forbes	X	
Diaptomus oregonensis Lilljeborg	X	X
CYCLOPOIDA		
Cyclops vernalis Fischer	X	X
Cyclops bicuspidatus thomasi Forbes	X	
Cyclops navus Herrick	X	
Eucyclops agilis (Koch)		X(L)
E. speratus (Lilljeborg)		X(L)
Macrocyclops albidus (Jurine)		X(L)
Microcyclops varicans rebellus Lilljeborg		X(L)
HARPACTICOIDA		X(L)

ROTIFERA[3]

Asplanchna	*Keratella cochlearis* (Gosse)
Brachionus calyciflorus (Pallas)	*K. quadrata* (Muller)
Conochilus unicornis (Rousselet)	*Nothalca*
Filinia longiseta (Ehrenberg)	*Polyarthra*
Hexarthra	*Synchaeta*

[1] denotes very rare species (i.e. only a few individuals ever observed.
[2] *Chydorus sphaericus* can occupy both littoral and open water (limnetic) zones.
[3] only documented at the regular sampling stations.

Rotifera

Figure 28 presents the population figure for rotifers, as well as the dominant species. Seasonal trends and dominant species were similar at the two stations, but RL-2 usually had higher numbers than RL-3. Population counts were highest in early May and in the late July to September period; at both stations maximum numbers occurred in late July. *Filinia longiseta* was the only rotifer observed in late March at which time oxygen concentrations were very low (0.1 - 0.7 ppm). It was still dominant at RL-2 in early May. During the summer months (June through August), *Keratella cochlearis* and *K. quadrata* were the major rotifers, but in the fall period (September to November), *Polyarthra* was usually dominant. Quantitative information on rotifers was not collected in previous years.

Cyclopoida

Cyclopoid copepod counts from 1974, 1975 and 1977 are portrayed in Figure 29. In 1977, copepod density was low in late March and early May but was much higher in early June (70,000 to 100,000 m^3) at which time early stage copepodites were dominant. By late June, numbers were very low again but increased in the late July-August period due to a pulse of early stage copepodites. After this period, counts were low. Abundance was not consistently different between the two stations, and unidentified early copepodite stages (I-III) were dominant throughout most of the season.

Cyclops vernalis was the most abundant adult cyclopoid in early June. This coincided with high numbers of nauplii and copepodites, and the majority of these stages probably belonged to *C. vernalis*. The subsequent development of the immature stages was not clear from the data. High numbers of nauplii and early stage copepodites occurred on August 24, but their origin was not known. Some adult *C. vernalis* were observed (only at RL-2) and may have produced this pulse. The copepodites may have subsequently had high mortality or entered diapause since they were not observed as more mature stages in later collections.

The population of *Cyclops bicuspidatus thomasi* in early May, 1977, was much less than it had been in the spring of 1974 and 1975. In 1977, *C. vernalis* was the most abundant cyclopoid in the spring, but it is possible the sampling program may not have coincided with the spring pulse of *C. b. thomasi*. In 1977 low numbers of *C. navus* also occurred in early May and early June, and

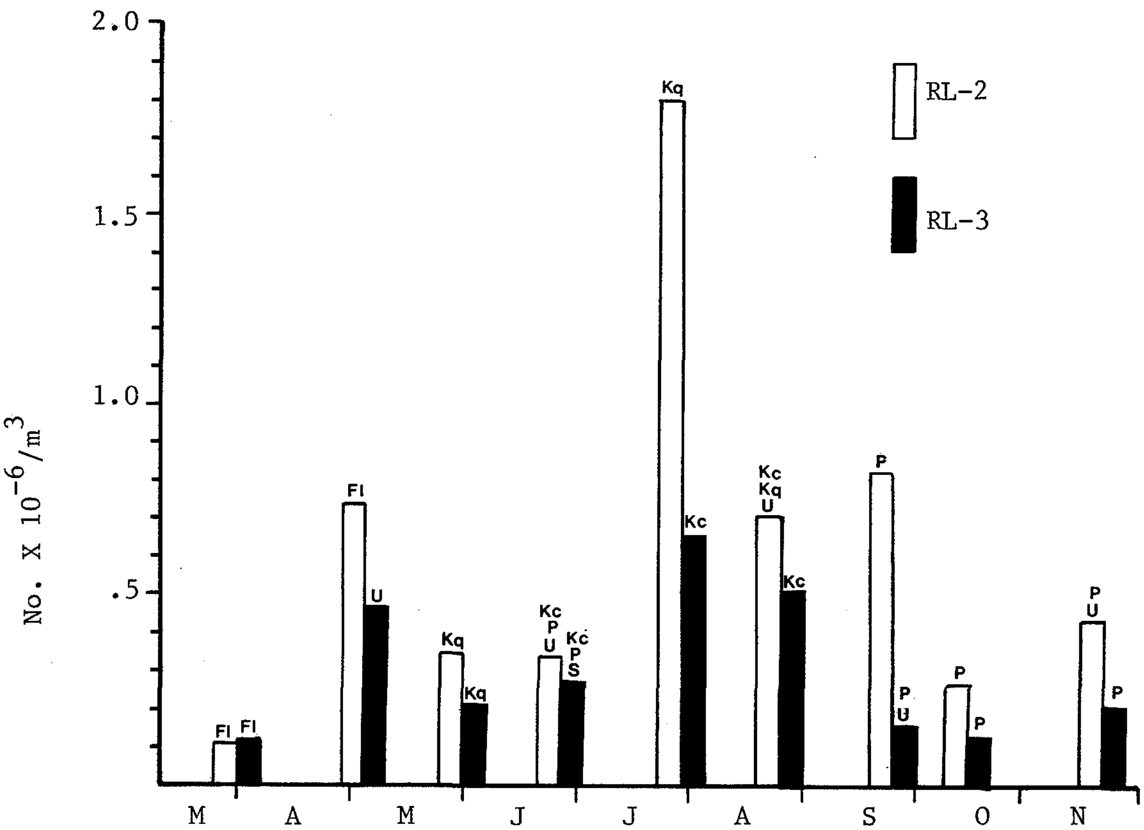


Figure 28. Abundance of Rotifera in Ruth Lake in 1977. Letters at the top of each bar indicate dominant types. Fl = *Filinia longiseta*, Kc = *Keratella cochlearis*, Kq = *K. quadrata*, P = *Polyarthra*, S = *Synchaeta*, U = unidentified.

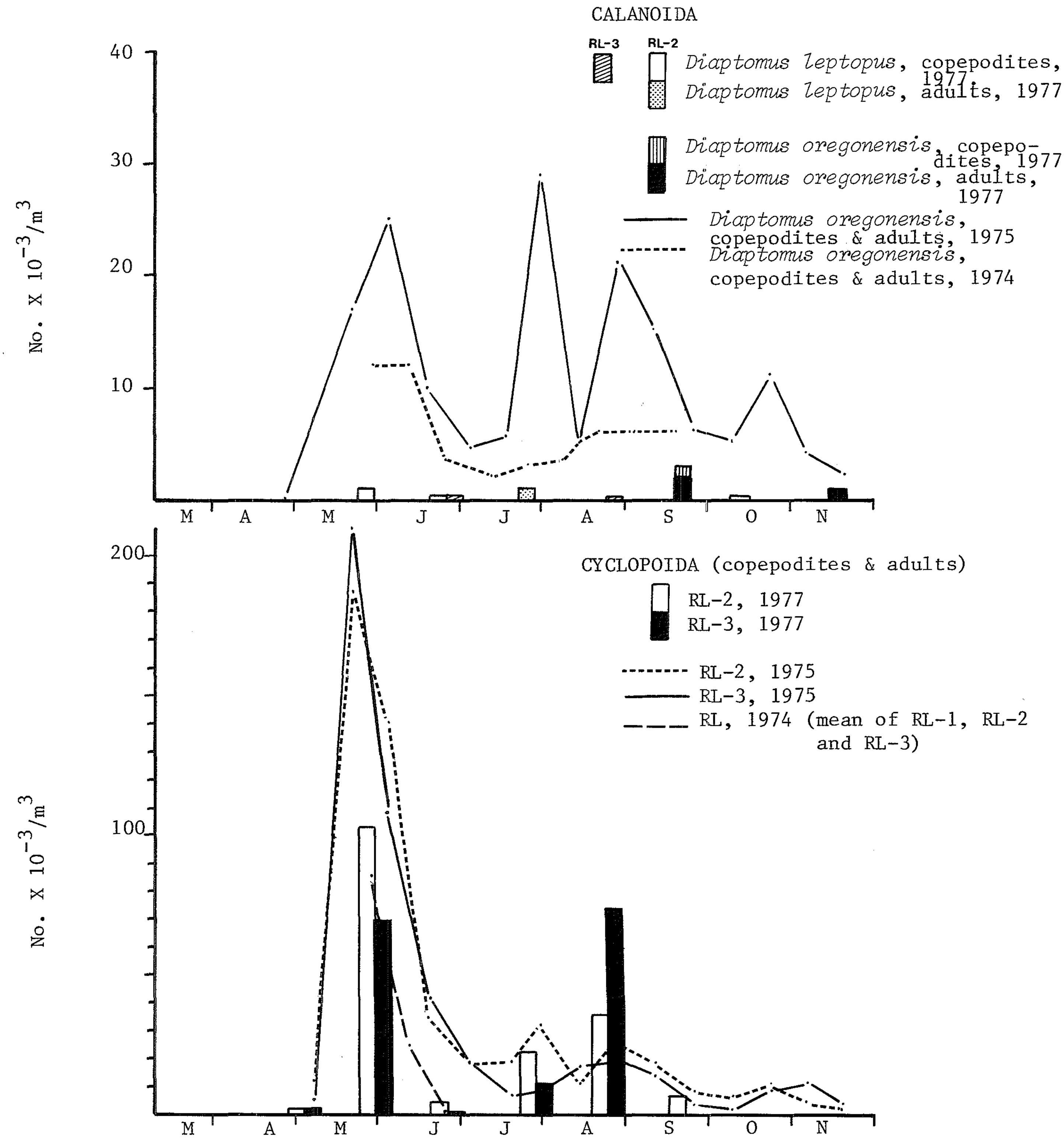


Figure 29. Abundance of Calanoida and Cyclopoida in Ruth Lake in 1974, 1975, and 1977.

it too may have had a spring peak. *C. navus* was not observed in earlier study years and was a new component of the zooplankton community.

Ruth Lake still exhibited a cyclopoid pulse in early spring of a magnitude similar to that observed in previous years. In all three study years, cyclopoid numbers declined sharply in June. In 1974 numbers remained very low after this, but in 1975 they had gradually decreased after the initial rapid decline in June. In 1977 numbers over the July-September period were similar to those observed in 1975 (excluding high numbers at RL-3 on August 24). Counts in the fall of 1977 were lower than in fall, 1975. The fall season was not examined in 1974.

Calanoida

Two species of calanoid copepods, *Diaptomus leptopus*, and *Diaptomus oregonensis*, were observed in Ruth Lake in 1977. Both species occurred in low numbers at RL-2 while only low numbers of *D. leptopus* appeared at RL-3 (Figure 29). *D. oregonensis* probably occurred at RL-3 in numbers too low to have been detected during counting procedures.

During pre-diversion conditions, *D. oregonensis* was the most important organism in the crustacean zooplankton community. From about June onwards in 1974 and 1975 it was very abundant and completely dominated the community (Figure 30). In 1977 *D. oregonensis* populations were very small and were a minor component of the community (Figures 29 and 33). This species has been severely reduced in Ruth Lake.

Cladocera

Figure 31 shows the 1974, 1975 and 1977 Cladocera data from Ruth Lake. The 1977 sampling collected only two major cladoceran species, *Bosmina longirostris* and *Diaphanosoma leuchtenbergianum*. At both RL-2 and RL-3, the two species had relatively small populations except on the July 29 sampling date; hence, both species apparently pulsed in the July-August period. Populations cannot be compared between stations or species because of the four week sampling interval and the short period of prominence of the two species.

In 1975 the major cladocerans were *Daphnia pulicaria* and *Diaphanosoma leuchtenbergianum*. The former had its peak abundance in early June, and *D. leuchtenbergianum* peaked in early July. In 1977 *D. pulicaria* was only observed in low numbers (Figure 31). *D. leuchtenbergianum* was present in

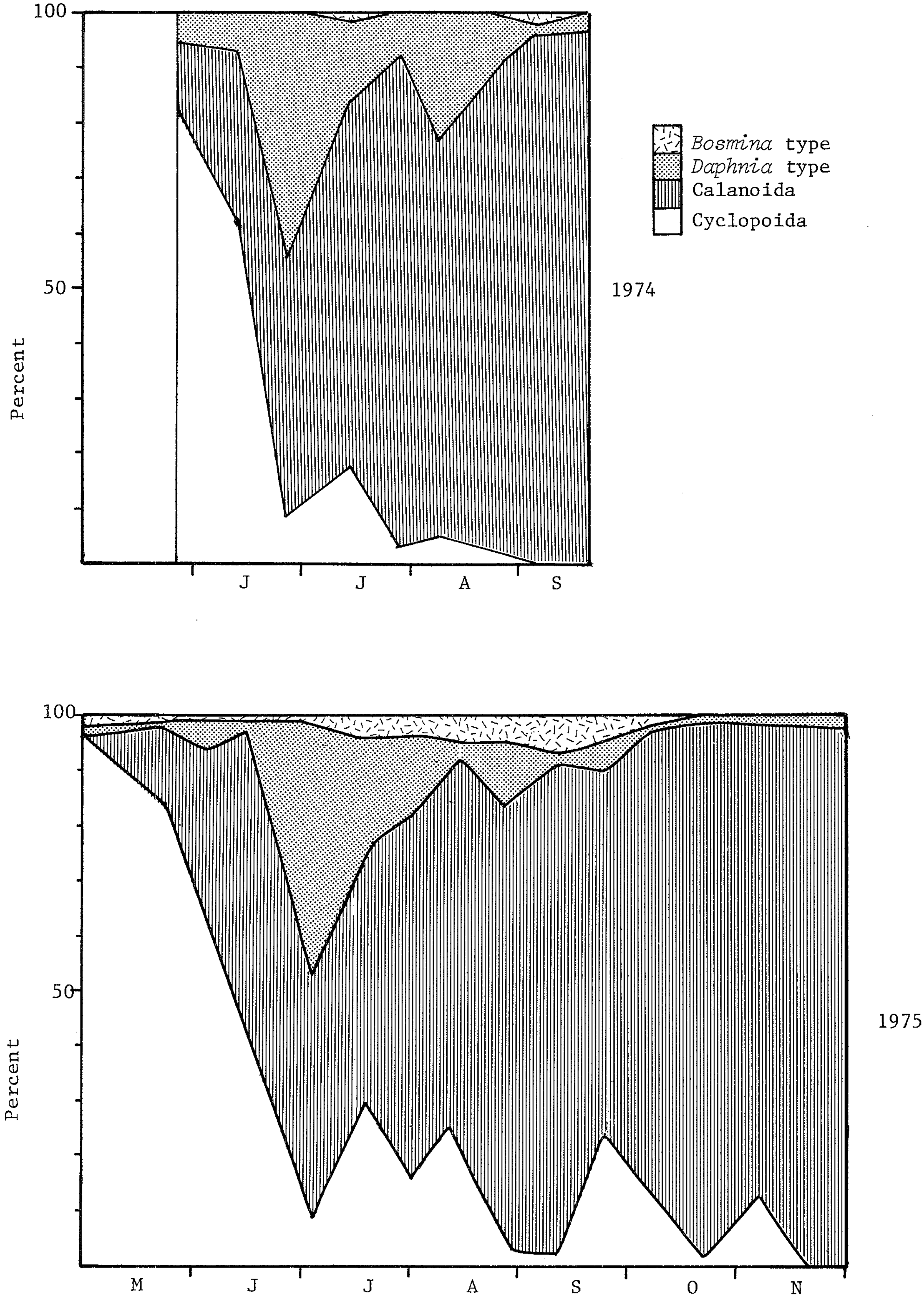


Figure 30. Numerical composition of the crustacean zooplankton in Ruth Lake in 1974 and 1975. Values are the mean of the three stations sampled in these years.

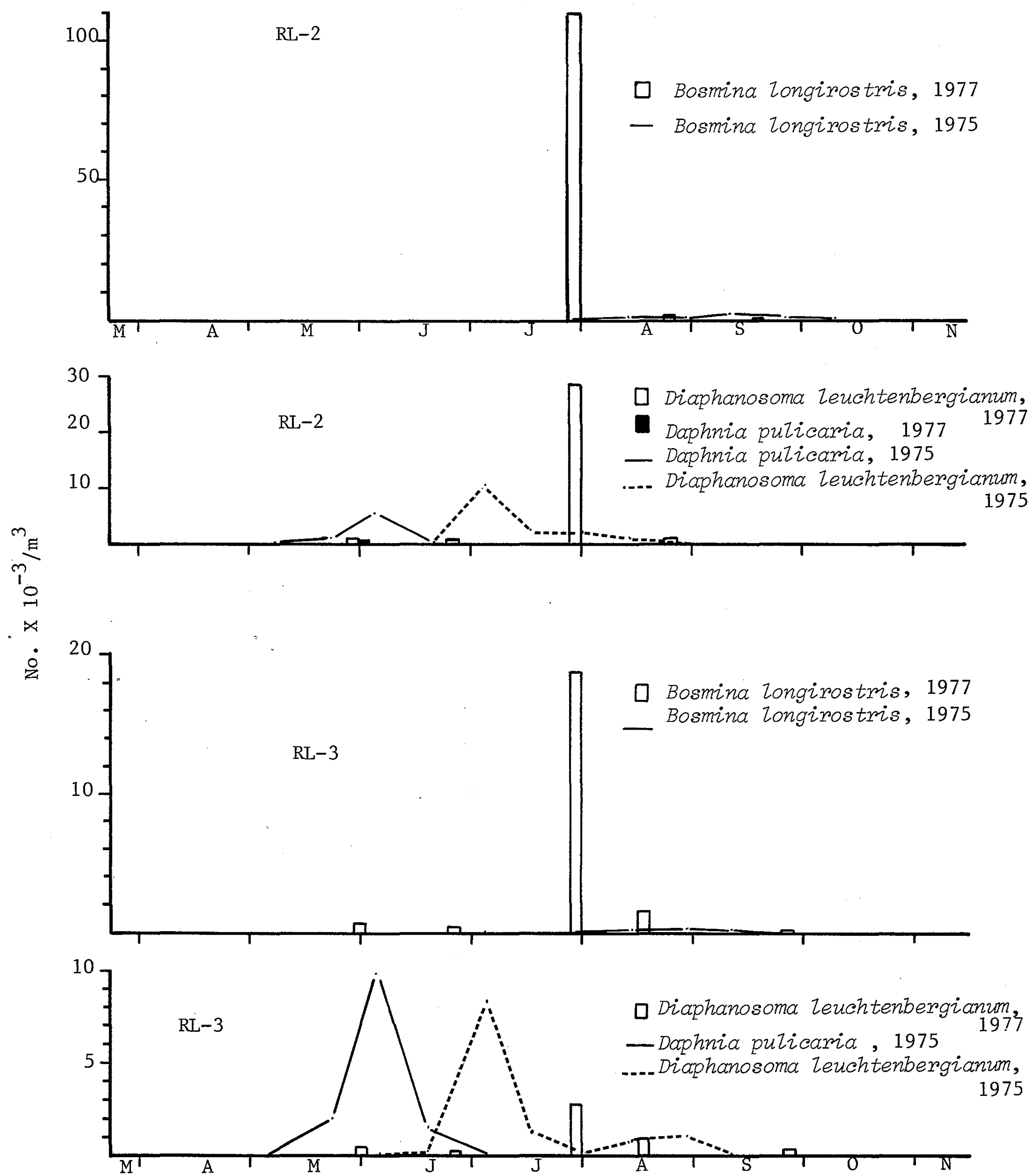


Figure 31. Abundance of the major species of Cladocera in Ruth Lake in 1974, 1975, and 1977.

1977, but its population pulse seemed to occur about a month later than in previous years. It was evident from the 1975 data that the number of *D. pulicaria* rose and fell quickly. The four week sampling program could have missed the major portion of a pulse, but this species appeared to be less abundant in Ruth Lake in 1977. The relatively high number of *B. longirostris* in mid-summer did not occur in previous years and was a major change in the dynamics of the cladoceran community.

Conchostraca

The life cycle of *Lynceus brachyurus* is not completely planktonic (Edmondson, 1959). Nauplii are planktonic, but as the species develops through juveniles to adults, it becomes more bottom-dwelling. Table 39 presents the conchostracan data for 1974, 1975 and 1977. According to the pre-diversion data (Noton and Chymko, 1977), there appeared to be a pulse of nauplii in the early May period in 1974-75. In 1977 abundance of nauplii was low, although a pulse could have been missed due to the sampling interval. Numbers of juveniles and adults, however, were also lower in 1977, and these stages did not occur in the plankton collections for as long as in previous study years. It appeared that conchostracans were less abundant at the regular sampling stations in 1977 than they were in pre-diversion years. The littoral sampling collected *L. brachyurus* only on May 4 at LZ-1, at which time counts were low; however, this sampling was not intensive.

Seasonal Trends

Seasonal community composition is shown in Figure 32, and this, in conjunction with individual species abundances (Figures 29 and 31), depicts the seasonal trends. Cyclopoid copepods were the most abundant crustacean zooplankters on the first three sampling dates, even though total abundance was low on the first two occasions. Cyclopoid numbers were high on May 31 but had decreased by late June. *Cyclops vernalis*, and possibly *Cyclops navus*, appeared to be the most abundant cyclopoid species in the spring. In the June-July period, cyclopoids were less important due to their reduced numbers and the increased abundance of other species, especially *Bosmina longirostris*. By late August cyclopoids were numerous again (mostly unidentified early stage copepodites) and with declines in abundance of other species, they dominated the zooplankton. In the September to November period, total abundance was very low, and few trends could be discerned; however, *Diaptomus oregonensis*, although low in numbers, was dominant at RL-2 in the fall.

Table 39. Abundance of *Lynceus brachyurus* in Ruth Lake in 1974, 1975, and 1977.

1974	May 29	June 6	June 25	July 7	July 25	Aug. 8	Aug. 21	Sept. 4	Sept. 19
juveniles & adults									
RL-2	667	107	26	14	194	83			
RL-3	588	175	196	294	-	-			

1975	May 7	May 22	June 5	June 19	July 4	July 17	July 31	Aug. 14	Aug. 28	Sept. 11	Sept. 23	Oct. 9	Oct. 23	Nov. 6	Nov. 19
RL-2															
nauplii	37764											24			
juveniles & adults		3779	356	42	88	86	29	94	47						
RL-3															
nauplii	22430									97	23	8			
juveniles & adults		1869	300	53	47	96		8							

1977	Mar. 31	May 4	June 1	June 26	July 29	Aug. 24	Sept. 23	Oct. 15	Nov. 19
RL-2									
nauplii		240	280						
juveniles & adults		40	5						
RL-3									
nauplii		100							
juveniles & adults		7	16	10					

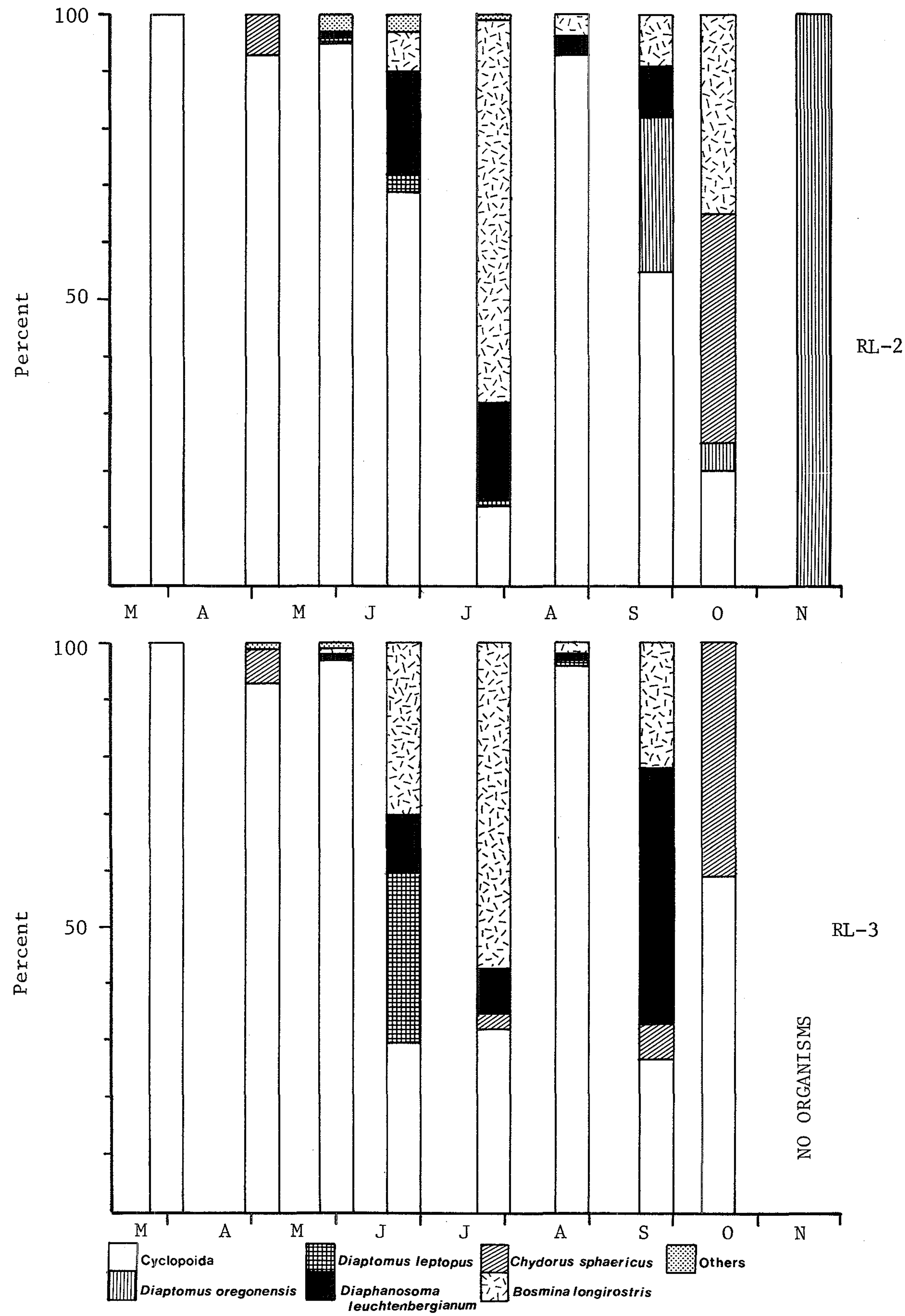


Figure 32. Numerical composition of the crustacean zooplankton at the main stations in Ruth Lake in 1977.

Total Numbers and Biomass

Figure 33 depicts total numbers and biomass of crustacean zooplankton in 1974, 1975 and 1977. In all years there was a spring pulse in both parameters due almost entirely to cyclopoid copepods. In 1974 and 1975, the population declined after the spring pulse until about July and then remained relatively constant. *Diaptomus oregonensis* dominated the relatively stable zooplankton community that existed after July in those years. In 1977 total numbers and biomass decreased after the spring pulse but then were high in late July (due to *Bosmina longirostris*) and in late August (due to cyclopoid copepods). In the fall both biomass and numbers were low. Overall, it appeared that numbers and biomass under pre-diversion and post-diversion conditions were similar in the spring. In pre-diversion conditions biomass tended to be slightly higher during the summer and definitely higher during the fall (Figure 33). In 1977 counts were higher during the late July-August period because of the abundance of *B. longirostris* and cyclopoid copepods.

The major changes in the crustacean zooplankton community between pre-diversion and post-diversion conditions are the following:

1) *Cyclops vernalis*, and possibly *C. navus*, appeared to dominate the cyclopoid copepods rather than *Cyclops bicuspidatus thomasi*.

2) *Daphnia pulicaria* appeared to have much smaller populations than in previous years.

3) As in previous years *Diaphanosoma leuchtenbergianum* showed a summer pulse, but in 1977 this seemed to occur about a month later.

4) *Bosmina longirostris*, formerly low in abundance, exhibited a large population pulse in mid-summer 1977, at which time it dominated the zooplankton community.

5) *Diaptomus oregonensis*, formerly the dominant zooplankter after mid-summer, was absent in 1977 except for a short period in the fall.

6) *Lynceus brachyurus* appeared to be less common at the regular sampling stations compared to pre-diversion years.

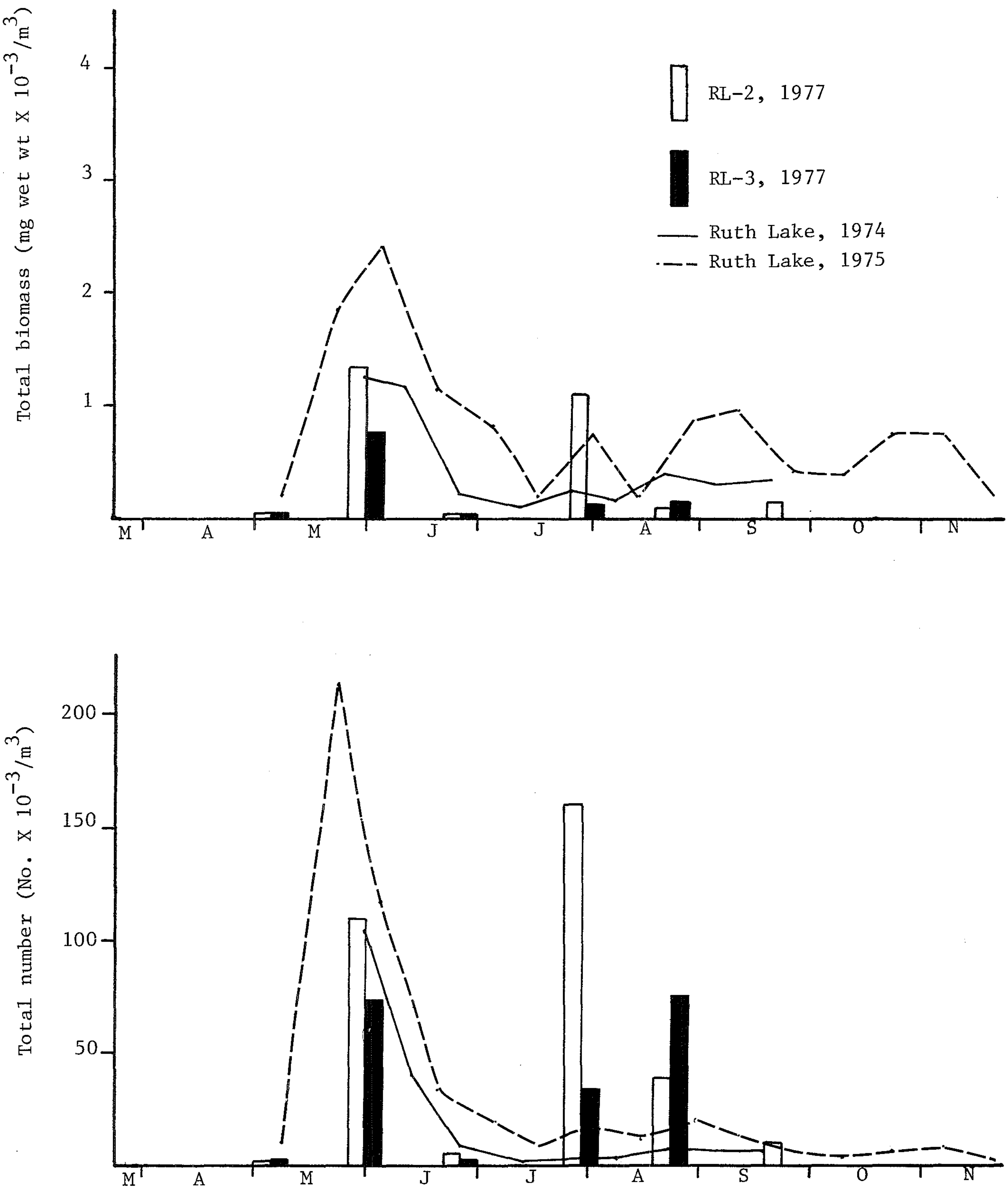


Figure 33. Total abundance and biomass of crustacean zooplankton in Ruth Lake in 1974, 1975, and 1977. Values in 1974 and 1975 are the means of the three stations examined.

Littoral Crustaceans[1]

Counts of crustaceans collected in the shallow water sampling are presented in Table 40, and sampling locations are given in Figure 21. As previously mentioned, the data is approximate because net tow lengths were estimated visually, and some debris blockage of the net occurred. Since the purpose of the sampling was to document the presence, and estimate the abundance, of littoral species, the limnetic species collected will not be discussed.

Twenty taxa were collected that can be considered littoral in lifestyle[2]. Cyclopoid copepodites could not be accurately identified at the species level, consequently it is not known if the group contained additional species or what portion of it belonged to littoral species. Littoral collections in 1975 were not quantitative and twenty-three littoral taxa were recorded. The taxa collected in the two years are compared in Table 41, and they are basically similar. In both years many of the species were very rare with only a few individuals collected; hence, it can be expected that some species would not be recorded in both years.

There were few obvious trends in the 1977 littoral crustacean data. In the spring, populations appeared larger, and there was a higher number of species at LZ-1 and LZ-2. *Chydorus sphaericus* which can also occupy the limnetic zone, and *Eucyclops agilis* were dominant at LZ-1 at this time.

Benthic macroinvertebrates

The counts of the benthic organisms at the two sampling sites in Ruth Lake are presented in Tables 42 and 43. It should be noted that the high variability in benthic samples necessitates that discussions be general in nature. Also, since only one dredge sample was collected at each site in 1974 and 1975, comparisons of these years with 1977 when three samples were collected, must deal with only obvious features of the data.

Porifera (sponges)

Although sponges do not grow on soft substrates and were not collected in Ekman dredge samples, their presence in Ruth Lake had been noted in 1974 and 1975. The preferred substrate was the stems of dead willow. These stems were relatively abundant in the shallow margins of the lake, and the

[1]See footnote 1, page 66.
[2]See footnote 2, page 66.

Table 40. Summary of crustaceans collected in shallow water sampling in Beaver Creek Reservoir in 1977. Values expressed as number/m^3.

	Site LZ-1			Site LZ-2		
	May 4	July 29	Oct. 15	May 4	July 29	Oct. 15
AMPHIPODA						
**Gammarus lacustris*		60		270		
**Hyalella azteca*		480			180	
CONCHOSTRACA						
**Lynceus brachyurus*						
juveniles & adults	200					
OSTRACODA	80	420	140	180	240	30
CLADOCERA						
**Acroperus harpae*	600					
**Alona affinis*		60				
**A. costata*						10
**A. rectangula*			40			20
Bosmina longirostris		60				10
**Chydorus sphaericus*	5400	360				10
Diaphanosoma leuchtenbergianum		240	20		780	
**Ilyocryptus spinifer*		420				
**Leydigia leydigii*			20			
**Pleuroxus denticulatus*		120				
**P. procurvus*	40					
**Sida crystallina*	40				60	
**Simocephalus serrulatus*	80					
COPEPODA						
CALANOIDA						
Diaptomus oregonensis			20			
CYCLOPOIDA						
copepodites	7200	2200	140	2150	540	130
cyclopoid adults						
Cyclops vernalis	2100	120	100	360		10
**Eucyclops agilis*	3600	300	120	360	420	120
**E. speratus*	40			45		
**Macrocyclops albidus*	300		80	180		
**Microcyclops varicans rebellus*	1800	120			60	
HARPACTICOIDA	80		20	90		
TOTAL	21,560	4,960	700	3,635	2,280	340
NUMBER OF LITTORAL TAXA	12	9	6	6	5	5

* denotes taxa considered to be littoral in lifestyle.

Table 41. Ruth Lake littoral crustaceans collected in 1975 and 1977.

	1975	1977
AMPHIPODA		
Gammarus lacustris	X	X
Hyalella azteca	X	X
OSTRACODA	X	X
CONCHOSTRACA		
Lynceus brachyurus	X	X
CLADOCERA		
Acroperus harpae	X	X
Alona affinis	X	X
A. costata	X	X
A. guttata	X	
A. rectangula		X
Chydorus globosus	X	
C. sphaericus	X	X
Eurycercus lamellatus	X	
Graptoleberis testudinaria	X	
Ilyocryptus spinifer	X	X
Leydigia leydigii		X
Pleuroxus denticulatus	X	X
P. procurvus	X	X
Sida crystallina	X	X
Simocephalus serrulatus	X	X
S. vetulus	X	
CYCLOPOIDA		
Eucyclops agilis	X	X
E. speratus	X	X
Macrocyclops albidus	X	X
Microcyclops varicans rubellus	X	X
HARPACTICOIDA	X	X

Table 42. Organisms in Ekman dredge samples from station RL-2, Ruth Lake, 1977.

	March			May			June			June			July			Aug.			Sept.			Oct.			Nov.		
	31			4			1			26			29			29			23			15			19		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																											
Ephemeroptera																											
Caenis							2	1																			
Odonata-Anisoptera																											
Leucorrhinia																											
Tetragoneuria																		1			1		2				
Diptera																											
Ceratopogonidae							1																				
Chironomidae																											
Chironomini		3	1			1	7		3	12	17	7	3	1	6	7	9	12	23	38	52	65	78	45	21	13	27
Tanytarsini							1					2	1														
Tanypodinae		2		2	1		9				2	1	1	2	1	2		1	6	11	6	1	11	2		2	
Orthocladiinae																							1			1	
Culicidae																											
Chaoborus																1	1		2	2	1	4			1	3	1
ARACHNOIDEA																											
Hydracarina							1	1			1								1	3	7	1	1		2		1
CRUSTACEA																											
Ostracoda																											
Amphipoda																											
Gammarus lacustris																					1		1	1			
Hyalella azteca																											
HIRUDINEA																											
Piscicolidae														1				1									
OLIGOCHAETA			1	1			5		1	1	2	1							1	4	7	9	12	14	4		
GASTROPODA																											
Armiger crista																											
Ferrissia parallela																					2					1	
Gyraulus																											
Helisoma																		1									
Menetus cooperi																1											
Physa																											
Promenetus exacuous																											
Valvata sincera ontariensis							1	1			1				1		1										
Valvata sincera sincera																										1	
Valvata tricarinata																1										1	
PELECYPODA																											
Pisidium	3		2		1	1	13	4	13	1	13	7		3	1			1	3		1	1	1		2	1	
Sphaerium	1	1					3	2	3	2	2	1	1		3	1	1	2			1	1	1		3		1
TOTAL	4	6	4	3	2	2	43	9	20	16	38	19	6	7	12	13	12	19	36	58	79	82	108	62	33	23	30
Mean per sample		5			2			24			24			8			15			58			84			29	
Mean per m^2		202			99			1033			1046			357			616			2484			3617			1236	

Three dredges (0.023 m^2 each) taken each time.

Table 43. Organisms in Ekman dredge samples from station RL-3, Ruth Lake, 1977.

	March 31			May 4			June 1			June 26			July 29			Aug. 29			Sept. 23			Oct. 15			Nov. 20	
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
INSECTA																										
Ephemeroptera																										
Caenis				8		4		12	1			1										1				
Trichoptera																										
Oecetis								1																		
Odonata-Anisoptera																										
Leucorrhinia					1			1		1	1					1				1						
Tetragoneuria																					1					
Odonata-Zygoptera																										
Enallagma																								1		
Diptera																										
Ceratopogonidae						1		1											1							
Chironomidae																										
Chironomini	9	7	6	129	159	122	375	148	194	81		136	29	34	11	12	33	47	36	19	45	87	114	80	53	84
Tanytarsini	1			1	2	1	20	20	1	2	125	20							3	2	1	5	4	1	3	4
Tanypodinae	1				1	3	7	1	1		1	3		2	1	14	13	9	47	26	26	26	16	30	19	40
Orthocladiinae							4																	3		1
Culicidae																										
Chaoborus					1				1				1							3		1	1		2	
Coleoptera																										
Donacia																1										
ARACHNOIDEA																										
Hydracarina				1		7	1			1											1	8	2	8		1
CRUSTACEA																										
Ostracoda				1		1			1																	
Amphipoda																										
Gammarus lacustris																					1	1				2
Hyalella azteca																			1							
HIRUDINEA								1			1					1			3		2				1	2
Piscicolidae																										
OLIGOCHAETA		1		3			2	36	17	15	7	17			1				9	25	22		5	14	9	14
GASTROPODA																										
Armiger crista									1					1												
Ferrissia parallela																			9		4	1				
Gyraulus						2		1	7										2	1	6			1		
Gyraulus deflectus																		1	2		4					
Helisoma									2										1							1
Menetus cooperi														1												
Physa																					1					
Promenetus exacuous										1						1			1	1	1		1		2	
Valvata sincera ontariensis	1		1					2		1	1		4	4	2		1	1	1	1	3		4	6	7	1
Valvata sincera sincera							4															4		1	1	
Valvata tricarinata		1	1		1	3	11	4	20	8	17	20	1	18		26	13	11	52	14	41	1	2	3	1	2
PELECYPODA																										
Pisidium	2	7	2	1		5	16	5	9	7	14	11		1				1	1			5	9	1	21	4
Sphaerium		1				1	51	23	4	7	9	26	6	12	1	7	1	2	6	5	4	2	8		7	1
NEMATA										4		1									8					
TOTAL	14	17	10	144	165	150	491	256	259	128	176	235	41	73	16	63	61	72	175	98	171	142	166	149	126	157
Mean per sample	14			153			335			180			43			65			148			152			142	
Mean per m^2	590			6588			14438			7738			1865			2819			6373			6558			6093	

Three dredges (0.023 m^2 each) taken each time.

sponges formed lobed colonies on them; however, in 1977 colonies were not observed in the lake. Water level changes were probably the major factor in the decline of the sponges since the level of Ruth Lake was lower than in 1974-75 and fluctuated more. The sponges were most common in water about one-half to one meter deep, and many of the attached colonies would have been exposed. Few willow stems were submersed in 1977, and suitable areas for recolonization were rare.

Annelida (segmented worms)

The classes of annelids in Ruth Lake consisted of Oligochaeta (bristle worms) and Hirudinea (leeches). As in previous years, oligochaetes were present in low numbers at both stations, but appeared to be even lower at RL-2 (Table 44). Leeches occurred sporadically in very low numbers, a situation similar to previous years.

Crustacea

Two amphipod species, *Gammarus lacustris* and *Hyalella azteca*, occurred in Ruth Lake, and Table 45 shows their counts in the study years. In 1977 *G. lacustris* was collected in very low numbers at both stations on September 23 and October 15. In pre-diversion years *G. lacustris* was only collected at RL-2 and was more numerous in 1975 than in 1974. Considering the variability of the numbers collected in 1974-75, it was not known whether or not the low numbers collected in 1977 indicate a change in the populations in the lake. However, in 1977 *H. azteca* was collected only once in the regular collections, and it appears this species was much less abundant at the main sampling stations in Ruth Lake than in 1974-75.

In previous study years, the conchostracan *Lynceus brachyurus* was occasionally collected in the benthos in the spring and summer. In 1977 no specimens were collected in dredge samples, and this, in conjunction with an apparent decline in abundance of *L. brachyurus* in the zooplankton, suggests that this species is now less common in Ruth Lake. The physical, chemical or biological factors involved in this change are not known.

The only other crustacean benthic organisms observed in 1977 were ostracods which, as in previous study years, were occasionally present in low numbers.

Ephemeroptera, Odonata, Trichoptera and Coleoptera

Caenis, the only mayfly recorded from Ruth Lake, is considered to be a bottom sprawler (Pennak, 1953) and can tolerate lower oxygen conditions

Table 44. Abundance of Oligochaeta in Ruth Lake in 1974, 1975, and 1977.[1]

	1974								
	May	June		July		Aug.		Sept.	
	29	12	25	12	25	8	21	4	19
RL-2		1	2	1	3		4	1	
RL-3			5		11	2		9	

	1975														
	May		June		July			Aug.		Sept.		Oct.		Nov.	
	8	22	5	19	4	17	31	14	28	11	25	9	23	6	19
RL-2	1	5	8	2			2	3	1			1		4	1
RL-3	1	1		12	4		9	32	19	7	23	4	2	4	18

	1977								
	March	May	June		July	Aug.	Sept.	Oct.	Nov.
	31	4	1	26	29	29	23	15	19
RL-2	0.7	0.7	2	1			4	12	1
RL-3	0.7	1	18	13	0.7		19	6	8

[1]In 1974 and 1975 one Ekman dredge sample was taken per site while in in 1977 three were taken. Results expressed as number per Ekman dredge sample (area = 0.023 m^2) and rounded off to the nearest whole number except when less than one.

Table 45. Abundance of Amphipoda in Ruth Lake in 1974, 1975, and 1977.[1]

	May	June		July		Aug.		Sept.	
	29	12	25	12	25	8	21	4	19
RL-2, 1974									
Gammarus lacustris							1	1	21
Hyalella azteca		2					3		3
RL-3, 1974									
Gammarus lacustris									
Hyalella azteca		2		1	8		26	1	11

	May		June		July			Aug.		Sept.		Oct.		Nov.	
	8	22	5	19	4	17	31	14	28	11	25	9	23	6	19
RL-2, 1975															
Gammarus lacustris	2	4	24	83		5			29	1	10	10	1	3	
Hyalella azteca	8	5	10	4		16		4		1	2	6	2	8	2
RL-3, 1975															
Gammarus lacustris															
Hyalella azteca	3	5	3		2	3	10	78	31	23	2	5		3	49

	March	May	June		July	Aug.	Sept.	Oct.	Nov.
	31	4	1	26	29	29	23	15	19
RL-2, 1977									
Gammarus lacustris							0.3	2	
Hyalella azteca									
RL-3, 1977									
Gammarus lacustris							0.3	0.3	
Hyalella azteca							0.3		

[1] In 1974 and 1975 one Ekman dredge sample was taken at each site while in 1977 three were taken per site. Results expressed as number per Ekman dredge (area = 0.023 m^2) and rounded off to the nearest whole number except when less than one.

than most mayflies (Hart and Fuller, 1974). In previous years, it was rare at RL-2 and occurred more frequently at RL-3 where there was more vegetation (Table 46). In 1977 *Caenis* was still rare at RL-2 and more individuals were collected at RL-2; however, the number found at RL-3 was less than in previous years, and this decline may have been associated with changes in the macrophyte community. In 1974 and 1975 there were dense *Chara* beds around RL-3 but in 1977 this macrophyte had decreased substantially.

In pre-diversion study years, odonate nymphs were rare at RL-2, and, as with the mayfly *Caenis*, numbers were higher at the more vegetated sites. In 1977 numbers were low at both sites, with four and eight specimens being collected from RL-2 and RL-3 respectively. The nature of the decrease at RL-3 is indicated in Table 46. The genera of Odonata that have been collected in Ruth Lake are typically climbers and crawlers on vegetation (Pennak, 1953), and the decrease in abundance at RL-3 is probably associated with the previously mentioned decline in macrophyte cover. In prior study years at this site, *Libellula, Leucorrhinia* and *Tetragoneuria* were the most common genera, but in 1977 *Leucorrhinia*, although low in numbers, appeared to be the most common genus.

In 1977 trichopteran larvae were uncommon at RL-2 and RL-3, a situation similar to prior study years. The only coleopteran larva found in the dredge samples was a specimen of *Donacia* on August 29 at RL-3.

<u>Diptera</u> (true flies)

Ceratopogonidae (biting midges), Culicidae (Chaoborinae - phantom midge) and Chironomidae (true midges) occurred as larvae in the benthic samples, the first two groups being uncommon (Tables 42 and 43). The phantom midge, *Chaoborus flavicans*, had not been collected in Ruth Lake in previous study years.

Table 47 lists the detailed data on the population counts of chironomid larvae at RL-2 and RL-3. Chironomid larvae were the most common dipterans collected, and, as noted earlier, the 0.6 mm aperture size used to wash the bottom samples would select for larger larval instars. Many small, early instars would be missed, and an increase in abundance must be interpreted as an increase in numbers of larger individuals. Also, as previously mentioned, only one Ekman dredge sample was collected at each site in 1974 and 1975; therefore comparisons between years must be general.

Table 46. Abundance of Ephemeroptera and Odonata at Station RL-3 in Ruth Lake in 1974, 1975, and 1977.[1]

RL-3, 1974	May 29	June 12	June 25	July 12	July 25	Aug. 8	Aug. 21	Sept. 4	Sept. 19
EPHEMEROPTERA (*Caenis*)	8	24	77			1	2		23
ODONATA			4		4	7	3	3	6

RL-3, 1975	May 8	May 22	June 5	June 19	July 4	July 17	July 31	Aug. 14	Aug. 28	Sept. 11	Sept. 25	Oct. 9	Oct. 23	Nov. 6	Nov. 19
EPHEMEROPTERA (*Caenis*)	7	11	28		2			20	16	27	22	7	31	4	32
ODONATA	2	1	3				1	15	10	7	1				44

RL-3, 1977	March 31	May 4	June 1	June 26	July 29	Aug. 29	Sept. 23	Oct. 15	Nov. 19
EPHEMEROPTERA (*Caenis*)		4	4	0.3				0.3	
ODONATA		0.3	0.7	0.7		0.3	0.7		

[1] In 1974 and 1975 one Ekman dredge sample was taken at each site while in 1977 three were taken per site. Results expressed as number per Ekman dredge (area = 0.023 m^2) and rounded off to the nearest whole number except when less than one.

Table 47. Abundance of Chironomidae at RL-2 and RL-3 in Ruth Lake, 1977. Three samples were collected on each date (area of one sample = 0.023 m^2)

STATION RL-2

	March 31			May 4			June 1			June 26			July 29			Aug. 29			Sept. 23			Oct. 15			Nov. 19		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Subfamily Chironominae																											
Tribe Chironomini																											
Chironomus								3		4	6	2	3		4	6	9	11	20	36	33	63	70	44	21	13	27
Glyptotendipes							1		3	4	6	1				1			2	2	5	3	8	1			
unidentified		3	1					4		4	5	4		1	2			1	1		4	1					
Tribe Tanytarsini								1				2	1														
Subfamily Orthocladiinae																											
Subfamily Tanypodinae																											
Ablabesmyia																											
Procladius		2		2	1		9			2	2	1	1	2	1	2		1	6	11	6	1	11	2		2	
TOTAL		5	1	2	1	1	17		3	14	19	10	4	3	7	9	9	13	29	149	48	68	89	47	21	15	27
Mean per sample		2			1			6			6			5			10			75			68			21	
Mean per m^2		87			43			261			261			217			435			3261			2957			913	

STATION RL-3

	March 31			May 4			June 1			June 26			July 29			Aug. 29			Sept. 23			Oct. 15			Nov. 19		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Subfamily Chironominae																											
Tribe Chironomini																											
Chironomus	9	7	6	2	6		10	28	10	28	50	89	28	30	10	12	33	47	27	16	30	67	102	68	42	78	
Einfeldia				127	152	121	364	112	183	52	73	12	1														
Glyptotendipes														1					3	2	14	11	10	3	5	5	
unidentified					1	1	1	8	1	1	2	35		3	1				2	1	1	9	2	9	6	1	
Tribe Tanytarsini				1	2	1	4	3	1	2		20							3	2		5	4	1	3	4	
Subfamily Orthocladiinae																								3		1	
Subfamily Tanypodinae																											
Procladius	1				1	2	3				1	3		2	1	14	13	9	47	26	26	26	16	30	19	40	
Thienemannimyia						1	4	1	1																		
TOTAL	10	7	6	130	161	126	386	152	196	83	126	159	29	36	12	16	46	52	82	47	71	118	134	114	75	129	
Mean per sample		8			139			245			123			26			39			67			122			102	
Mean per m^2		348			6043			10652			5348			1130			1696			2913			5304			4435	

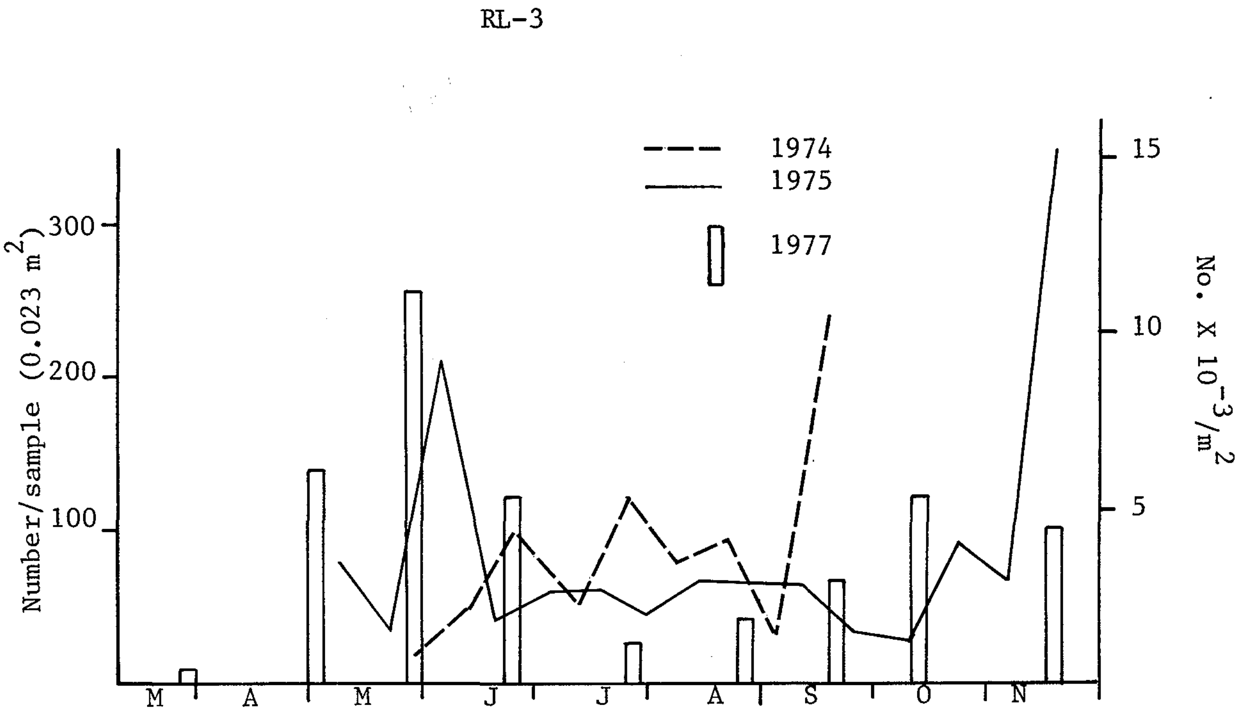
At RL-2, as in former years, *Chironomus* was clearly the dominant genus, and total chironomid numbers were largely a reflection of the abundance of this genus. In the earlier studies chironomids were more abundant in spring and summer than in fall; however, in 1977 the opposite occurred, with numbers being low in spring and summer and higher in fall (Figure 34). This suggests that one or more new species of *Chironomus*, with different temporal dynamics, may be present, or that the seasonal dynamics of the former species have changed. Although the trends were different, maximum numbers were fairly similar.

At RL-2, overall abundance of chironomids in 1977 was not obviously different from previous years (Figure 34), and *Chironomus, Einfeldia* and *Procladius* were still the dominant general. In 1974 and 1975 these species did not show obvious seasonal trends. In 1977 *Chironomus* and *Procladius* tended towards high numbers in the fall, and *Einfeldia* was distinctly more abundant in the May to June period. The general increase of *Chironomus* in the fall involved late instar larvae and was similar to situations observed in Beaver Creek Reservoir and at PCR-2 in Poplar Creek Reservoir. Rasmusson (pers. comm.) has noted that the species of *Chironomus* in Lake Wabamun, Alberta show maximum numbers of fourth instar larvae in the fall. These larvae overwinter, then pupate and emerge in the spring and summer.

Figure 35 compares chironomid abundance between the two sites during the study years. In pre-diversion years, values were basically similar at the two sites for the first portion of the season, but after late July, RL-3 tended to have higher numbers than RL-2. In 1977 counts at RL-3 were consistently higher than at RL-2. In the spring this was due to large numbers of *Einfeldia*, but over the remainder of the season it was due to higher numbers of *Chironomus* and *Procladius*.

Mollusca

Table 48 shows the abundance of gastropods (snails) and pelecypods (clams) at the two sites in the three study years. Most species of snails are vegetarians, living on the algae that cover submersed surfaces such as aquatic macrophytes. At RL-2, water depth and shading by water lilies limited submersed macrophytes and their attached algae, and this probably accounted for the low numbers of gastropods observed at this site in all study years. RL-2 was shallower, with more macrophytes, and gastropods were more abundant



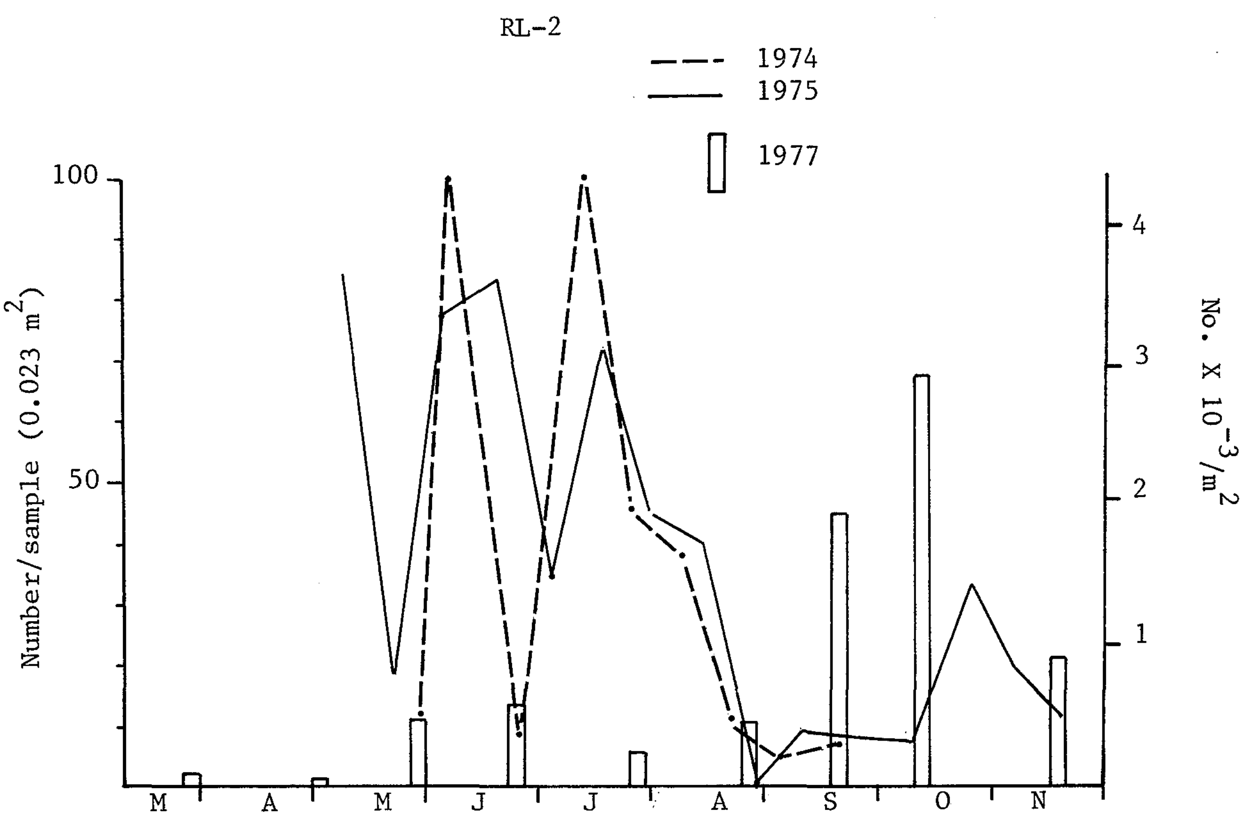


Figure 34. Comparison of abundance of Chironomidae between study years at RL-2 and RL-3 in Ruth Lake. Values in 1974 and 1975 were from single samples while values in 1977 were the mean of three samples.

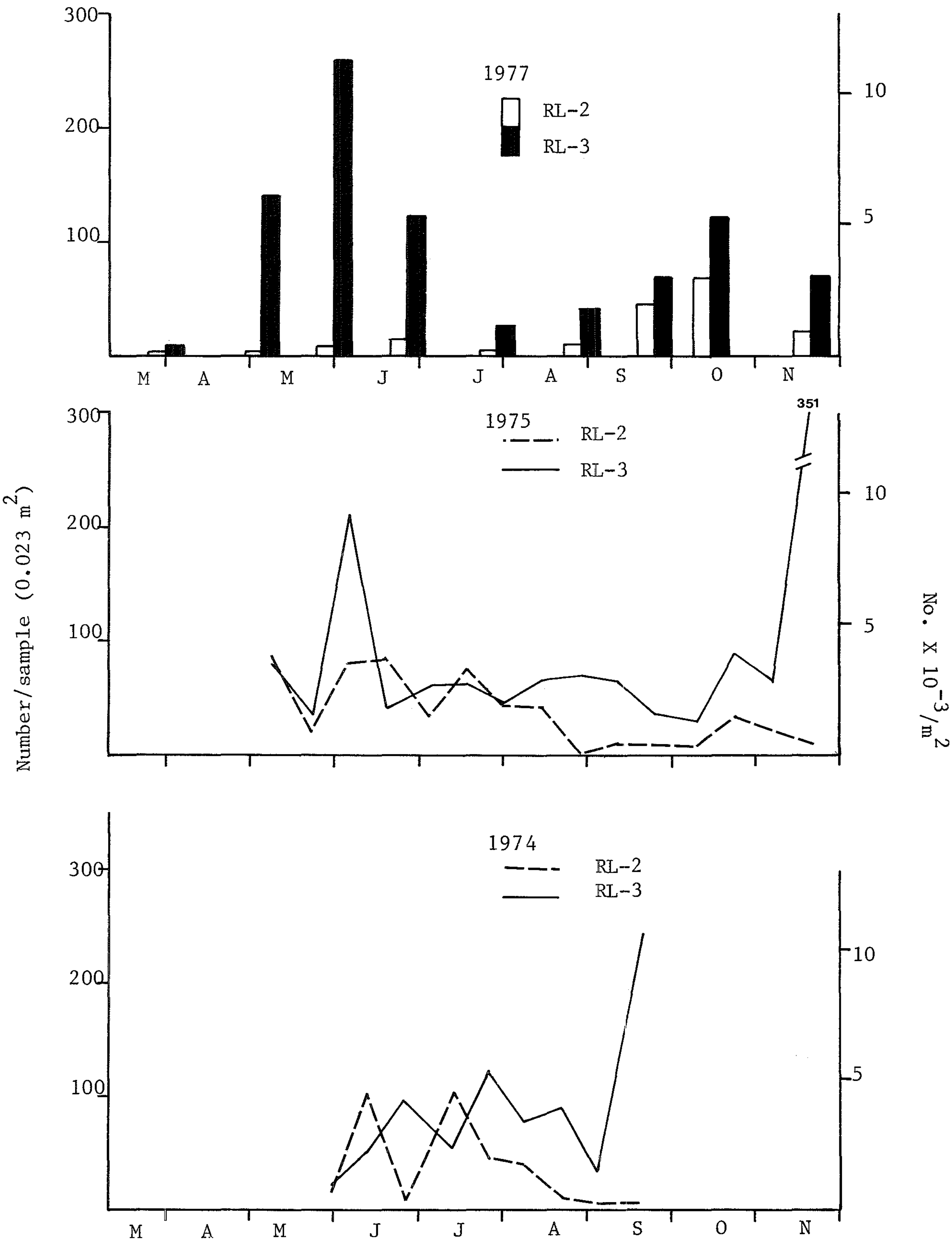


Figure 35. Comparison of abundance of Chironomidae between RL-2 and RL-3 in Ruth Lake in 1974, 1975, and 1977. Values in 1974 and 1975 were from single samples while values in 1977 were the mean of three samples.

Table 48. Abundance of Mollusca in Ruth Lake in 1974, 1975, and 1977.[1]

1974	May 29	June 12	June 25	July 12	July 25	Aug. 8	Aug. 21	Sept. 4	Sept. 19
RL-2									
Pelecypoda									
Sphaeriidae	3	3	5		1	2	7	2	1
Gastropoda	2						1	1	1
RL-3									
Pelecypoda									
Sphaeriidae	2	3	4		1	6	2	2	7
Gastropoda		3	4			2		18	3

1975	May 8	May 22	June 5	June 19	July 4	July 17	July 31	Aug. 14	Aug. 28	Sept. 11	Sept. 25	Oct. 9	Oct. 23	Nov. 6	Nov. 19
RL-2															
Pelecypoda															
Sphaeriidae	45	13	25	60	2	15	8	5	10	10	5	16	12	4	18
Gastropoda	3	1	1	3	2	1			1	1	4	3	2		
RL-3															
Pelecypoda															
Sphaeriidae	41	40	62	14	33	25	6	7	21	25	8	4	18	6	22
Gastropoda	4		23	1	2	11	8	4	26	38	8	4	77	6	44

1977	March 31	May 4	June 1	June 26	July 29	Aug. 29	Sept. 23	Oct. 15	Nov. 19
RL-2									
Pelecypoda									
Sphaeriidae	2	0.7	13	9	3	2	1	1	2
Gastropoda			0.7	0.3	0.3	0.7			1
RL-3									
Pelecypoda									
Sphaeriidae	4	2	36	25	7	4	5	8	11
Gastropoda	1	2	17	16	10	18	48	8	5

[1] In 1974 and 1975 one Ekman dredge sample was taken at each site while in 1977 three were taken per site. Results expressed as mean number per Ekman dredge (area = 0.023 m^2) and rounded off to the nearest whole number except when less than one.

than at RL-2. Although *Chara* (the dominant macrophyte) apparently declined at this site after diversion, total numbers of gastropods appeared similar between 1975 and 1977. As in previous study years, *Valvata tricarinata* was clearly the dominant species.

All the pelecypods collected were members of the Family Sphaeriidae (fingernail clams) and belonged to two common genera, *Sphaerium* and *Pisidium*. In 1974 pelecypods were low in number at both sites. In 1975 they were abundant; *Pisidium* was the dominant genus, and no obvious differences were detected between sites. Pelecypods appeared to be less abundant in 1977 at RL-2 than in 1975 but about the same for both years at RL-3. Neither *Pisidium* nor *Sphaerium* was obviously predominant.

Total Numbers and Community Composition

Total numbers and community composition of the benthos are shown in Figure 36. In all three study years, the number of benthic macroinvertebrates were higher at the shallower sampling stations. As observed in previous years, chironomids were the most abundant group in the benthos; however, in 1977 pelecypods were well represented at RL-2 in the first half of the season. Most of the trends in the populations were a reflection of the abundance of chironomids. At RL-3 numbers were high in spring due to late instars of the chironomid *Einfeldia*; declined to a low in late summer; then rose in the fall as *Chironomus* and *Procladius* increased. At RL-2, numbers were low until the fall when the numbers of *Chironomus* increased.

Figure 37 compares total numbers at each station during the three study years. There were no consistent, obvious differences in the benthic macroinvertebrates collected before and after the diversion at RL-3. Populations at RL-2 in 1977, as compared to previous years, appeared to be lower during the spring to midsummer period but basically similar in the fall. The lower values in the spring to midsummer period apparently were a result of *Chironomus'* being less abundant during this period than it had been in previous years. As was already mentioned, it is possible that a species change has occurred within this genus, resulting in different temporal patterns of abundance. Reasons for such a change were not clear.

Fish

Four species of fish were collected in Ruth Lake in 1977 (Table 49). As in past years (RRCS, 1975; Noton and Chymko, 1977), brook sticklebacks

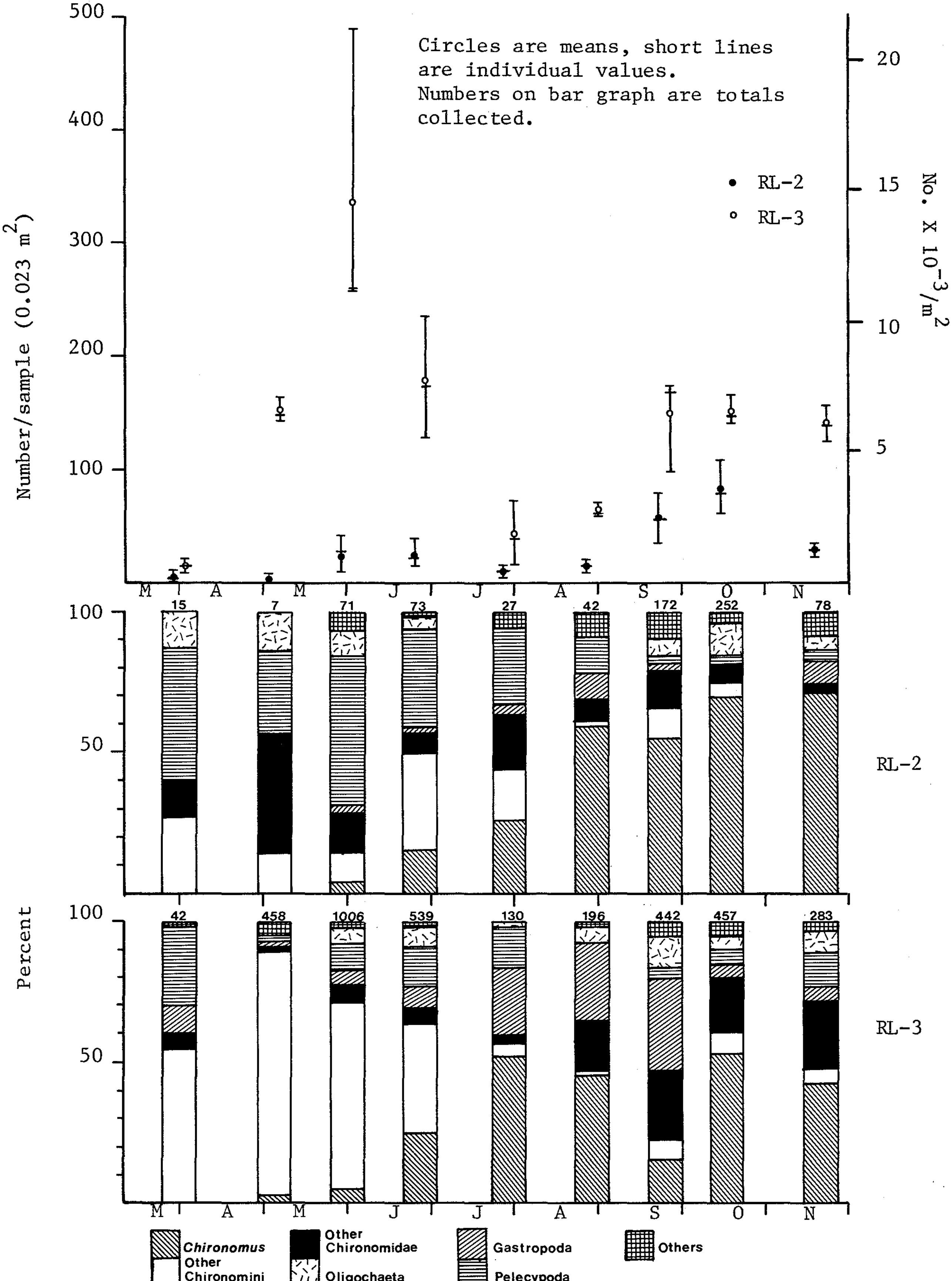


Figure 36. Total abundance and numerical composition of the benthos in Ruth Lake, 1977.

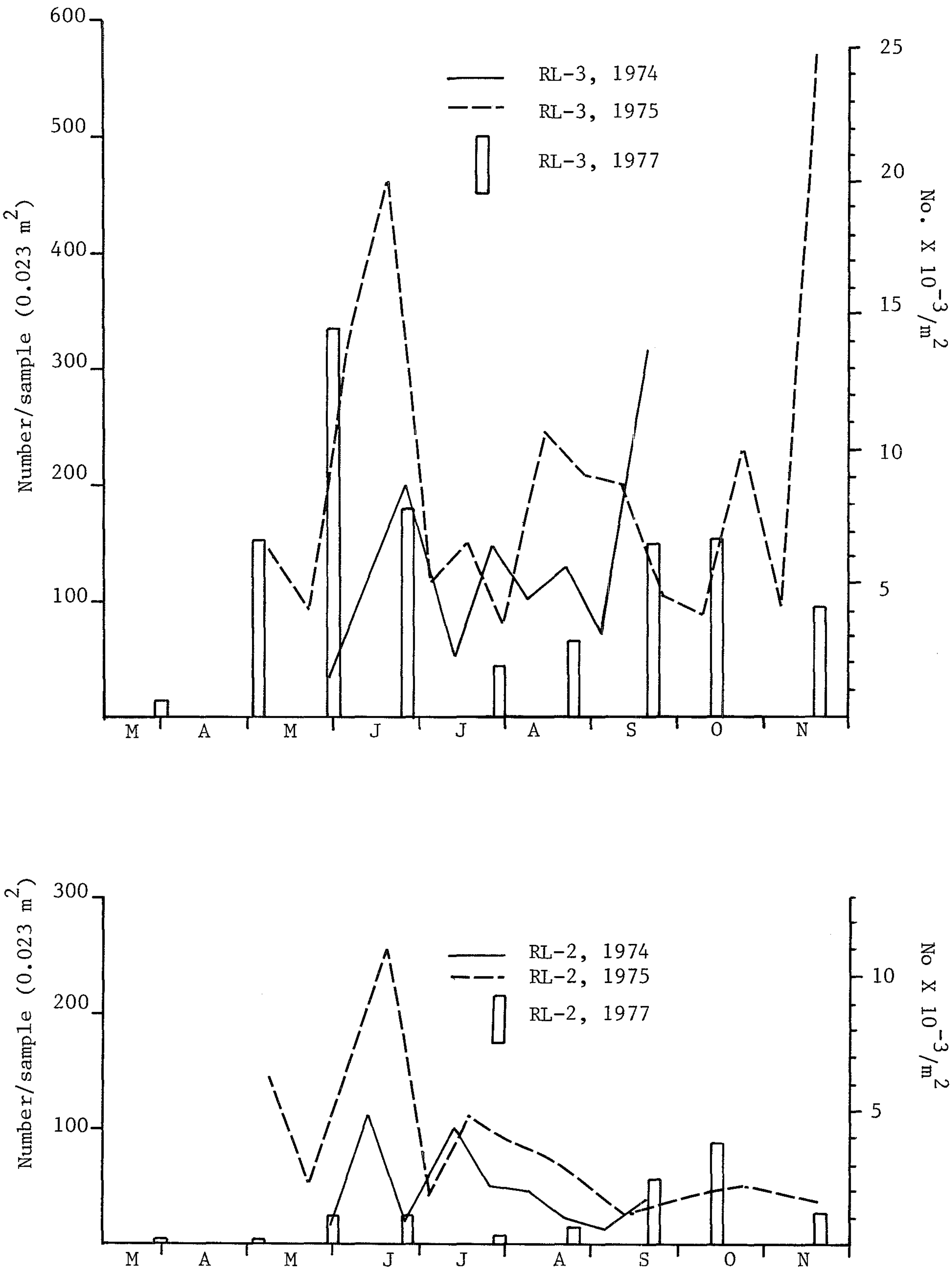


Figure 37. Total abundance of the benthos in Ruth Lake in 1974, 1975, and 1977. Values in 1974 and 1975 were from single samples while values in 1977 were the mean of three samples.

Table 49. Fish collected in Ruth Lake, 1977.

	Site S1	S2	S4	G1	G2
June 26-27					
Brook stickleback	++++	++++	++++		
Fathead minnow	++	+++	+++		
White sucker			1	36	39
Longnose sucker				2	7
August 23-24					
Brook stickleback					
Fathead minnow					
White sucker				19	33
Longnose sucker					3

Sites S1, S2, S4 - seine hauls (June only)

Sites G1 & G2 - one test gang gill net set overnight at each site on each occasion

Relative abundance of small fish in seine hauls:

++++ - Very abundant

+++ - Common to abundant

++ - Occasional

and fathead minnows formed abundant populations in the lake and were successfully reproducing. Their status has not been noticeably affected by the diversion.

White and longnose suckers have gained access to Ruth Lake via the diversion canal from Beaver Creek Reservoir. White suckers were abundant in gill net catches in June and August, but no young of the year were taken in seine hauls. Because of this and the lack of firm substrates in the lake for spawning, this species was probably not reproducing in Ruth Lake in 1977. No young of the year of longnose suckers were collected and this species was less abundant in gill net catches than white suckers (Table 49). Weights and lengths of collected fish are placed in Appendix 10.

The stomach contents of suckers examined in June are summarized in Table 50. Larval chironomids were the most abundant food item at that time, with amphipods next in importance. No other single type of food accounted for more than 1% of the total items consumed. The high incidence of chironomids undoubtedly reflects their availability as food.

No pike were collected in Ruth Lake in 1977, but this species may eventually enter Ruth Lake from Beaver Creek Reservoir. Abundant forage fish in the lake (sticklebacks and fathead minnows) are a potential food supply for pike, and the abundant macrophyte growth there may provide spawning habitat. Because of the history of winter oxygen depletion in Ruth Lake (Noton and Chymko, 1977), pike would not be able to overwinter there, and consequently their use of the lake may be only seasonal. Burbot and lake chub also may eventually enter Ruth Lake and use it on at least a seasonal basis. At present chub are common in Beaver Creek Reservoir and burbot may occur in upper Beaver Creek. Fathead minnows and brook stickleback have overwintered in Ruth Lake in the past and are probably the only species that will be able to continue doing so.

The fate of fish that enter the lake in the open season is uncertain. Winter oxygen concentrations are too low (Table 30) to permit fish, other than fathead minnows and brook sticklebacks, to survive. It is uncertain whether the fish (primarily suckers) are able to return to the vicinity of upper Beavcr Creek, the only location in the immediate system likely to have oxygen levels adequate for overwintering. The alternative is that the suckers are perishing in the lake in the winter and that the fish observed in the summer

Table 50. Composition of food of suckers collected in gill nets in Ruth Lake, June 26-27, 1977.

Food Items	Mean percent (by numbers) of total items in stomachs White sucker (n=10) (260 - 306 mm FL.)	Longnose sucker (n=8) (243 - 290 mm FL.)
Ephemeroptera	-	1
Odonata - Zygoptera	<1	-
Trichoptera	<1	-
Ceratopogonidae	<1	<1
Hydroptilidae	-	<1
Chironomidae (larvae)	71	69
(pupae)	3	12
Corixidae	1	<1
Other Hemipterans	<1	-
Hydracarina	-	<1
Amphipoda	23	16
Conchostraca	<1	<1
Gastropoda	<1	1
No. of Empty stomachs	1	-

are new individuals re-invading in the spring. If this is the case, then considerable mortality must be occurring in the sucker population of upper Beaver Creek and the diversion system.

POPLAR CREEK RESERVOIR

METHODS

Regular sampling was conducted on March 30 and approximately every 4 weeks from May 5 through November 19, 1977 at sites PCR-1 and PCR-2 in Poplar Creek Reservoir. At both sites, temperature and oxygen were measured, and water for chemical and phytoplankton analysis was collected from two evenly spaced depths in the epilimnion (usually 1 and 4 m). At site PCR-1 two depths in the hypolimnion (usually 8 and 13 m) were also sampled for chemical and phytoplankton analysis. Seasonal water samples were collected at these depths on May 5, July 29 and October 15, and substrate samples were collected on July 29. Top, middle and bottom water samples were taken on each occasion for conductivity analysis. In July and August excessive amounts of colonial blue-green algae were removed from the water quality samples by filtration through a plankton net. Six vertical net hauls for zooplankton were taken at each station on each date, and three Ekman dredge samples were collected at the same time. A series of 10 sites were sampled on August 7 to assess the distribution and colonization of zoobenthos in the reservoir (Figure 38). Three Ekman dredge samples were collected at each of the ten sites. A vertical series of Schindler-Patalas trap samples for zooplankton was collected at 2 m intervals at PCR-1 on August 9. Two shore sites were sampled in spring, summer and fall for littoral crustaceans. Composition, approximate abundance and distribution of aquatic macrophytes was assessed by boat on August 7 and 8.

Seining and gill netting were carried out in Poplar Creek Reservoir on June 27-28 and August 25-26 in 1977. Four sites, encompassing a variety of habitats, were sampled with a beach seine (S1 to S4 - Figure 38). These sites included areas of gravel substrates with sparse aquatic plant growth (S1), clay substrates with moderate plant coverage (S4) and peat substrates with moderate to abundant aquatic macrophyte growth and plant debris (S2 and S3). Test gang gill nets were set overnight on each occasion, on the bottom at sites G1 (2-4 m depth) and G2 (3-5 m depth). Aquatic macrophytes were rare at both these sites.

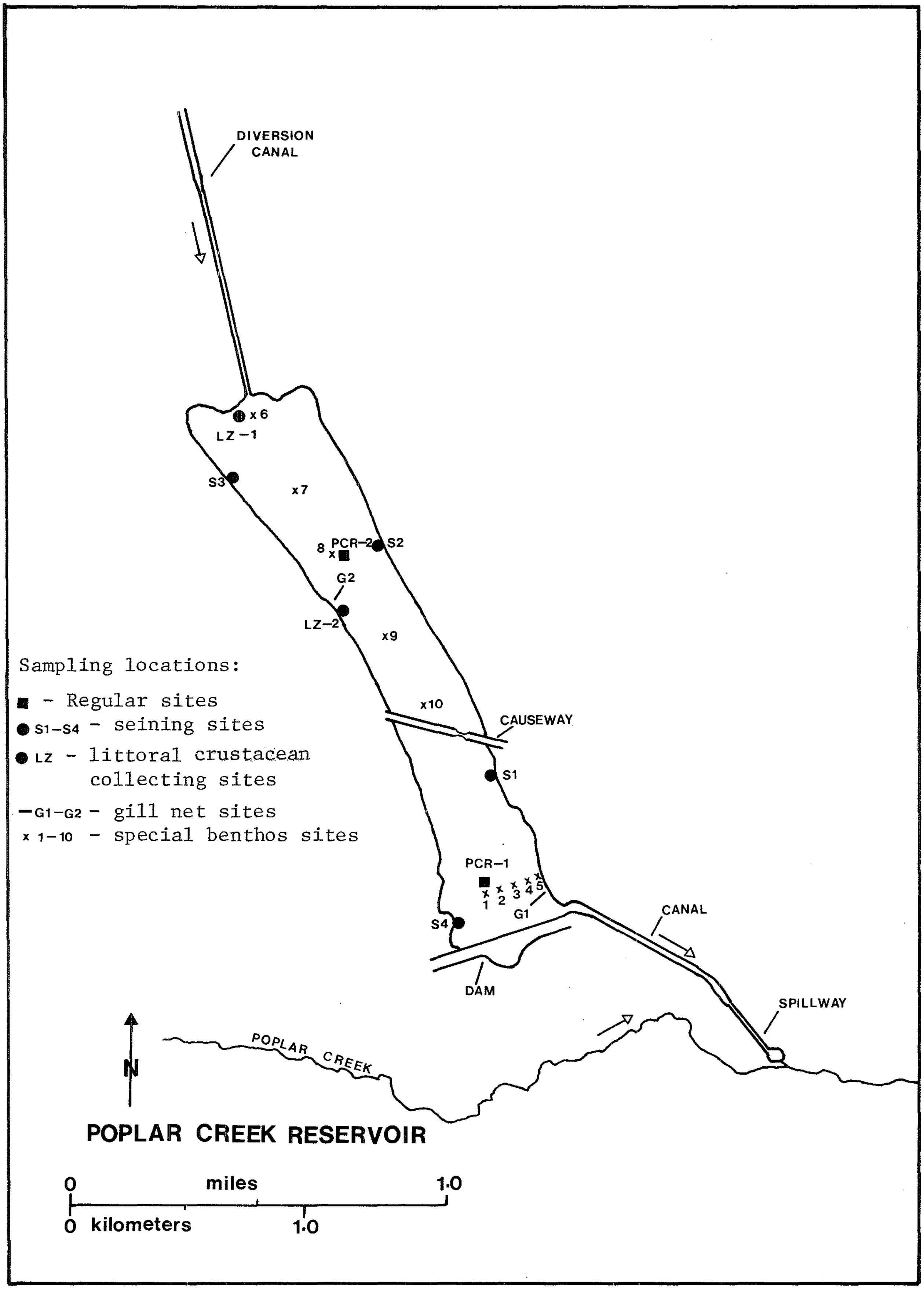


Figure 38. Sampling locations in Poplar Creek Reservoir, 1977.

RESULTS AND DISCUSSION

Poplar Creek Reservoir is formed by a dam across a small tributary and ravine leading to Poplar Creek (Figure 39). Water enters from Ruth Lake via a diversion canal and leaves down another canal which terminates at the spillway where the flow descends to Poplar Creek. Reservoir water was brown coloured and slightly turbid in 1977. The reservoir is relatively deep as a result of its ravine nature with most shorelines sloping fairly abruptly into the lake. Only the north end of the basin slopes gently. Much of the substrate close to the dam was disturbed during dam construction and now consists of sand, gravel and clay. North of the causeway that crosses the reservoir the substrate contains more undisturbed organic muskeg-type material, some of which has floated to the surface in large mats similar to those in Beaver Creek Reservoir. Station PCR-1 was situated in the south basin over the ravine and, consequently, was about 18 m deep with a substrate of clay, sand and some organic debris. PCR-2, in the north half of the reservoir, had an organic substrate at a depth of 6-7 m.

Physical and chemical parameters

Figure 39 shows the general nature of the Poplar Creek Reservoir basin. From the preliminary depth contours (a comprehensive sounding of the lake has not been done), a lake volume of about 6×10^6 m^3 was estimated. Water replacement time in this reservoir was similar to that of Beaver Creek Reservoir, about once in two months at the maximum monthly Beaver Creek flows recorded this year. Although thermal stratification in Poplar Creek Reservoir may prevent hypolimnetic water from being involved in this flushing, thereby reducing the lake volume being renewed, this would not greatly affect the flushing rate since 5×10^6 m^3 of the lake volume was in the epilimnion. Much of the hypolimnion occupied the central deep ravine which may reach 20 m depth in places but was not large in horizontal extent.

Poplar Creek Reservoir first reached spillway crest levels in July of 1976. In 1977, water level in the reservoir was more stable than in upstream lakes, barely exceeding 0.5 m in total fluctuation (Figure 40). The spillway was closed during September-October 1977, resulting in a water level rise at that time. Subsequently, this water level was drawn down below the spillway crest by about one metre so that no discharge over the spillway

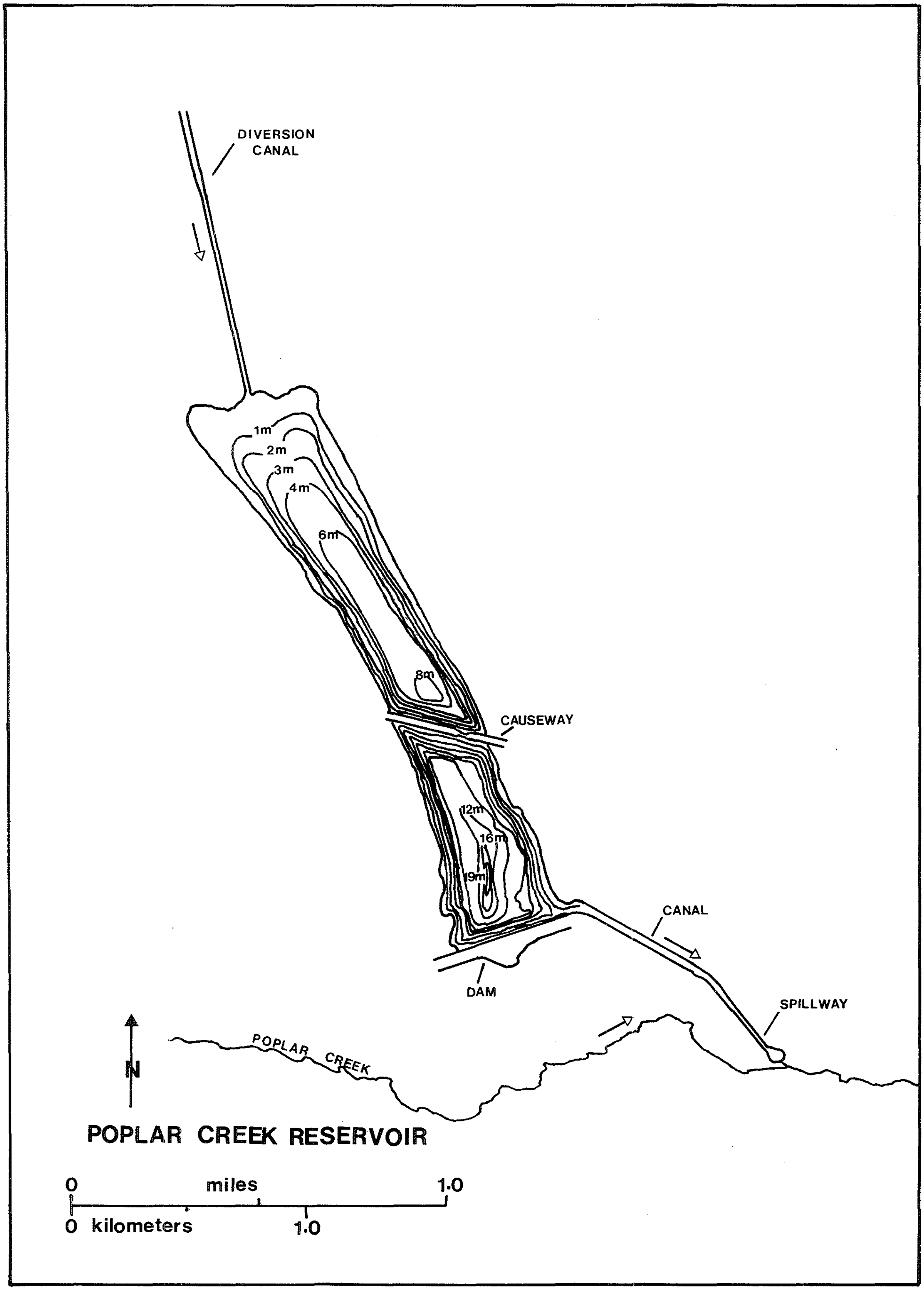


Figure 39. Approximate depth contours of Poplar Creek Reservoir.

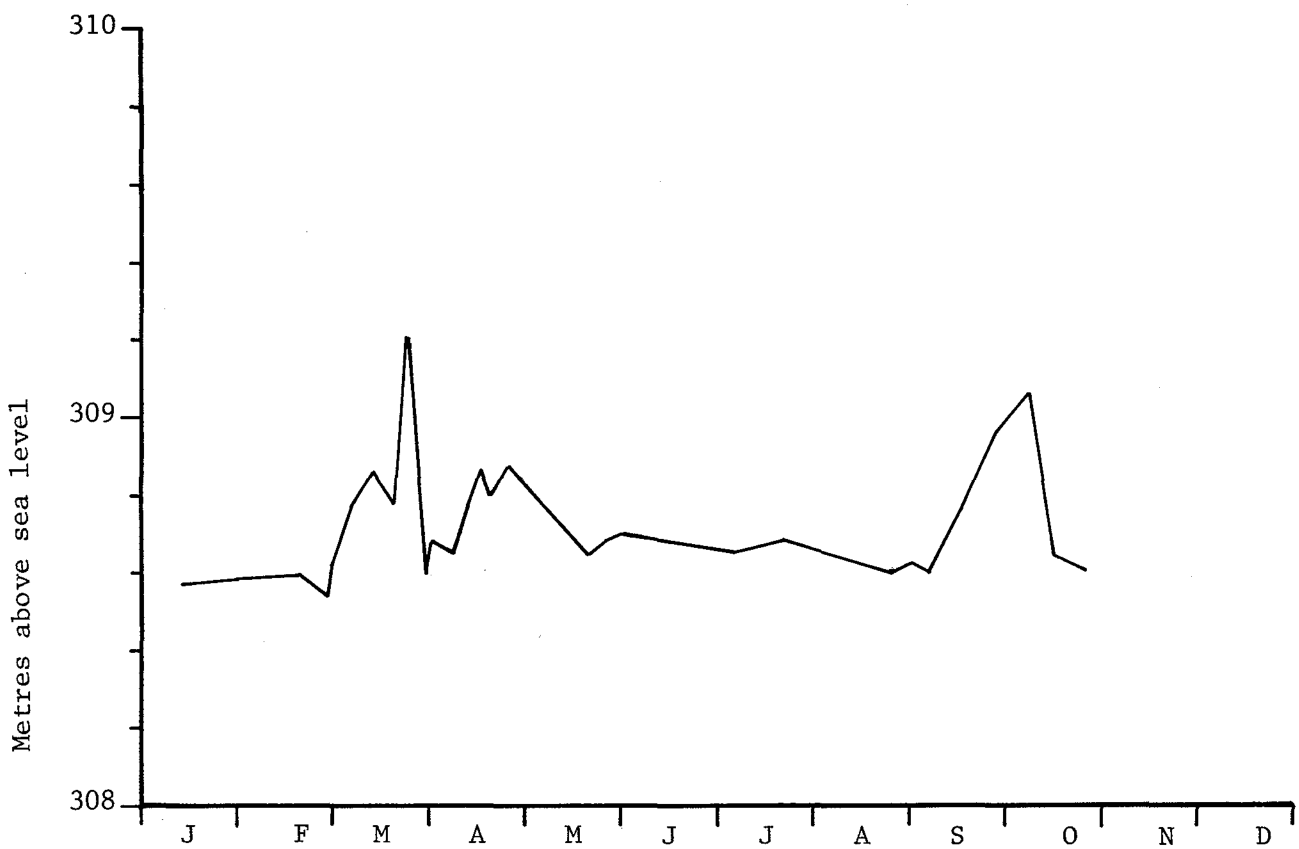


Figure 40. Water levels in Poplar Creek Reservoir, 1977.

would be necessary in winter. It is expected that this fall drawdown will be a regular procedure in future.

Temperature and oxygen measurements from the two sampling stations in the reservoir are placed in Figure 41 and Tables 51 and 52. Temperature profiles for station PCR-1 show a classic stratification pattern. During the open season a thermocline occurred in the 4 to 8 m stratum and was deepest during the late summer. Epilimnetic temperatures increased through spring and summer to a maximum surface temperature of 20^{o}C recorded in late July. Through August and September cooling occurred, and in mid-October the water column was isothermal. Hypolimnetic temperatures at PCR-1 were generally about 6^{o}C. Epilimnetic water temperatures at station PCR-2 were similar to those recorded at PCR-1, and although PCR-2 was only about 6 m deep, the bottom two metres of water showed temperatures noticeably lower than the top 4 m of the water column. This indicated that the thermocline extended throughout the reservoir. By late August, the water column at PCR-2 was isothermal, and turnover was occurring. On March 30, 1977, the ice on the reservoir was 60-65 cm thick. Spring break-up occurred about the end of April, and by November the reservoir was ice covered. Ice was 10 cm thick on November 19, 1977.

Oxygen saturation at station PCR-1 showed a clinograde pattern, with the hypolimnion being essentially anaerobic (Figure 41). The highest saturation observed was 101% at the surface on July 29 when blue-green algae were most abundant. Saturation was normally less than 80% in surface waters and very often only about 50%. It would appear that spring turnover was not complete or was very short-lived; and oxygen did not have time to thoroughly dissolve into the water column since by May 5 temperature stratification was established, and the hypolimnion was already anaerobic. On October 15, the water column was isothermal, and oxygen saturation was 52% throughout. Oxygen saturation at PCR-2 was slightly lower than at PCR-1, only reaching a maximum of 82% on July 29 (Table 51). This was perhaps a result of shallower depths and therefore a greater influence of oxygen demanding substrates in the north half of the basin. Oxygen depletion occurred in bottom waters at PCR-2 from May through July, but saturation was homogeneous from August to October at levels of 35 to 55%. As was observed in Beaver Creek Reservoir, a considerable oxygen demand apparently existed in the bottom regions of Poplar Creek Reservoir. Whenever a slight gradation of temperature was recorded in the epilimnion, implying reduced vertical mixing of water, a parallel gradation

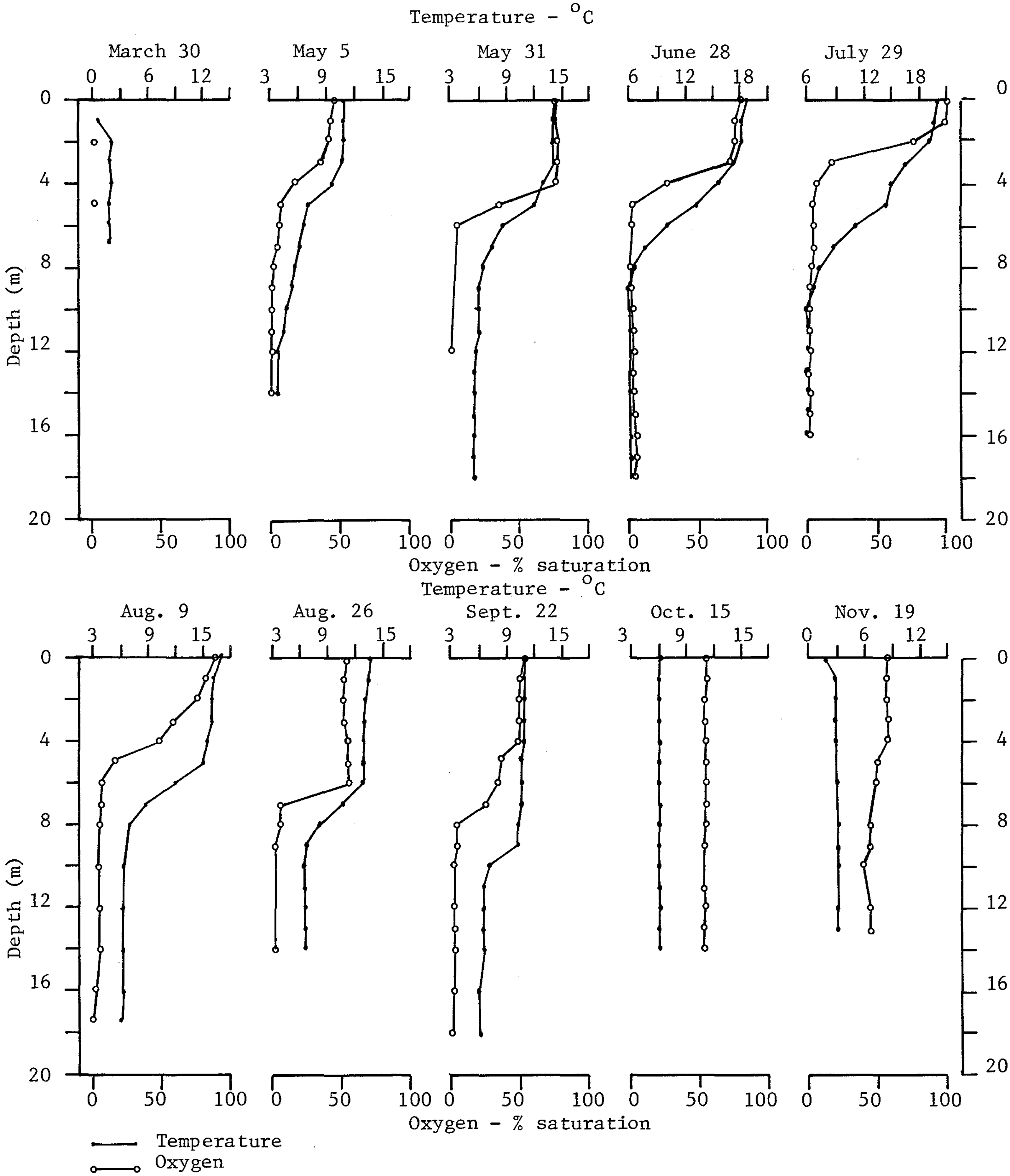


Figure 41. Temperature and oxygen saturation profiles for Station PCR-1, Poplar Creek Reservoir, 1977.

Table 51. Temperature and oxygen saturation at station PCR-2, Poplar Creek Reservoir, 1977.

	Temperature - °C/Oxygen - % saturation								
Depth (m)	March 30*	May 5	May 31	June 28	July 29	Aug. 26	Sept. 22	Oct. 15	Nov. 19
0		12.8/56	15.5/74	20.5/76	20.5/81	12.5/35	12.0/48	5.0/55	1.5/43
1.0	0.4/2	12.5/55	15.5/74	20.0/77	20.0/81	12.0/34	12.0/48	5.0/55	1.5/40
2.0	1.3/<1	12.5/53	15.0/71	19.0/68	20.0/82	11.5/34	12.0/46	5.0/55	1.5/40
3.0	1.0/<1	10.5/28	15.0/71	18.0/59	19.5/64	11.5/33	12.0/46	5.0/54	2.0/8
4.0	1.0	9.9/15	14.0/56	17.0/24	18.0/2	11.5/33	12.0/45	5.0/54	2.0/11
5.0	1.3/0	8.0/3	13.0/28	15.5/1	16.0/1	11.5/34	12.0/44	5.0/54	
6.0	1.4/0	7.3/3	10.0/<1	12.0/<1	12.5/1	11.0/33	12.0/42	5.0/49	
7.0	1.5								

Measurements with dissolved oxygen - temperature meter, unless noted otherwise.

* Measurements with azide - Winkler method.

Table 52. Oxygen concentrations at stations PCR-1 and PCR-2, Poplar Creek Reservoir, 1977.

Depth (m)	Oxygen concentration - mg/l PCR-1/PCR-2 March 30[1]	May 5	May 31	June 28	July 29	Aug. 9[2]	Aug. 26	Sept. 22	Oct. 15	Nov. 19
0		4.7/5.5	7.1/6.9	7.0/6.4	8.6/6.8	7.9	5.0/3.5	5.2/4.8	6.2/6.6	7.2/5.6
1	/0.4	4.2/5.4	7.3/6.9	6.9/6.4	8.4/6.8	7.4	4.9/3.5	5.1/4.8	6.2/6.5	7.0/5.2
2	0.1/0.2	4.1/5.3	7.4/6.7	6.8/5.8	6.6/7.0	6.8	5.0/3.5	5.1/4.6	6.0/6.5	7.0/5.2
3		4.0/2.9	7.4/6.8	6.6/5.2	1.4/5.5	5.4	5.0/3.4	5.1/4.6	6.0/6.4	7.0/1.1
4		1.6/1.6	7.4/5.4	2.5/2.2	0.4/0.3	4.4	5.1/3.4	4.9/4.5	6.0/6.4	7.0/0.2
5	0/0	1.0/0.4	3.4/2.7	0.2/0.2	0.3/0.2	1.2	5.1/3.5	3.8/4.4	6.0/6.4	6.4
6	/0	0.8/0.4	0.1/0.1	0.1/0.1	0.3/0.2	0.3	5.2/3.4	3.6/4.2	6.0/5.8	6.0
7		0.4	0.05	0.1	0.2	0.25	0.3	2.6	6.0	5.4
8		0	0.05	0.1	0.2	0.25	0.1	2.0	6.0	5.3
9		0	0.05	0.1	0.2		<0.1	0.2	6.0	5.3
10		0	0.05	0.1	0.1	0.2	<0.1	<0.1	6.0	4.9
11		0	0.05	0.1	0.1		<0.1		6.0	4.9
12		0	0	<0.1	0.1	0.2	<0.1	<0.1	6.0	5.2
13			0	<0.1	0.1		<0.1		6.0	4.9
14		0	0	<0.1	0.1	0.2	<0.1	0	6.0	
15			0	<0.1	0.1					
16			0	<0.1	0.1	0.15		0		
17			0	<0.1						
18			0	<0.1				0		

Measurements with dissolved oxygen - temperature meter, unless noted otherwise.

[1] Measurements with azide-Winkler method

[2] PCR-1 only

occurred in oxygen saturation. This was observed in June, July and early August at PCR-1 and indicated that when subsurface oxygen replenishment by circulation was hindered, oxygen was quickly consumed in the lower depths. Oxygen consumption probably resulted from the decomposition of both dissolved and particulate organic matter.

The results of the regular chemical analysis of water samples are placed in Table 53. Poplar Creek Reservoir resembled the upstream water bodies in most aspects of water quality, but many of its chemical characteristics showed smaller fluctuations in concentration during 1977 than did upstream water bodies. This was perhaps a result of its distance from upper Beaver Creek. Although a brown-water system like the two other lakes, Poplar Creek Reservoir was not quite as turbid in 1977 (mean Secchi visibility was 1.3 m) and was somewhat lower in pH, alkalinity and filtrable residue. Nutrient concentrations were quite similar to the other two lakes and also showed similar patterns of change during the study.

During the 1977 ice-free season, the pH of the epilimnion of Poplar Creek Reservoir averaged 7.7, with a high of 8.0 during maximum blue-green algal abundances on July 29. In March pH was 6.8-6.9 and averaged 7.2 in the hypolimnion from May through September. After overturn, the hypolimnion pH was similar to surface pH values. Alkalinity of the epilimnion at both stations declined from highs of 180-195 mg/l in March to lows of 135-146 mg/l in May then rose through the rest of the season to high levels in November. Hypolimnetic alkalinities at station PCR-1 were somewhat higher and did not fluctuate quite as much as alkalinity in the epilimnion. Filtrable residue in epilimnetic samples fluctuated in a similar manner to alkalinity, being high in March, lowest after break-up, and then climbing somewhat erratically to its highest levels in October (318-344 mg/l). Samples from the hypolimnion fluctuated less in value, being fairly constant at about 240-270 mg/l. Turbidity was moderate and stable in the epilimnion (1.6-4.5 NTU) but higher in the hypolimnion (2.1-20 NTU). Similarly, suspended sediment in the hypolimnion remained at high levels (7.5-31.0 mg/l) until overturn in October, but epilimnetic suspended solids declined from spring maxima to lower and more stable levels (less than 0.5 to 3.0 mg/l) during the June to November period.

Total organic carbon concentrations were highest in July-September and were generally in the range of 30-40 mg/l. Concentrations in the hypolimnion

Table 53. Chemical characteristics of Poplar Creek Reservoir, 1977.

	March 30	May 5	May 31	June 28	July 29	Aug. 26	Sept. 22	Oct. 15	Nov. 19
				PCR-1 - Top					
pH	6.9	7.4	7.9	7.9	8.0	7.7	7.6	7.6	7.7
pp alkalinity	0	0	0	0	0	0	0	0	0
Total alkalinity	180	146	151	156	156	166	168	175	180
Turbidity (NTU)	4.0	4.0	1.6	1.7	1.9	3.2	2.3	3.4	2.6
Suspended solids	10.6	8.4	2.0	<0.5	<0.5	0.5	0.8	0.8	<0.5
Total organic carbon	30	22	21.0	30	37	42	36	30	30
$NO_3 + NO_2$ - N	0.16	0.09	0.04	0.038	0.038	<0.03	0.023	0.109	0.195
Total Kjeldahl - N	14.2	10.2	0.3	0.2	0.3	0.3	0.346	0.8	0.5
Ortho PO_4 - P	0.210	0.051	<0.016	0.032	<0.016	<0.016	0.016	<0.016	<0.016
Total P	0.291	0.056	0.04	0.072	0.092	0.047	0.051	0.055	0.048
Reactive SiO_2	6.6	7.0	3.3	5.2	6.1	4.7	6.1	1.0	2.6
Filtrable residue	285	208	256	268	244	302	278	318	278
Ignition loss	130	98	74	64	144	74	102	112	90
				PCR-1 - Bottom					
pH		7.1	7.3	7.1	7.1	7.1	7.2	7.5	7.7
pp alkalinity		0	0	0	0	0	0	0	0
Total alkalinity		181	173	169	174	189	180	174	179
Turbidity (NTU)		20	12	8.3	7.0	13.0	11.0	2.1	3.3
Suspended solids		10	7.5	8.0	12.5	31.0	23.6	<0.5	1.2
Total organic carbon		26	26	43	33	51	44	26	29
$NO_3 + NO_2$ - N		0.13	0.045	<0.03	0.04	0.074	0.022	0.115	0.224
Total Kjeldahl - N		10.4	0.5	0.2	0.4	0.3	0.886	1.0	0.4
Ortho PO_4 - P		0.056	0.053	0.095	0.043	0.028	0.120	<0.016	<0.016
Total P		0.158	0.118	0.138	0.106	0.187	0.168	0.056	0.052
Reactive SiO_2		8.6	8.3	6.3	7.3	7.6	8.6	4.9	5.2
Filtrable residue		250	254	238	244	258	270	242	302
Ignition loss		106	60	76	116	72	132	72	54
				PCR-2					
pH	6.8	7.4	7.8	7.7	7.7	7.7	7.6	7.7	7.5
pp alkalinity	0	0	0	0	0	0	0	0	0
Total alkalinity	195	135	154	155	155	167	175	175	187
Turbidity (NTU)	4.5	4.0	22	2.2	3.4	3.4	1.8	3.5	2.9
Suspended solids	4.8	14.8	6.5	<0.5	1.0	3.0	0.5	<0.5	2.0
Total organic carbon	34	36	20.0	38	35	38	36	30	29
$NO_3 + NO_2$ - N	0.235	0.08	0.035	0.038	0.035	<0.03	0.023	0.139	0.219
Total Kjeldahl - N	13.3	7.9	0.2	0.2	0.3	0.4	0.250	0.8	<0.1
Ortho PO_4 - P	0.320	0.04	0.024	0.021	0.024	0.031	0.016	<0.016	<0.016
Total P	0.529	0.05	0.092	0.092	0.092	0.051	0.058	0.054	0.047
Reactive SiO_2	11.2	7.0	4.1	6.3	7.3	4.6	5.6	4.7	5.3
Filtrable residue	330	202	260	270	200	272	320	344	274
Ignition loss	200	92	76	68	116	110	125	172	72

Results in mg/l except pH and turbidity. Alkalinities as $CaCO_3$.

were somewhat more variable but were of the same magnitude. Hypolimnetic samples had a loss on ignition in the range of 54-132 mg/l and were similar in this regard to epilimnetic samples which ranged from 64-200 mg/l. This parameter was highest in March but declined to 60-80 mg/l in early summer, then rose to as much as 172 mg/l in the latter part of the study.

Of the macronutrients, the nitrogen parameters did not show any regular differences between samples from above and below the thermocline, but both phosphorus and silica did. Nitrate-nitrogen (NO_3 + NO_2 - N) declined steadily from March highs of 0.16-0.24 mg/l to lows in September of about 0.02 mg/l. Values subsequently increased, and November samples contained nitrate concentrations as high as those of March. TKN levels were very high in March but by the end of May had declined to 0.3 mg/l and remained at that level until October when a slight increase occurred. Orthophosphates were highest at both sites in March, dropped markedly in concentration by May, and then declined more gradually to less than 0.016 mg/l (ortho PO_4 - P) by September. Values were generally slightly higher at PCR-2. During the summer, orthophosphate-phosphorus was much higher and more variable (0.028-0.168 mg/l) in the hypolimnion, but at overturn in October values were more uniform in the water column. Total phosphorus concentration in the hypolimnion was about 2-3 times higher than in the epilimnion until overturn when values were similar. Reactive silicates showed a gradual decline through the study from about 7-11 mg/l in spring to around 2-5 mg/l in late fall in the epilimnion. In the hypolimnion, silicate was slightly higher in concentration and remained fairly stable until overturn when it declined to about 5 mg/l.

The results of analyses of seasonal samples are placed in Table 54. Most parameters were similar in value to those of Ruth Lake and Beaver Creek Reservoir. Colour ranged from 55-140 units with the exception of hypolimnetic samples from station PCR-1 in May which were exceedingly high. Water collected from the hypolimnion usually had a black tinge when observed in the clear-plastic, Kemmerer water sampler. Epilimnetic water appeared yellowish-brown under the same conditions. Oil and grease concentrations were highest in summer, probably a reflection of the high biotic standing crop present then. They ranged from 5 to 141 mg/l. Phenols were low at all times but reached a peak in spring. Chemical oxygen demand ranged from 49-123 mg/l, was highest in the hypolimnion, and averaged 81 mg/l

Table 54. Results of seasonal water analysis, Poplar Creek Reservoir, 1977.

	PCR-1 - Top			PCR-1 - Bottom			PCR-2		
	May 5	July 29	Oct. 15	May 5	July 29	Oct. 15	May 5	July 29	Oct. 15
True colour (APHA)	140	65	55	500	55	70	120	120	95
Oil and grease	4.8	141	51.2	10.6	44.8	26.4	4.8	43	24.2
Phenols	0.003	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	<0.001
C.O.D.	82	61	71	123	91	77	91	82	49
Hardness[1]	127	110	87	115	132	116	97	114	193
Na	3.45	52.1	31.6	3.59	33.2	43.9	2.68	41.9	46.5
Mg	10.8	9.3	7.1	8.9	10.5	9.9	8.4	9.2	10.2
Ca	33.2	28.7	23.0	31.3	35.6	30.2	25.2	30.7	60.4
K	2.1	1.3	1.7	1.4	2.3	2.7	2.3	1.8	2.5
Cl	6	20	27	9	13	25	7	20	31
SO_4	5	4	5	5	4	4	6	3	4
Fe	2.43	0.79	0.98	1.39	6.36	0.96	0.88	0.71	0.69
Cu	0.014	0.014	0.014	0.009	0.016	0.016	0.007	0.013	0.029
Cr	0.02	<0.01	0.03	0.03	<0.01	0.03	0.02	<0.01	0.02
Pb	0.03	<0.02	0.04	0.03	0.024	0.06	0.02	<0.02	0.05
Zn	0.012	<0.005	0.068	0.009	0.033	0.065	0.064	0.006	0.774
Ni	<0.02	<0.02	0.02	<0.02	<0.02	0.03	<0.02	<0.02	0.03
Co	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al	<0.1	0.1	<0.1	<0.1	0.2	0.5	0.1	0.2	0.2
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B	0.123	0.173	0.117	0.086	0.200	0.156	0.137	0.176	0.374

Results as mg/l unless noted.

[1] Ca & Mg hardness, as $CaCO_3$.

overall. Hardness was usually in the 100-300 mg/l range and had no discernible pattern of fluctuation.

Of the major ions, calcium was fairly stable at about 25-35 mg/l and was the dominant cation in spring. Sodium, however, increased tenfold from about 3 mg/l in spring samples and became co-dominant with calcium in summer and fall samples. Concomittant increases occurred in chloride concentrations from 6-9 mg/l in spring to 13-31 mg/l in summer and fall. Despite the increase in chloride, the prinicpal anion was still bicarbonate. Parallel increases in sodium and chloride were observed in Ruth Lake and Beaver Creek Reservoir, and all may be related to the discharge of saline minewater into Beaver Creek Reservoir.

Of the metals analyzed in the seasonal samples, only iron showed distinctly higher concentrations in the hypolimnion than in the epilimnion (Table 54). It was as high as 6 mg/l in PCR-1 bottom waters. Copper, zinc and boron showed very high values at site PCR-2 in fall, and calcium was also quite high in concentration then.

Substrate samples collected in July (Table 55) reflected the more inorganic nature of the sediment in the south half of the reservoir where construction activity removed much of the ground cover. At PCR-1, organic compounds formed only 22% of the dry weight of substrate samples collected, while samples from PCR-2 contained 68% organics. Most substrate metals were higher in concentration in PCR-1 samples. Only copper and nickel were higher at PCR-2.

Stratification of electrical conductance was investigated in the reservoir on samples from the top, middle and bottom of the water column at each station (Table 56). Although this was for the purpose of investigating the possible pooling of heavier saline minewater discharged into the diversion system, it was not likely that such minewater would enter this reservoir without being thoroughly mixed into the water mass and diluted when passing through the diversion canals and Ruth Lake. Therefore, the small amount of stratification of conductivity observed (e.g. - early May and November at PCR-1) was probably not related to minewater discharges but rather was more a reflection of the differing chemical regime in the hypolimnion and epilimnion at station PCR-1.

Phytoplankton

The phytoplankton cell counts for the two sampling stations in Poplar Creek Reservoir are placed in Appendix 11. Differences in algal abundance

Table 55. Results of substrate analysis, Poplar Creek Reservoir, July 29, 1977.

	PCR-1	PCR-2
% organic	22	68
% inorganic	78	32
Fe	38621	22141
Cu	24.7	58.3
Cr	54.9	31.5
Pb	123.1	80.8
Zn	115.2	109
Ni	40.2	130
Co	25.1	13.4
Al	54952	14798
Cd	24.7	13.7

Results are by weight of air dried samples. Metals as ppm.

Table 56 . Specific conductance at the top, middle, and bottom of the water column in Poplar Creek Reservoir, 1977.

	SPECIFIC CONDUCTANCE - µmhos/cm @ 25°C							
	May 5	June 1	June 28	July 29	Aug. 26	Sept. 23	Oct. 15	Nov. 19
				PCR-1				
Top	280	235	320	350	335	365	385	335
Middle	315	245	320	350	330	375	425	465
Bottom	360	265	340	390	340	355	435	475
				PCR-2				
Top	270	245	320	360	360	390	445	520
Middle	260	275	320	360	350	380	430	505
Bottom	300	250	330	380	355	395	445	530

were apparent at times between the two stations, but one site was not consistently richer in phytoplankton than the other, and the information will be considered as a whole. Figure 42 portrays the abundance and composition of the phytoplankton at both stations in the epilimnion during the 1977 study.

The standing crop of algae generally was not very high in the epilimnion of Poplar Creek Reservoir in 1977. Total numbers rose from lows in spring of less than 2500 cells/ml to about 4000-8000 cells/ml in June and then climbed to their highest levels in July-August during a bloom of blue-green algae (more than 30,000 cells/ml). Cell densities then declined by late September and were similar to early spring levels (less than 2500 cells/ml) by November.

The phytoplankton in the reservoir was composed of a shifting assemblage of primarily four of the five major algal groups. Ultraplankton and blue-green algae (Cyanophyta) dominated in samples collected in March, but in May-June, flagellates, ultraplankton and green algae (Chlorophyta) predominated. Cyanophytes reappeared in June and were the most abundant type during the June to August period. They had declined in importance by the end of September and were very low in numbers by October. Ultraplankton and flagellates had reestablished their importance in September, and with the green algae, all three were numerically codominant until the end of the study. The abundance of non-blue-green algae was relatively stable through the study (Table 57). Their numbers were low in spring (about 600-1400 cells/ml) but fluctuated at higher levels (about 2000-6000 cells/ml) from May through September and declined to lower levels again (1000-2000 cells/ml) at the end of the study. The abundance of these algae did not appear to decline during the bloom of blue-green algae in July-August.

The blue-green algae (Cyanophyta), although represented in small numbers in March by *Dactylococcopsis* and filamentous types, were mainly comprised of *Aphanizomenon flos-aquae* and *Anabaena flos-aquae* and formed large populations in the June to August period. Although during the summer bloom they reached an average of 28,000 cells/ml in the epilimnion, the tendency for these species to float resulted in higher numbers near the water surface. For example, on June 28 at site PCR-1, 2226 cells/ml of blue-green algae were counted in the epilimnion but 9510 cells/ml were counted in a sample from the water

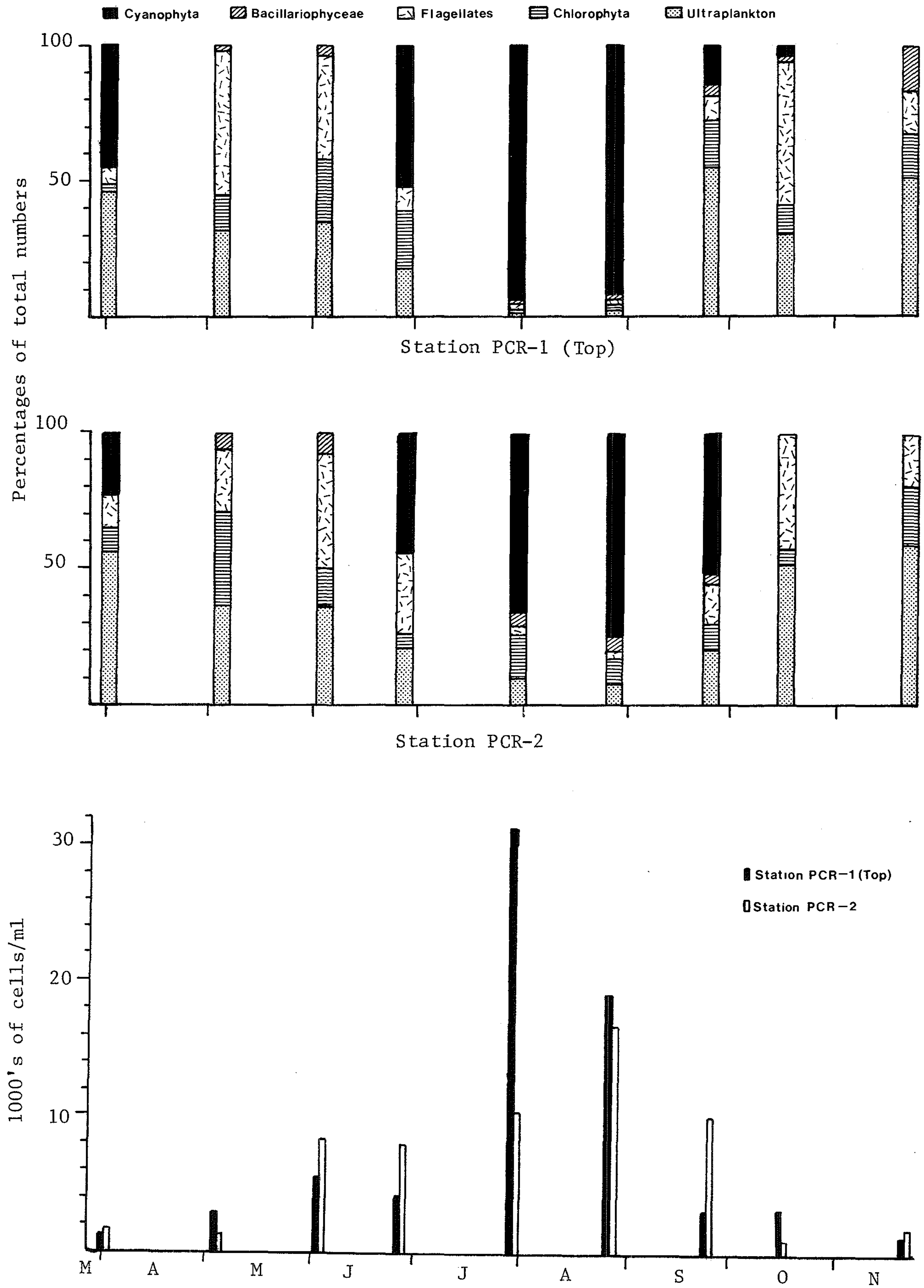


Figure 42. Abundance and composition of phytoplankton in Poplar Creek Reservoir, 1977.

Table 57. Abundance and composition of non blue-green phytoplankton in Poplar Creek Reservoir, 1977.

	March 30	May 5	May 31	June 28	July 29	Aug. 26	Sept. 22	Oct. 15	Nov. 19
					cells/ml				
					STATION PCR-1 - Top				
Bacillariophyceae	0	77	211	13	120	299	172	0	246
Flagellates	75	1648	2189	370	216	36	268	1845	229
Chlorophyta	30	422	1315	883	1318	334	595	325	229
Ultraplankton	587	1016	1979	778	599	615	1840	1075	738
Total	692	3163	5694	2044	2253	1284	2875	3245	1442
					STATION PCR-2				
Bacillariophyceae	0	90	570	113	553	1096	405	0	0
Flagellates	220	331	3627	2278	185	316	1459	517	375
Chlorophyta	169	497	1118	433	1740	1644	985	38	445
Ultraplankton	1040	542	3163	1751	1186	1328	2144	613	1171
Total	1429	1460	8478	4575	3664	4384	4993	1168	1991

surface. Blue-green algae had declined by September and were almost absent by October.

Flagellated algae and ultraplankton co-dominated the phytoplankton in May-June and fall when blue-green algae were not abundant. Flagellates were apparently most abundant in Poplar Creek Reservoir in early summer and fall, when their numbers were about 1500 to 3500 cells/ml. This group was most commonly represented by the genera *Cryptomonas, Dinobryon* and *Rhodomonas*.

Chlorophyta (green algae) were generally highest in summer (at about 300 to 1700 cells/ml). At other times their abundance was about 40-300 cells/ml. *Ankistrodesmus* and *Scenedesmus* were the most prevalent green algae. The ultraplankton were slightly different in abundance between the two sampling sites so that overall patterns in their numbers are not evident. Their densities tended to fluctuate in the range of 600-2000 cells/ml. As in both Ruth Lake and Beaver Creek Reservoir, euglenoid algae were commonly found in the phytoplankton, perhaps reflecting the fairly high organic content of the reservoir water.

Diatoms (Bacillariophyceae) were never an important group in the reservoir phytoplankton, reaching only about 1000 cells/ml at their highest levels. These levels occurred in summer, and diatoms were less abundant at other times. *Melosira, Synedra* and *Cyclotella* were the most common diatoms in the reservoir phytoplankton.

Macronutrient concentrations (N, P, Si) in Poplar Creek Reservoir were quite similar in level and seasonal pattern to those of Ruth Lake and Beaver Creek Reservoir, yet the concentration of phytoplankton in this impoundment was lower than in the other two water bodies. As in Beaver Creek Reservoir, turbidity of the upper mixing layer (the epilimnion) may have been suppressing non-blue-green algal growth. The trophogenic zone was probably shallow in the turbid reservoir water and the non-blue-green algae, which cannot resist vertical circulation, may have spent a considerable time below this zone in the course of normal vertical circulation. The blue-greens, with their ability to float, could concentrate near the surface and thereby receive adequate light to allow them to exploit the high nutrient concentrations in the reservoir.

Hypolimnetic samples from station PCR-1 generally contained lower amounts of algae than samples from the epilimnion (Table 58). With the exception of

Table 58. Abundance and composition of phytoplankton in the epilimnion and hypolimnion at site PCR-1, Poplar Creek Reservoir, 1977.

	May 5	May 31	June 28	July 29	Aug. 26	Sept. 22	Oct. 15	Nov. 19
% of total numbers:				PCR-1 - Top				
Cyanophyta	0	0	52	93	93	14	5	0
Bacillariophyceae	2	4	1	1	2	5	1	17
Flagellates	53	38	9	1	1	8	54	16
Chlorophyta	13	23	21	4	2	18	10	16
Ultraplankton	32	35	18	2	3	55	31	51
Total cells/ml	3163	5693	4270	31461	19223	3355	3426	1441
% of total numbers:				PCR-1 - Bottom				
Cyanophyta	0	0	14	44	48	0	0	0
Bacillariophyceae	1	1	0	3	16	0	0	0
Flagellates	11	1	2	12	2	4	46	3
Chlorophyta	6	2	9	14	7	60	13	23
Ultraplankton	82	96	75	27	27	36	41	73
Total cells/ml	1095	11175	795	1835	2636	1913	972	1652

two occasions, epilimnion samples contained from 2 to 15 times more algal cells than did the hypolimnetic samples. Blue-green algae were much less prevalent in the total count of hypolimnetic algae, but ultraplankton formed a higher proportion in hypolimnetic than in epilimnetic phytoplankton. The other groups were about the same percentage of total numbers in both the epilimnion and hypolimnion (Table 58).

Aquatic macrophytes

In August 1977, approximately one year after reaching full water level, Poplar Creek Reservoir contained a moderately abundant and widespread submergent plant population and an emergent community that was locally abundant. Fourteen taxa of aquatic plants were identified from the reservoir and are listed in Table 59. The reservoir is relatively deep with shorelines of moderate slope so that aquatic plants were generally confined to narrow bands along the lake margin. An exception to this was the north end of the reservoir where a dense and extensive growth of the emergent *Menyanthes trifoliata* (buckbean) occupied a more gently sloping substrate. The reservoir contains a diversity of substrates including muskeg, exposed forest floor, clay, sand, gravel and boulder. Except for the boulder-covered dam face, all of these substrates have been colonized by aquatic plants to at least some extent.

The emergent plant community along the east and west shores of the lake was poorly developed, being restricted to scattered occurrences of *Carex* (which also occurs with *Equisetum* on muskeg rafts) and a few isolated clumps of *Typha latifolia* in the southwest corner. In the north end, however, *Menyanthes trifoliata* formed an almost monospecific stand that extended north approximately 300 m from the open water. Plants at the edge of this stand were growing in 1 m of water, a depth not normally reported as preferred habitat for this species (Moss, 1959; Budd and Best, 1969). On boggy ground north of Ruth Lake, this species reached heights of only 20-30 cm. It may have existed in this location in the Poplar Creek Reservoir basin prior to flooding and has simply been eliminated from areas now covered by more than 1 m of water. Plants in water shallower than this may have been able to survive the rise in water levels by elongating. The northern edge of this stand of buckbean was not examined closely but appeared to grade into other emergent species. Floating mats of muskeg were present in the reservoir but were not as abundant as in Beaver Creek Reservoir. They occurred in waters of variable depths and often did not have any submergents associated with them.

Table 59. Aquatic macrophytes observed in Poplar Creek Reservoir, 1977.

Submergents:

Callitriche palustris L. - rare, a few individuals in SW section
Ceratophyllum demersum L. - one specimen collected
Myriophyllum exalbescens Fernald - abundant and widespread
Potamogeton berchtoldii Fieb. - abundant and widespread
P. alpinus Balb. - occasional and widespread
Ranunculus gmelinii DC - occasional in NW section
Utricularia vulgaris L. - abundant and widespread

Floating-leafed:

Lemna minor L. - occasional
Polygonum natans A. Eaton - rare, in NW section
Sparganium - common and widespread

Emergents:

Carex - common and widespread
Equisetum - occasional on muskeg rafts
Menyanthes trifoliata L. - very abundant in N end
Typha latifolia L. - occasional in SW section

Submergent plants occupied all substrates in the reservoir except the dam face and were found growing to depths of about 2 m. Three submergent species, *Potamogeton berchtoldii*, *Utricularia vulgaris* and *Myriophyllum exalbescens*, were quite abundant in the reservoir and dominated the submerged aquatic plant assemblages. They existed in varying proportions and densities along all of the east and west shores, but only *U. vulgaris* was found along the northern end of the lake. It was difficult to rank these three species in their abundance since *U. vulgaris* commonly grew prostrate on the bottom and had to be sampled with a rake. *P. berchtoldii* and *M. exalbescens* grew to, or near, the water surface and their abundance was more easily assessed. Of the other species of submerged and floating-leafed macrophytes, *P. alpinus* occurred occasionally in many locations, and *Sparganium* sp. was quite common along the east and west shores. Most other submergent and floating-leafed aquatic plants occurred only incidentally in the reservoir (Table 59).

Five categories of macrophyte communities were described, based on the dominant species occurring in them and their overall abundance of plants. Plant abundance, as coverage of the substrate, was estimated visually. These categories are not necessarily indicative of ecological relationships within the plant communities but represent macrophyte assemblages that could be distinguished in the field and which will therefore allow comparisons with future conditions. Quite often, changes in the categories may simply reflect changes in the combination of the three main submergents, *P. berchtoldii*, *U. vulgaris* and *M. exalbescens*. The categories and their corresponding zones which are plotted in Figure 43 are as follows:

I Low coverage of few species

U. vulgaris was the most common macrophyte in this type but aquatic plants were very low in density. Some *P. berchtoldii*, *M. exalbescens* and *Sparganium* also occurred in this type which occupied the steeply sloping sand, gravel and boulder substrates along the causeway.

II Moderate coverage, *P. berchtoldii* dominated

U. vulgaris was next most abundant in this type; *M. exalbescens* and *Sparganium* were common as well. *P. alpinus* was occasionally found in this grouping, but other species were rare. Coverage of the substrate ranged up to 50% locally but probably averaged 10% or less. This type occupied the south half of the reservoir on east and west shores (Figure 43).

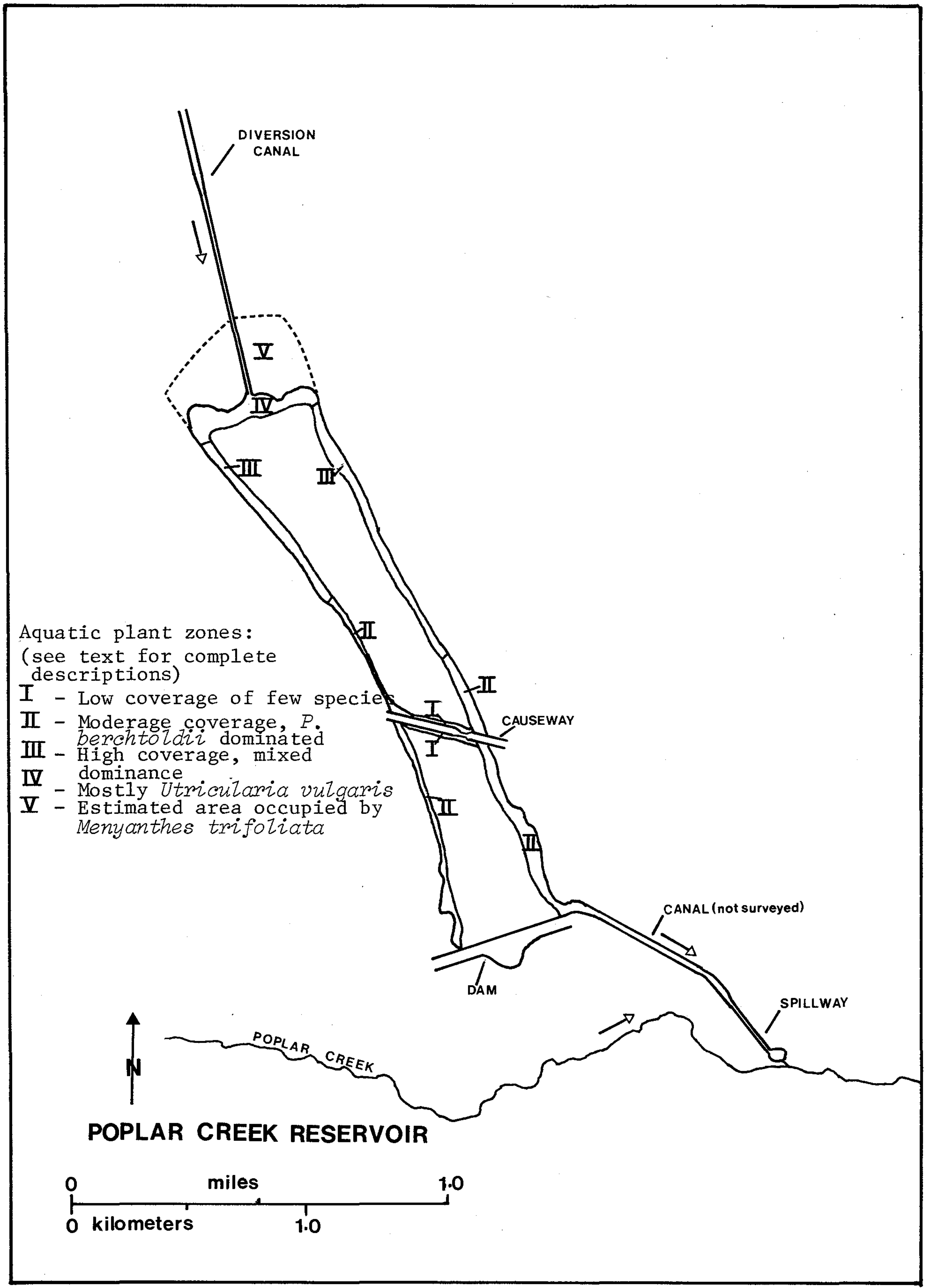


Figure 43. Occurrence of aquatic macrophytes in Poplar Creek Reservoir, 1977.

III High coverage, mixed dominance

Substrate coverage here was as high as 75% but averaged around 30%. This type occurred on east and west sides of the north half of the reservoir and was dominated by *M. exalbescens* and *U. vulgaris*. *P. berchtoldii* was also abundant in this category which contained occasional plants of *P. alpinus* and *Sparganium* sp.

IV *Utricularia vulgaris*

This was the only species encountered along the deep edge of the *Menyanthes* emergent zone. It was moderately abundant there, covering up to 50% of the substrate.

V *Menyanthes trifoliata*

This emergent zone consisted of little else but this species, although *Carex* and other emergents appeared in it around its borders. This species covered up to 100% of the water surface over some of this area.

As in Beaver Creek Reservoir, a fairly abundant population of a limited number of aquatic macrophytes occurred in the reservoir in its early stage of existence. Other species of aquatic plants may subsequently colonize the reservoir although, because it is relatively deep, it may never develop the populations that could develop in the shallower Beaver Creek Reservoir. Fall drawdown was occurring in Poplar Creek Reservoir in 1977, and this may hinder the development of emergent communities and have some effect on the submergent plants as well.

Zooplankton

The composition and counts of the zooplankton collected at the two regular stations in Poplar Creek are shown in Appendices 12 and 13. The species collected at the two regular sampling stations and at the shallow water sampling sites are listed in Table 60. At the two regular sampling stations the number of common[1] species in the major zooplankton groups were as follows: Rotifera - 11, Cladocera - 8, Cyclopoida - 4, Calanoida - 2.

Rotifera

The abundance and composition of the rotifers collected are shown in Figure 44. The populations appeared to be greatest around August. *Filinia longiseta* was dominant in late March (when dissolved oxygen concentrations were

[1]See footnote 1, page

Table 60. Poplar Creek Reservoir zooplankton.

	Open water	Shallow water
AMPHIPODA		
Hyalella azteca (Saussure)		X(L)
OSTRACODA		X(L)
CONCHOSTRACA		
Lynceus brachyurus Muller	X	
CLADOCERA		
Acroperus harpae Baird		X(L)
Alona quadrangularis (Muller)		X(L)
A. rectangula Sars		X(L)
Bosmina longirostris (Muller)	X	X
Ceriodaphnia affinis Lilljeborg	X	
C. lacustris Birge	X	
Chydorus sphaericus (Muller)	X	X(L)
Daphnia galeata Sars *mendotae* Birge	X	X
D. parvula Fordyce	X	
D. pulicaria Forbes	X	X
D. rosea Sars	X	
Diaphanosoma leuchtenbergianum Fischer	X	
Macrothrix laticornis (Jurine)		X(L)
Pleuroxus striatus Schoedler		X(L)
P. trigonellus (Muller)		X(L)
Polyphemus pediculus (Linne)		X(L)
Sida crystallina (Muller)		X(L)
Simocephalus serrulatus Koch		X(L)
S. vetulus Schoedler		X(L)
COPEPODA		
CALANOIDA		
Diaptomus leptopus Forbes	X	
Diaptomus oregonensis Lilljeborg	X	X
CYCLOPOIDA		
Cyclops vernalis Fischer	X	X
Cyclops bicuspidatus thomasi Forbes	X	
Cyclops navus Herrick	X	
Eucyclops agilis (Koch)		X(L)
E. speratus (Lilljeborg)		X(L)
Macrocyclops albidus (Jurine)		X(L)
Mesocyclops edax (Forbes)	X	X
M. leuckarti (Claus)		X
Microcyclops varicans rubellus Lilljeborg		X(L)
HARPACTICOIDA		X(L)
ROTIFERA		
Asplanchna		
Brachionus calyciflorus (Pallas)		
Conochilus unicornis (Rousselet)		
Filinia longiseta (Ehrenberg)		
Hexarthra		
Keratella cochlearis (Gosse)		
K. quadrata (Muller)		
Polyarthra		
Synchaeta		
Platyias		
Testudinella		

L - species collected in shallow water and that can be considered littoral in habit.

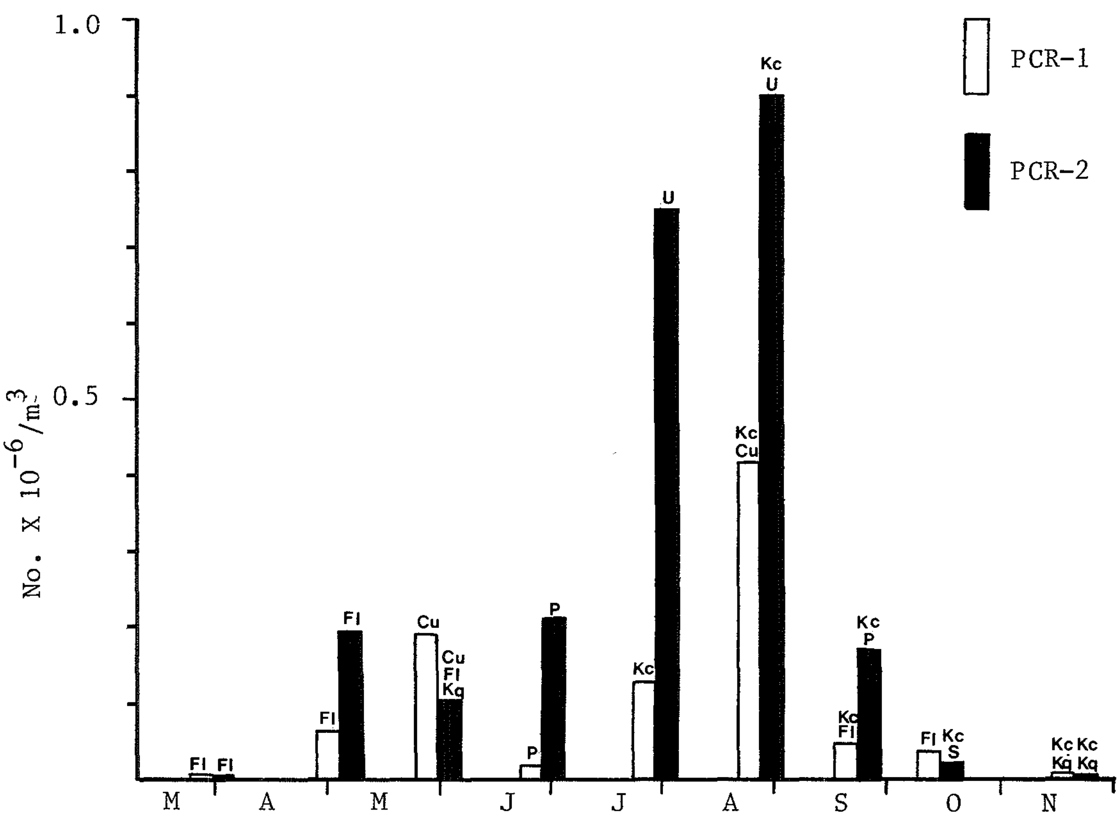


Figure 44. Abundance of Rotifera in Poplar Creek Reservoir in 1977. Letters at the top of each bar indicate dominant type. Cu = *Conochilus unicornis*, Fl = *Filinia longiseta*, Kc = *Keratella cochlearis*, Kq = *K. quadrata*, P = *Polyarthra*, S = *Synchaeta*, U = unidentified.

less than 0.35 ppm) and in early spring. *Conochilus unicornis* dominated in late May and was succeeded by *Polyarthra* in late June. After June *Keratella cochlearis* was generally the most abundant rotifer.

Cyclopoida

Figure 45 depicts seasonal abundance of Cyclopoida. Numbers were low in the early spring but a pulse occurred in late May - early June. After this period there was a rapid decline followed by a more gradual decrease. At PCR-1 there was a pulse in the fall, but it was not as great as in the spring. The spring peak involved *Cyclops vernalis* and *Cyclops bicuspidatus thomasi*. *C. navus* adults were also observed, but they occurred in low numbers, and it is probable that the majority of undetermined *C. vernalis* - *C. navus* late stage copepodites belonged to *C. vernalis*. Although both *C. vernalis* and *C. bicuspidatus thomasi* were abundant in the spring, their pattern of development appeared to be different. *C. vernalis* late - stage copepodites seemed to mature directly into adults since the copepodite pulse coincided with a pulse of adults. In the case of *C. bicuspidatus thomasi*, few adults were associated with the copepodite pulse, and it is likely that the copepodites entered a diapause. The occurrence of a summer diapause in the copepodite IV stage has been well documented for this species (Birge and Juday, 1908; Cole, 1953, 1955). The same situation was observed for this species in Ruth Lake in 1975 (Noton and Chymko, 1977).

There was a pulse of late stage copepodites and adults of *C. bicuspidatus thomasi* at PCR-1 in the fall. No peak of nauplii or early stage copepodites occurred immediately prior to this, and it appeared that copepodites emerged from diapause and continued their development. The reason for this occurrence is not known. Some of these individuals probably survive through winter since low numbers of late stage copepodites and adults were observed in late March of 1977.

Mesocyclops edax was the only other cyclopoid copepodite collected in the plankton but its numbers were low (Appendix 12 and 13).

Calanoida

Diaptomus leptopus and *Diaptomus oregonensis* both occurred in Poplar Creek Reservoir. The former species was recorded only in low numbers in the late May - July period. *D. oregonensis* was much more abundant, and life history data is presented in Figure 46. Immature stages were abundant in the July - August period, and adults were present throughout the fall. The adults apparently

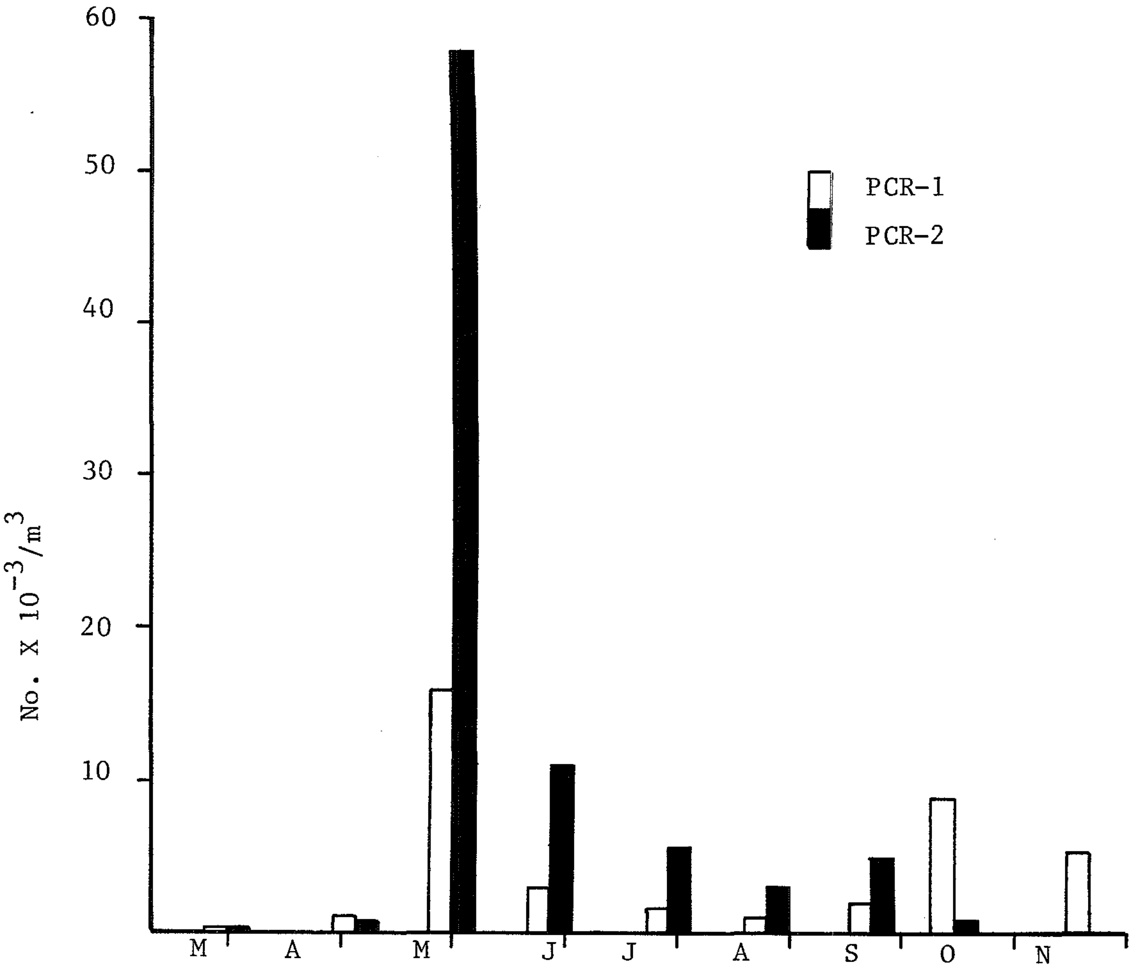


Figure 45. Abundance of Cyclopoida in Poplar Creek Reservoir in 1977. Values are the sum of copepodite and adult stages.

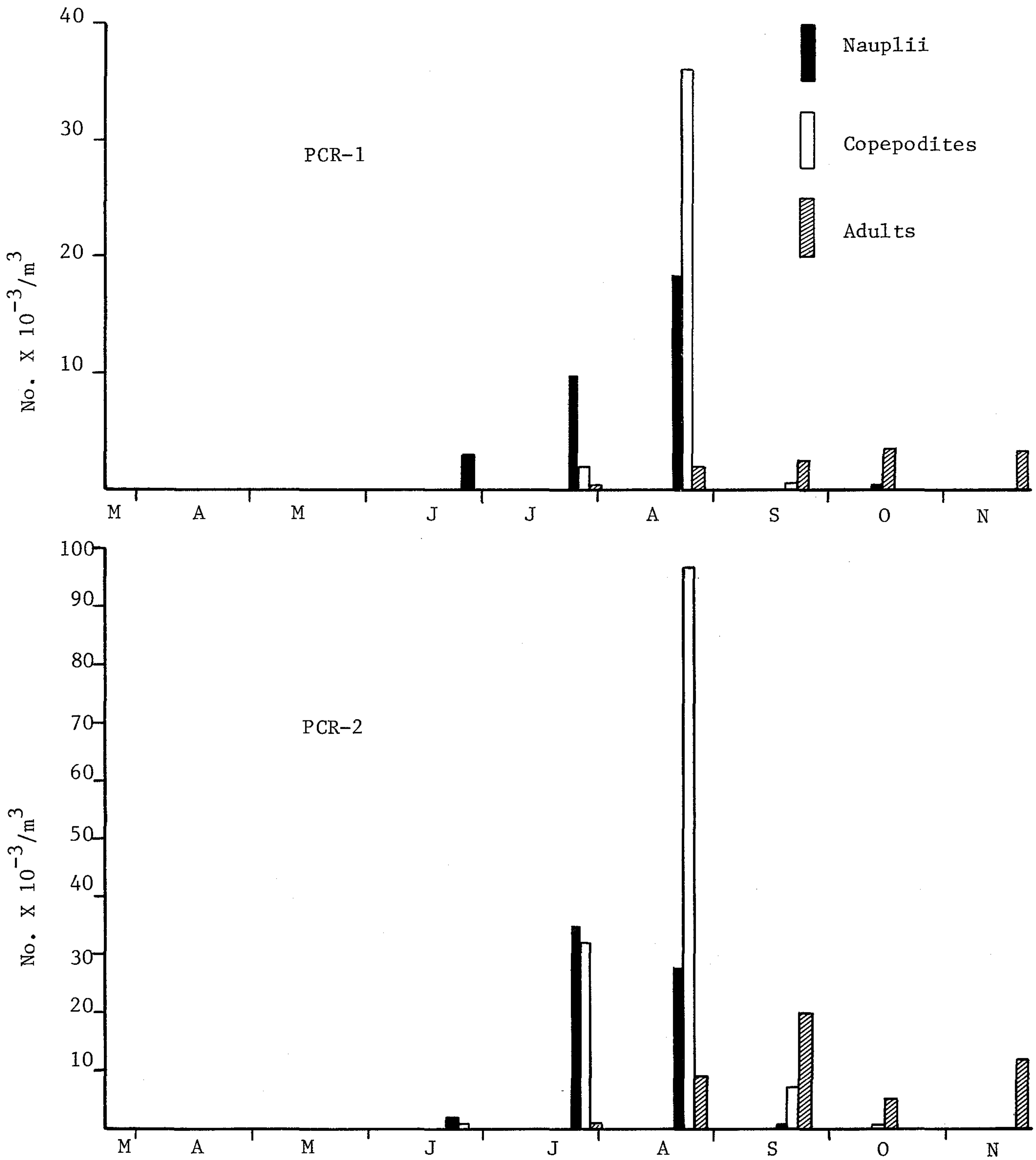


Figure 46. Abundance of *Diaptomus oregonensis* in Poplar Creek Reservoir in 1977.

do not survive through the winter since none were observed in late March of 1977. In the fall of 1977, the adults were producing resting eggs that would have given rise to nauplii in the summer of 1978.

Cladocera

Figure 47 presents the numbers of the common cladoceran species. The *Daphnia* species were the first cladocerans present in large numbers with *D. pulicaria* occurring around June and *D. galeata mendotae* in the June-July period. *Bosmina longirostris, Ceriodaphnia lacustris* and *Diaphanosoma leuchtenbergianum* were most numerous around August. In the fall there was a small pulse by a third *Daphnia* species, *D. parvula*, which appeared to be more abundant at PCR-1. *D. parvula* is very uncommon in Alberta (Brooks, 1957; Anderson, 1974), and the reason for its occurrence in Poplar Creek Reservoir was not clear.

Conchostraca

Low numbers of *Lynceus brachyurus* nauplii were observed in early May (Appendices 12 and 13) at the regular sampling stations, and low numbers of juveniles and adults occurred in spring and summer. The juvenile and adult stages of this species, however, are not truly planktonic, and the sampling program at the regular stations would not have completely assessed their biological status in the reservoir.

Seasonal Trends

Figure 48 depicts seasonal community composition of the crustacean zooplankton, and this, in conjunction with individual species, counts (Figures 45 to 47; Appendices 12 and 13), indicates the trends in zooplankton composition over the study period. On the first three sampling dates, cyclopoid copepods were very dominant. On the first two dates numbers were low but on May 31 they had increased markedly. *Cyclops vernalis* and *Cyclops bicuspidatus thomasi* were the dominant cyclopoids. By late June cyclopoid numbers had greatly decreased. At this time they were still numerically the most important group, but cladocerans were also abundant. *Daphnia galeata mendotae, D. pulicaria, Bosmina longirostris* and *Diaphanosoma leuchtenbergianum* were important cladocerans during the summer. Populations of the first two species were at a maximum in late June. *B. longirostris* was very important from late July to late September and was most abundant in late August. *D. leuchtenbergianum,* which was less abundant than *B. longirostris*, had its maximum abundance in late July at PCR-1 and late August at PCR-2. At PCR-2, after late June, *Diaptomus*

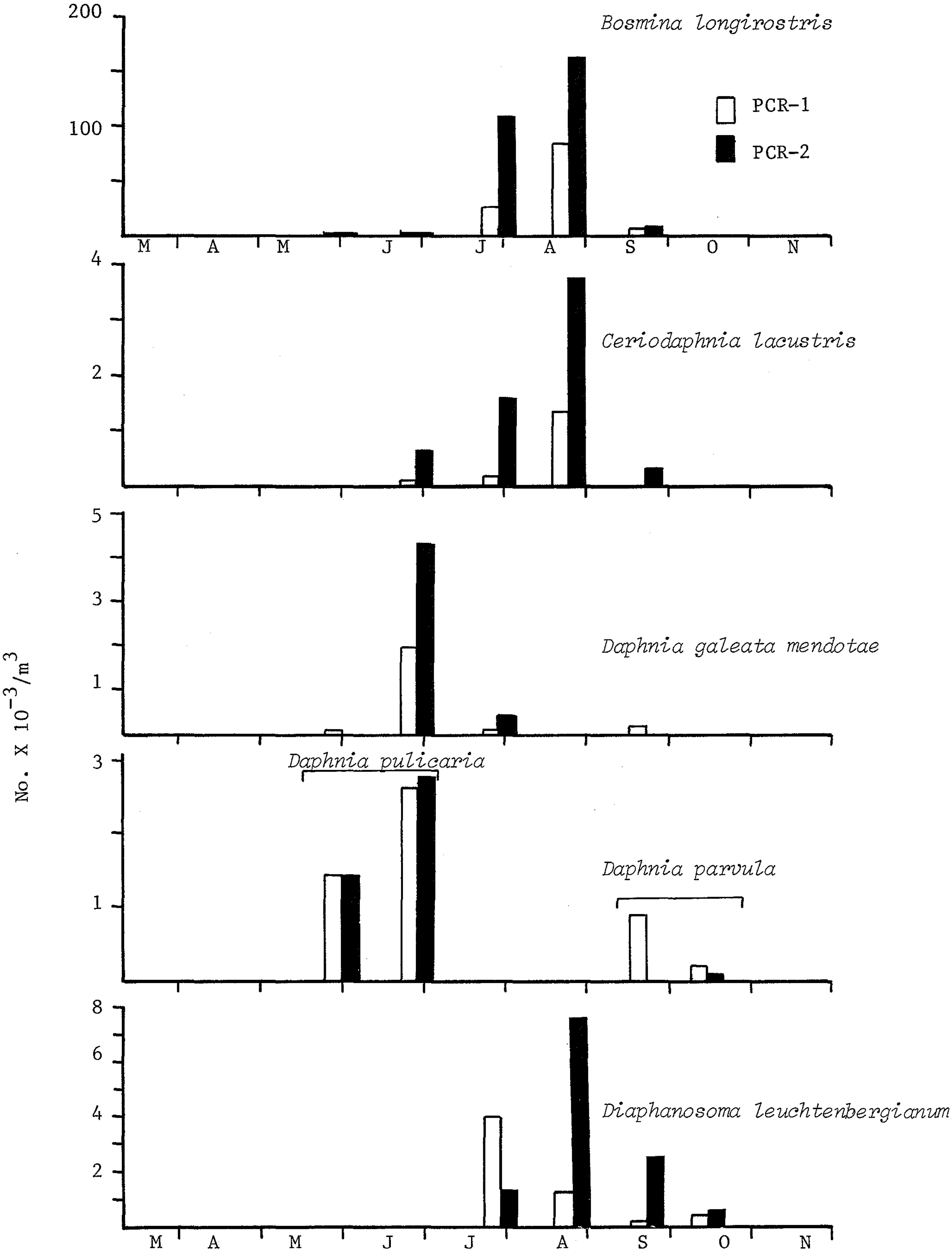


Figure 47. Abundance of the major species of Cladocera in Poplar Creek Reservoir in 1977.

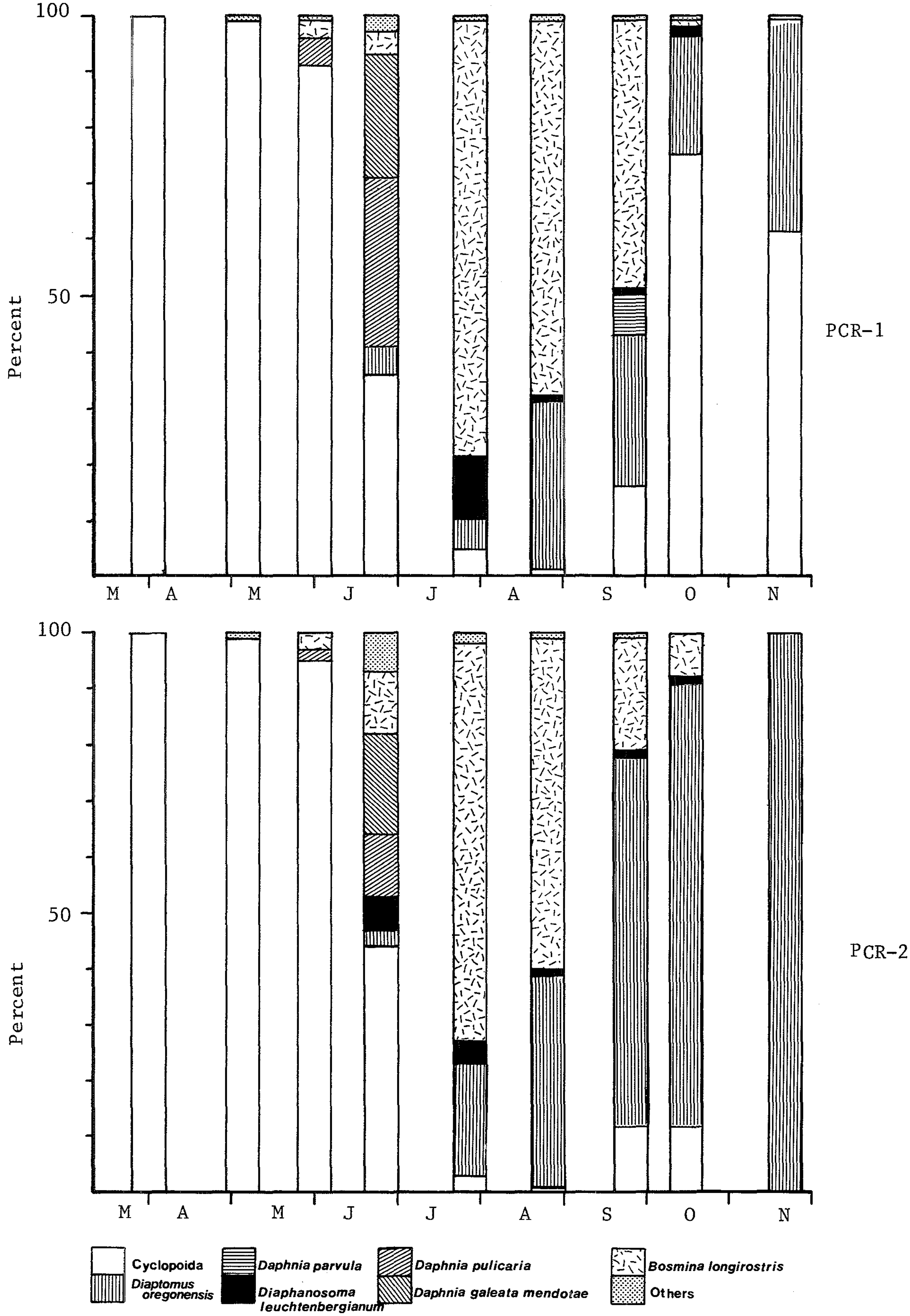


Figure 48. Numerical composition of the crustacean zooplankton in Poplar Creek Reservoir in 1977.

oregonensis began to increase its numerical importance and completely dominated the community during the fall. At PCR-1, its numerical importance also increased after late June but remained about the same after late August. *D. oregonensis* did not dominate at this station during the fall due to a pulse of *Cyclops bicuspidatus thomasi*. *Daphnia parvula*, although not a numerically important species, had a peak in abundance in the fall.

Total Numbers and Biomass

The trends in total numbers and biomass were similar to one another (Figure 49). Both parameters were low in late winter and early spring but had increased by late May when cyclopoids became abundant. Maxima in both parameters were observed on the late August sampling date at which time *Bosmina longirostris* was most abundant and *Diaptomus oregonensis* contributed most to biomass. Numbers and biomass declined in the fall.

Total abundance and biomass per unit volume of water were usually higher at PCR-2 than PCR-1. This may, however, be a misleading comparison. During much of the season an anaerobic hypolimnion existed in the reservoir below about 6 m, and the August 7, vertical stratification study at PCR-1 indicated that crustacean zooplankton were largely confined to the upper 6 m of water. Since most of the zooplankton probably occurred above 6 m at both sites (i.e. in the epilimnion), it would be more meaningful to compare total abundance and biomass per unit of water surface. These figures are included in Appendices 12 and 13. On a m^2 basis, the two parameters were fairly similar between the stations through much of the season. Since total abundance and biomass were similar between stations (in the epilimnion), and zooplankton composition was also similar at the two sites, it is probable that zooplankton dynamics in the epilimnion were fairly homogeneous throughout the reservoir.

Littoral Crustaceans[1]

Counts of crustaceans collected in the shallow water sampling are presented in Table 61 and sampling locations are given in Figure 38. Net tow lengths were estimated visually, and some debris blockage of the net occurred so that numbers collected are approximate. Since the purpose of the sampling was to document the presence and estimate the abundance of littoral species, the limnetic species collected will not be discussed.

[1]See footnote 1 , Page 66.

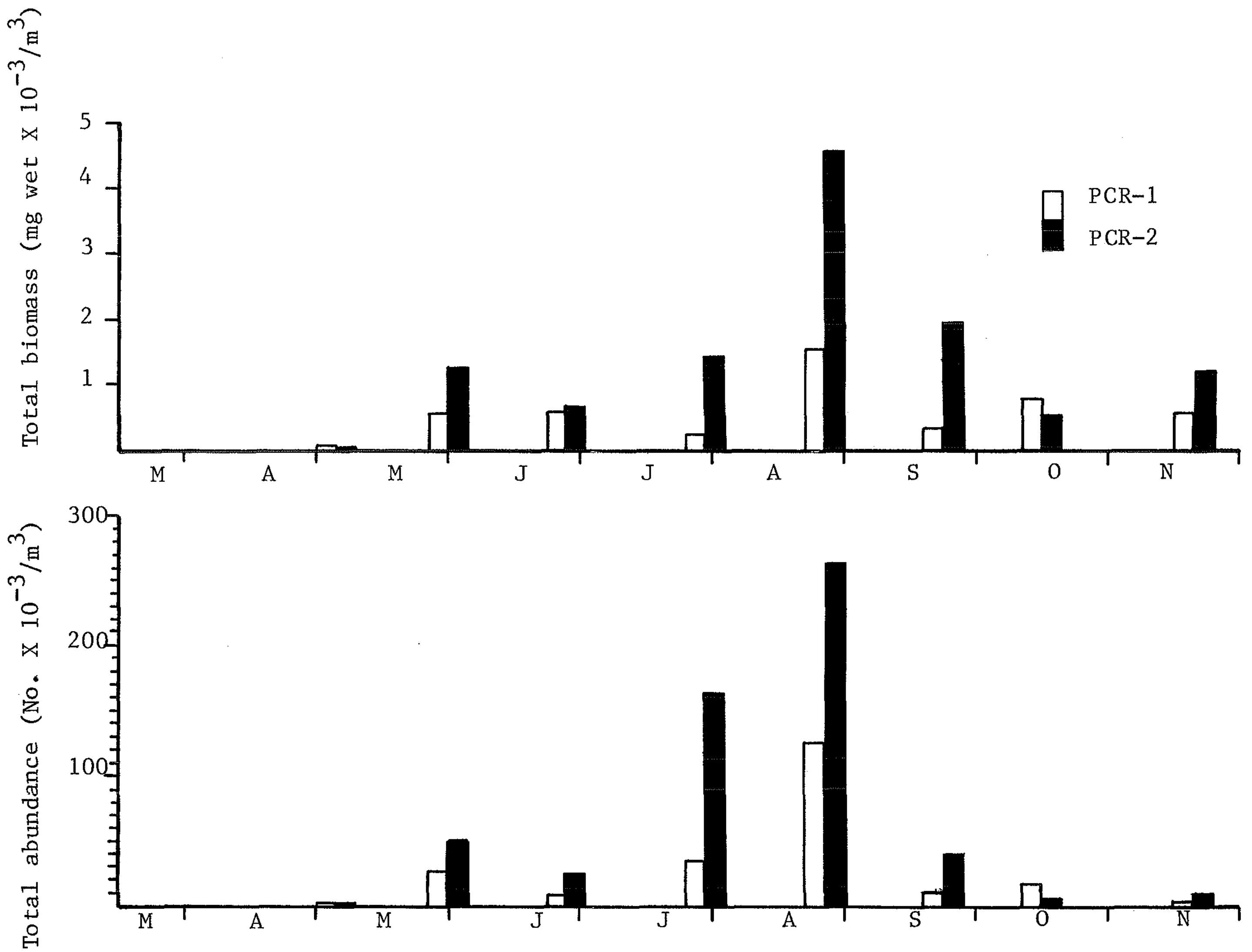


Figure 49. Total abundance and biomass of crustacean zooplankton in Poplar Creek Reservoir, 1977.

Table 61. Summary of crustaceans collected in shallow water sampling in Poplar Creek Reservoir in 1977. Values expressed as number/m^3.

	LZ-1 May 5	LZ-1 July 29	LZ-1 Oct. 15	LZ-2 May 5	LZ-2 July 29	LZ-2 Oct. 15
AMPHIPODA						
Hyalella azteca (*)					60	
*OSTRACODA				180	120	
CLADOCERA						
* *Acroperus harpae*		240	10	120	360	
* *Alona quadrangularis*					60	
* *A. rectangula*					180	
Bosmina longirostris			70		420	10
* *Chydorus sphaericus*	950		40	2820	120	50
Daphnia galeata mendotae					60	
D. pulicaria				60		
Diaphanosoma leuchtenbergianum					480	20
* *Macrothrix laticornis*						20
* *Pleuroxus striatus*				180		
* *P. trigonellus*				60		
* *Polyphemus pediculus*				60		
* *Sida crystallina*					780	
* *Simocephalus serrulatus*		720				
* *S. vetulus*	45			30	1020	
COPEPODA						
* HARPACTICOIDA			30	180		
CALANOIDA						
Diaptomus oregonensis		180	2410			130
CYCLOPOIDA						
copepodites	630	9560	250	5400	11000	140
adults						
Cyclops vernalis	360	540	10		120	20
* *Eucyclops agilis*	900	1080	50	420	180	40
* *E. speratus*	45		10			10
* *Macrocyclops albidus*	135	720		120	180	20
Mesocyclops edax	90	360		180		
M. leucktari		540				
* *Microcyclops varicans rubellus*	45			180		
TOTAL	3,200	13,940	2,880	9,990	15,140	460
NUMBER OF LITTORAL TAXA	6	4	5	11	10	5

* denotes taxa considered to be littoral in style.

Eighteen taxa were collected that can be considered littoral[1]. Cyclopoid copepodites could not be accurately identified to the species level, therefore it is not known how many species this group contained, or how many were littoral types. There were few obvious trends in the data, but in spring and summer collections, more littoral cladoceran species were found at LZ-2 than LZ-1.

Vertical Distribution

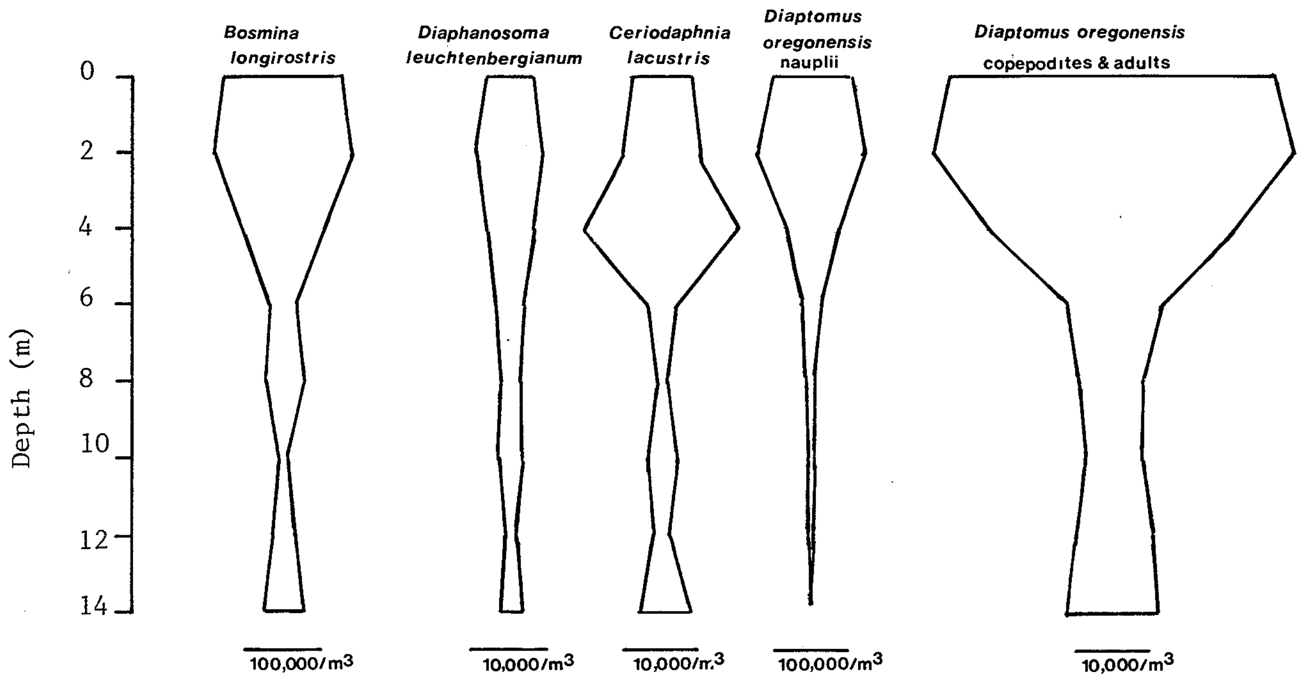
The vertical distribution of crustacean zooplankton was examined in Poplar Creek Reservoir at PCR-1 on August 6. Samples were collected at 2 m intervals, and oxygen and temperature were measured. Figure 50 shows the vertical distribution of the major crustacean zooplankton and the temperature and oxygen profiles.

In the south basin of Poplar Creek Reservoir there was a marked preference by the major zooplankton for water in the 0-6 m stratum. Within this stratum *Bosmina longirostris, Diaphanosoma leuchtenbergianum* and *Diaptomus oregonensis* nauplii and copepodites were concentrated above 4 m with slight peaks in population at the 2 m depth. *Ceriodaphnia lacustris* was concentrated slightly lower, in the 2-6 m range with a peak at the 4 m sample depth. The preference of zooplankton for water above approximately 6 m is probably a result of physical-chemical conditions. From Figures 41 and 50 it is evident a thermocline existed in the 5-7 m range, and that, at the time of these collections, dissolved oxygen decreased from 4.4 ppm at 4 m to 0.25 ppm at 6 m. The hypolimnion was very low in oxygen, and the zooplankton obviously preferred the epilimnion. The existence of an oxygen deficient hypolimnion was a rather prevalent feature of Poplar Creek Reservoir, and zooplankton were probably concentrated in the regions above this hypolimnion.

Benthic macroinvertebrates

The counts of the benthic organisms collected at the two sampling sites are presented in Tables 62 and 63; Figure 51 summarizes total abundance and composition of the benthos. As previously mentioned, the 0.6 mm mesh used to sieve bottom samples would miss smaller instars of insect larvae and select for later, larger instars. Hence, an increase in numbers would result from growth into the larger instars.

[1]See footnote 2 , Page 66.



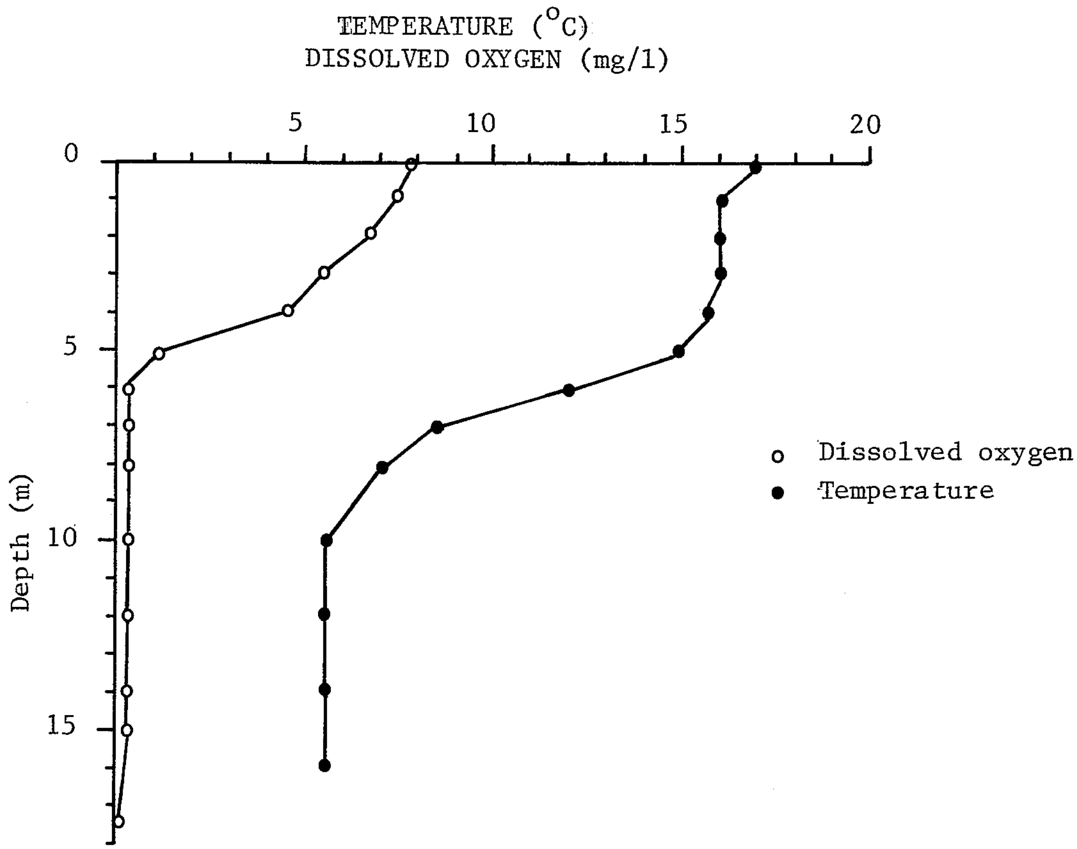


Figure 50. The vertical distribution of temperature, oxygen, and major crustacean zooplankton at PCR-1, August 7, 1977.

Table 62. Organisms in Ekman dredge samples from station PCR-1, Poplar Creek Reservoir, 1977.

	March 31			May 4			June 1			June 28			July 29			Aug. 26			Sept. 22			Oct. 15			Nov. 19		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																											
Ephemeroptera																											
Caenis													1														
Diptera																											
Ceratopogonidae															1												
Chironomidae																											
Chironomini	21		4		1	2	1	2		3	5	4	6	1	3	9	3	6	1		2	6	5	2	1	1	2
Tanytarsini													1														
Tanypodinae										1				1													
Orthocladiinae																							1				
Culicidae																											
Chaoborus	7		2			1						1		2	2	2	4	1	6	6	11	14	45	45		47	24
Coleoptera																											
Haliplus													1	1													
ARACHNOIDEA																											
Hydracarina						1																					
CRUSTACEA																											
Amphipoda																											
Hyalella azteca																											
OLIGOCHAETA	1							1	2																		
PELECYPODA																											
Pisidium							2	1																			
NEMATA									3																		
TOTAL	29	0	6	0	1	4	3	4	5	4	5	5	9	5	6	11	7	7	7	6	13	20	51	47	1	48	26
Mean per sample		12			2			4			5			7			8			9			39			25	
Mean per m^2		504			73			172			202			289			357			375			1692			1077	

Three dredges (0.023 m^2 each) taken on each date.

Table 63. Organisms in Ekman dredge samples from station PCR-2, Poplar Creek Reservoir, 1977.

	March 31			May 4			June 1			June 28			July 29			Aug. 26			Sept. 22			Oct. 15			Nov. 19		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																											
Ephemeroptera																											
Caenis																											
Diptera																											
Ceratopogonidae								1																			
Chironomidae																											
Chironomini					1		2	4	5	1	5					3	1		13	6	8	17	35	10	82	2	47
Tanytarsini					1																			1			
Tanypodinae							1																				
Orthocladiinae	1							1									1							1			
																								1			
Culicidae																											
Chaoborus																6	1	2	1	5	2		3			5	2
																								2			
Coleoptera																											
Haliplus																											
ARACHNOIDEA																											
Hydracarina	1		1																								
CRUSTACEA																											
Amphipoda																											
Hyalella azteca																					1						
OLIGOCHAETA	1																										
PELECYPODA																											
Pisidium									1																		
NEMATA																											
TOTAL	3	0	1	0	2	0	3	6	6	1	5	0	0	0	0	9	3	2	14	11	11	17	38	15	82	7	49
Mean per sample		1			1			5			2			0			5			12			23			46	
Mean per m^2		56			30			215			86			0			202			517			1003			1980	

Three dredges (0.023 m^2 each) taken on each date.

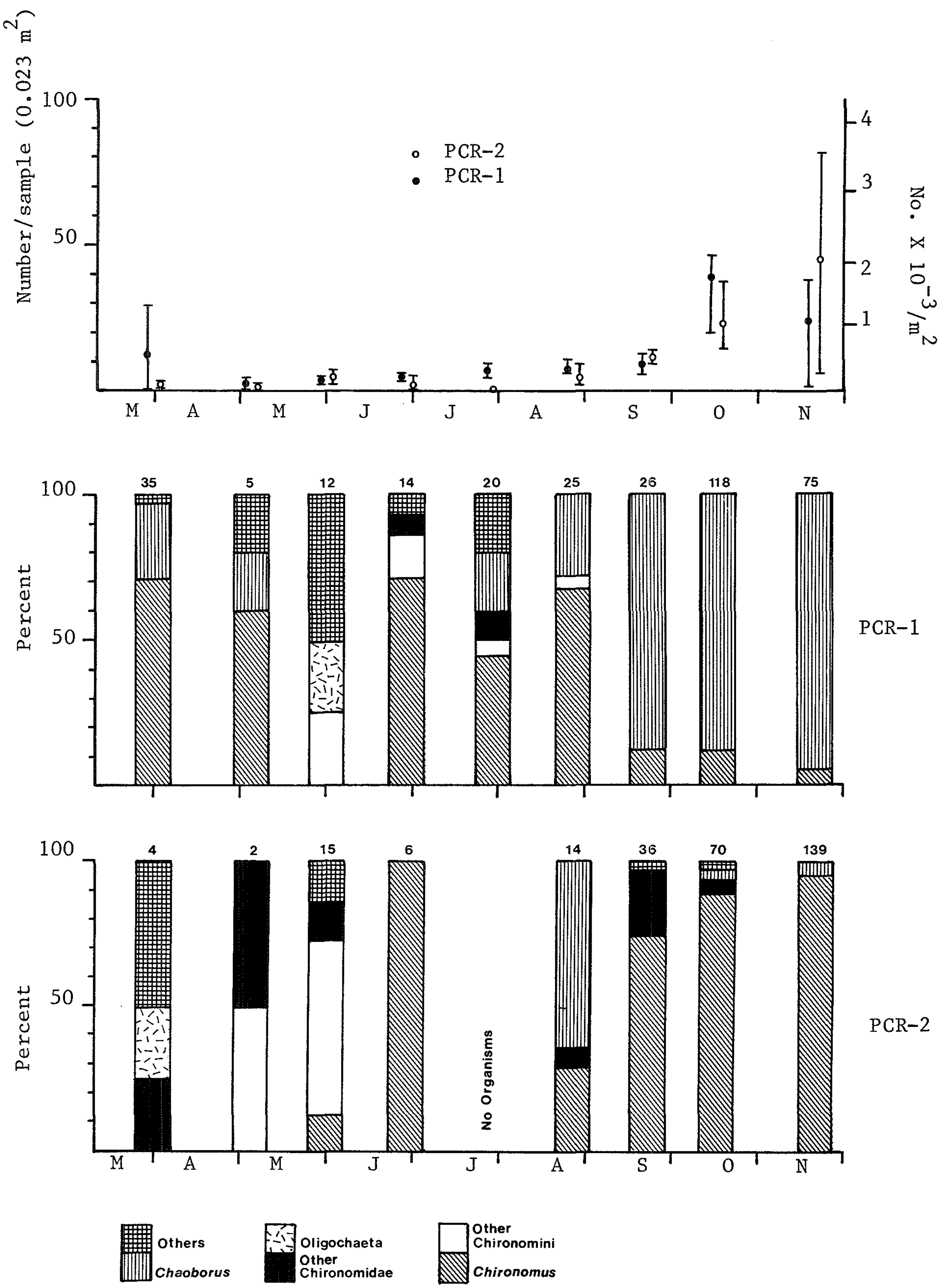


Figure 51. Total abundance and numerical composition of the benthos in Poplar Creek Reservoir in 1977. On the abundance graph circles indicate mean values while short bars indicate individual values. Values along the top of the composition graphs indicate number of organisms collected.

Total numbers of benthos were very low (usually less than 10 individuals/dredge) during spring, summer and early fall, and chironomid larvae (almost entirely *Chironomus*) were dominant (Table 64). In October and November numbers increased, however, different organisms accounted for the increases at the two stations. At the deeper station (PCR-1) the higher abundance was due to late instars of *Chaoborus flavicans*, which had also shown high numbers in November at BCR-1 in Beaver Creek Reservoir. *Chaoborus* is not a truly benthic organism since it spends much of its time actively feeding in the plankton. In other Alberta lakes late instars of *C. flavicans* normally appear in fall at which time they become more common in the benthos (P. Mitchell, pers. comm.). There was no obvious explanation of why *C. flavicans* was more abundant at PCR-1 than PCR-2.

At PCR-2 the increase was comprised of late instar larvae of *Chironomus*. This occurrence of *Chironomus* in the late fall may be related to destratification and resultant oxygenation of bottom waters. Jonasson (1972) demonstrated that *C. anthracinus* in Lake Esrom, Denmark grew rapidly from small first and second instars through the third and into the fourth instar stage in autumn immediately after overturn. A similar situation could have occurred in Poplar Creek Reservoir. The lack of late instars of *Chironomus* at PCR-1 in the fall may be related to the inorganic nature of its substrate and the more severe oxygen deficiency there.

Benthic colonization

To examine benthic colonization, five sites were established on August 7 on each of two transects, one south of the causeway, Transect A; and one north, Transect B (Figure 38). Depth, temperature, oxygen concentration and substrate conditions at each site are described in Table 65. The numbers of organisms collected are presented in Table 66, and Figure 52 shows total abundance and percent composition of the benthos at each site.

Transect A, south of the causeway, contained five evenly spaced stations between PCR-1 and the east shore. Benthic abundance was very low; only one of the fifteen dredge samples collected on the transect had more than twelve organisms. That sample (at Site 5) contained 148 organisms which were associated with abundant filamentous algae that only occurred in that particular sample. Other observations indicated that such filamentous algae were common along the southeast shore of the reservoir. Chironomids were dominant in the benthos, with *Chironomus* the most important genus.

Table 64. Abundance of Chironomidae at PCR-1 and PCR-2 in Poplar Creek Reservoir, 1977. Three Ekman dredge samples were collected on each date (area of one sample = 0.023 m^2).

STATION PCR-1

	March 31			May 5			May 31			June 28			July 29			Aug. 29			Sept. 22			Oct. 15			Nov. 19		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Subfamily Chironominae																											
Tribe Chironomini																											
Chironomus	21		4		1	2				1	5	4	5	1	3	9	3	5	1		2	6	5	2	1	1	2
Glyptotendipes							1	2		2			1														
unidentified																		1									
Tribe Tanytarsini													1														
Subfamily Orthocladiinae																								1			
Subfamily Tanypodinae																											
Procladius										1				1													
TOTAL	21		4		1	2	1	2		4	5	4	7	2	3	9	3	5	1		2			1	1	1	2
Mean per sample		8			1			1			4			4			6			1			0.3			1	
Mean per m^2		347			43			43			174			174			261			43			13			43	

STATION PCR-2

	March 31			May 5			May 31			June 28			July 29			Aug. 29			Sept. 22			Oct. 15			Nov. 19		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Subfamily Chironominae																											
Tribe Chironomini																											
Chironomus							1		1	1	5					3	1		13	6	8	17	35	10	82	2	47
Glyptotendipes					1		1	1																			
Einfeldia								4	4																		
unidentified																								1			
Tribe Tanytarsini					1																			1			
Subfamily Orthocladiinae	1																1							1			
Subfamily Tanypodinae																											
Procladius																											
Thienemannimyia							1																				
TOTAL	1				2		3	5	5	1	5					3	2		13	6	8	17	35	13	82	2	47
Mean per sample		0.3			0.7			4			2						2			9			22			44	
Mean per m^2		13			30			174			87						87			391			957			1913	

Table 65. Description of benthic colonization sampling sites in Poplar Creek Reservoir, August 7, 1977.

Site	Depth (m)	Dissolved Oxygen (mg/1)	T (^{o}C)	Substrate
1	17.0	0.2	6.0	clay-mud; with branches and twigs
2	8.2	1.0	7.0	sand-mud-clay; a few branches and twigs
3	6.5	0.8	14.0	sand-clay-small pebbles
4	3.2	6.3	18.0	mud-clay with some gravel-sand
5	0.5	11.5	21.5	hard, firm substrate; mostly clay with some sand and stones; some filamentous algae
6	1.2	3.6	17.0	moss and plant debris[1]; some twigs, some macrophytes
7	2.7	3.0	18.0	small amount of moss, branches, and twigs
8	7.6	0.7	13.0	small smount of moss and plant debris[1]
9	7.5	0.9	10.0	plant debris[1]
10	9.8	0.9	6.5	clay and plant debris[1]

[1] plant debris refers to dead vegetation arising from flooded forest litter, flooded terrestrial plants, and/or dead aquatic macrophytes; sticks, twigs, and branches are not included in this category.

Table 66. Organisms in Ekman dredge samples from benthic colonization survey in Poplar Creek Reservoir, August 1977. Area of each sample = 0.023 m^2. Three samples taken at each station.

	STN-1			STN-2			STN-3			STN-4		
	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA							2					
HIRUDINEA												
CRUSTACEA												
CONCHOSTRACA												
Lynceus brachyurus												
AMPHIPODA												
Hyalella azteca							1					
OSTRACODA												
ARACHNOIDEA-Hydracarina											1	1
INSECTA												
DIPTERA												
Chironomidae												
Chironomini												
Chironomus	1	1	2	3	1	3	2			2		
Glyptotendipes					1							
unidentified				1						1	2	5
Orthocladiinae												
Tanypodinae												
Ablabesmyia												
Procladius												
Tanytarsini												3
Culicidae												
Chaoborus				1	4	4		1	1	1		
Stratiomyidae												
EPHEMEROPTERA												
Caenis												
TRICHOPTERA												
Agraylea												
Oecetis												
MOLLUSCA												
PELECYPODA												
Pisidium												
GASTROPODA												
Aplexa hypnorum												
Armiger cristata												
Gyraulus parvus												
Helisoma												
Physa gyrina												
TOTAL	1	1	2	3	6	7	5	1	1	4	3	9
MEAN TOTAL/SAMPLE		1			6			2			5	

Table 66. Continued

	STN-5			STN-6			STN-7			STN-8		
	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA		20		10		4		6				
HIRUDINEA					1							
CRUSTACEA												
CONCHOSTRACA												
Lynceus brachyurus		1										
AMPHIPODA												
Hyalella azteca	3	11										
OSTRACODA									1			
ARACHNOIDEA-Hydracarina	1	4	1		1							
INSECTA												
DIPTERA												
Chironomidae												
Chironomini												
Chironomus		7		74	52	68	30	35	42			
Glyptotendipes		9		6	6	12	2	3	2			
unidentified	2	50	3	80	27	66	6	12			1	1
Orthocladiinae												
Tanypodinae												
Ablabesmyia		1										
Procladius	3	4	2	6	3							
Tanytarsini	3	11	2				1				1	
Culicidae												
Chaoborus										1	1	
Stratiomyidae												
EPHEMEROPTERA												
Caenis		17										
TRICHOPTERA												
Agraylea		3										
Oecetis		2										
MOLLUSCA												
PELECYPODA												
Pisidium												
GASTROPODA												
Aplexa hypnorum												
Armiger cristata						2						
Gyraulus parvus		4		5		4						
Helisoma				1								
Physa gyrina		4										
TOTAL	12	148	8	182	90	156	39	56	45	1	3	1
MEAN TOTAL/SAMPLE		56			143			47			2	

Table 66. Continued

	STN-9			STN-10		
	1	2	3	1	2	3
OLIGOCHAETA						
HIRUDINEA						
CRUSTACEA						
CONCHOSTRACA						
Lynceus brachyurus						
AMPHIPODA						
Hyalella azteca						
OSTRACODA						
ARACHNOIDEA-Hydracarina						
INSECTA						
DIPTERA						
Chironomidae						
Chironomini						
Chironomus						
Glyptotendipes						
unidentified						
Orthocladiinae						
Tanypodinae						
Ablabesmyia						
Procladius						
Tanytarsini						
Culicidae						
Chaoborus						
Stratiomyidae					1	1
EPHEMEROPTERA						
Caenis						
TRICHOPTERA						
Agraylea						
Oecetis						
MOLLUSCA						
PELECYPODA						
Pisidium						
GASTROPODA						
Aplexa hypnorum						
Armiger cristata						
Gyraulus parvus						
Helisoma						
Physa gyrina						
TOTAL					1	1
MEAN TOTAL/SAMPLE					1	

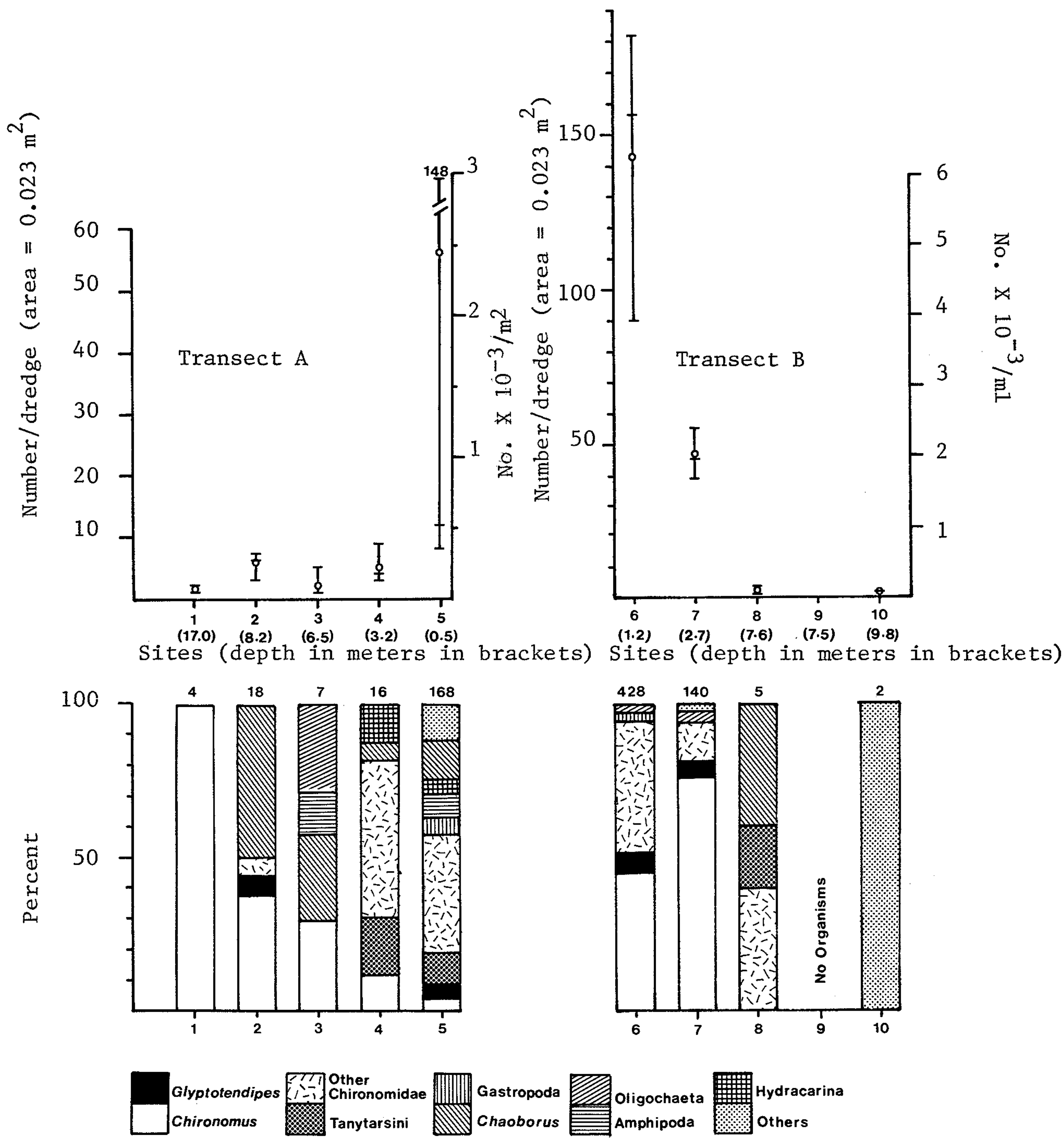


Figure 52 . Abundance and numerical composition of the benthos at the benthic colonization sample sites in Poplar Creek Reservoir, August 1977. On the abundance graph open circles indicate means while short bars indicate individual values. Values along the top of the composition graphs indicate number of organisms collected.

The low amounts of benthic macroinvertebrates on Transect A may reflect the nature of the substrate and the chemical nature of the reservoir. The substrate in the south portion of Poplar Creek Reservoir was largely clay-mud or sand-clay with some gravel and very little detrital material. Such a substrate would not provide an abundant food supply for the profundal benthos. In addition, at the deeper sites oxygen content was low (1 ppm or less). The long period of stratification and oxygen depletion of bottom waters below the thermocline would restrict the type of organisms occurring in such an environment and would reduce respiration, growth and survival of such organisms. Even if these areas were oxygenated, it is questionable if there would be an adequate food base. At PCR-1, which was close to Site 1, the one substrate analysis conducted as part of the physical-chemical program indicated an approximate composition of 20% organic material and 80% inorganic. From field observations, the shallower sites had less detrital material such as twigs, branches and forest litter, therefore, even with adequate oxygen levels, the food base appears restricted. It is possible, however, that as the reservoir develops, organic material in the substrates will increase.

Transect B, north of the causeway, consisted of five evenly spaced stations along the long axis of the reservoir (Figure 38). Depth increased towards the south, and as this occurred, total abundance declined. Populations at Sites 8, 9 and 10 were extremely low, with no individual dredge sample having more than three ogranisms. At the shallower stations, Site 6 and 7, chironomid larvae were the most abundant group with *Chironomus* being the dominant genus.

In general, the portion of the reservoir north of the causeway had more detrital material on the substrate than the portion south of the causeway. At the shallower, better oxygenated sites, abundance was higher than at the deeper sites, and the extremely low abundance at Sites 8 to 10 were probably a result of the low oxygen levels (less than 1 ppm). A thermocline occurred over most of the season at about the 4 to 6 m level, and water below this was very oxygen deficient. Jonasson (1972) has shown that early instar larvae of *Chironomus anthracinus* in Lake Esrom, Denmark could not utilize potential food because of low oxygen concentrations. These larvae essentially starved in these conditions until fall overturn when oxygen levels rose and conditions became favorable for growth. In shallower regions where oxygen levels were higher the larvae thrived. In Poplar Creek Reservoir the same situation may exist. Fourth instar larvae of *Chironomus* were common in the shallow regions of the reservoir in early August, earlier than in the deeper regions. In the oxygen deficient regions they were virtually absent in the July-August period and were not abundant until after overturn had occurred.

Both the regular benthic samples and the August transect information indicate that conditions below the thermocline in the north portion of Poplar Creek Reservoir do not appear to favor the growth of *Chironomus* larvae, the major benthic organism, until the fall period when overturn restores oxygen to the deeper waters. In the south portion of the reservoir most of the substrate is inorganic in nature, and this, in conjunction with oxygen deficiency in regions below the thermocline, limits the benthos.

Fish

Brook sticklebacks and fathead minnows were common to abundant in both June and August at all seining sites in Poplar Creek Reservoir (Figure 38). Young of the year collected at these sites indicates both species were reproducing in the reservoir. They have undoubtedly entered the reservoir via the diversion canal from Ruth Lake and have now become established in the impoundment. Both species suffer some overwinter mortality since dead individuals were observed at the top of the spillway in March. Such winterkill, however, was not complete since these species were present shortly after break up in the reservoir.

The only other species of fish collected in the reservoir was the white sucker. Individuals were taken in low numbers in gillnets in August (8 at G2 and 1 specimen at G1) but none were taken in June. It would appear that white suckers were only present in low numbers. All the fish caught in gill nets were in the 2½ inch (64 mm) mesh and were of a fairly uniform size. They averaged 287 mm fork length and 337 grams in weight (Table 67). An examination of scale samples indicated these fish were about 6 to 7 years old. No younger white suckers were found, and this, plus the low number of larger suckers, indicates that spawning within this reservoir has probably not occurred to any great extent. Suitable spawning substrates, however, do exist for this species on the dam face and on the southeast shore where much of the substrate is sand and gravel. Overwintering in this reservoir may not be possible for suckers because of the almost complete lack of oxygen which was found in March of 1977 (Figure 41 and Table 51).

Table 67. Fish collection data from gill net catches in Poplar Creek Reservoir, 1977.

Sample No.	Date	Site	FL (mm)	Wt. (g)
		White Suckers		
1	26/8	G2	293	397
2	26/8	G2	287	340
3	26/8	G2	292	340
4	26/8	G2	289	340
5	26/8	G2	293	340
6	26/8	G2	289	340
7	26/8	G2	280	284
8	26/8	G2	285	312
9	26/8	G1	290	340

Site: refer to map of sampling locations.

Winter deoxygenation may strongly limit the species of fish that can become established in the reservoir, at least until the oxygen demand of the flooded reservoir basin decreases, and winter oxygen deficiencies are not as severe. At present, fish that enter the reservoir in summer would have to move back, at least, to Beaver Creek Reservoir to find water with sufficient oxygen for overwintering. Consequently, only occasional or temporary use of Poplar Creek Reservoir by fish other than brook sticklebacks and fathead minnows can be expected for the immediate future.

POPLAR CREEK

METHODS

Poplar Creek was first sampled on March 30 for water chemistry and benthic macroinvertebrates. Three sites (PC-1, PC-2 and PC-B4, Figure 53) were sampled, but benthic samples were not obtainable at PC-B4 because of a thick layer of overflow ice on upper Poplar Creek. Subsequently, regular sampling was carried out at the three sites at four week intervals from May 3 to November 18, 1977. Temperature was measured at each site, and oxygen, pH and alkalinity were determined from samples the same day (oxygen samples were fixed when collected). Other standard chemical analyses were performed on samples from sites PC-1 and PC-B4, and three benthic invertebrate samples were collected with a Hess-type cylinder sampler at each of the three sites in 10 to 30 cm of water. Water for analysis of seasonal parameters was collected from sites PC-1 and PC-B4 on May 3, July 27 and October 14. Substrate samples were collected for analysis from all three sites on July 27. They were collected from sand-silt substrates at, or adjacent to, the regular sampling sites.

One 24-hour collection of drifting organisms was made at sites PC-B4 and PC-1 in Poplar Creek. The sampling was done simultaneously at both stations from 1500 on June 23 to 1500 on June 24. A collection of plankton was made at the stilling basin outlet to Poplar Creek during each regular sampling of the creek. A Wisconsin plankton net (80 micron mesh) was anchored in this flow for a timed interval (usually 1 min), and current speed was estimated with a float. Unconcentrated water samples were collected for analysis of algal content from PC-1 and PC-B4 on July 27.

On September 21, a field survey of the physical dimensions and characteristics of Poplar Creek was carried out on the reach downstream of the spillway. Methods used in 1974 (RRCS, 1975) were followed, in which width, depth at 3 points, pool/riffle proportions, substrate composition, bank stability and bank vegetative cover were assessed at cross-sectional stream transects. Substrate categories were from Herrington and Dunham (1967). In lower Poplar Creek (downstream of the channelized section) eight transects were sampled, situated in the same positions as in 1974. The channelized section was measured at more frequent intervals (39 transects in total) in order to encompass its more variable habitat. Each drop structure was measured, and

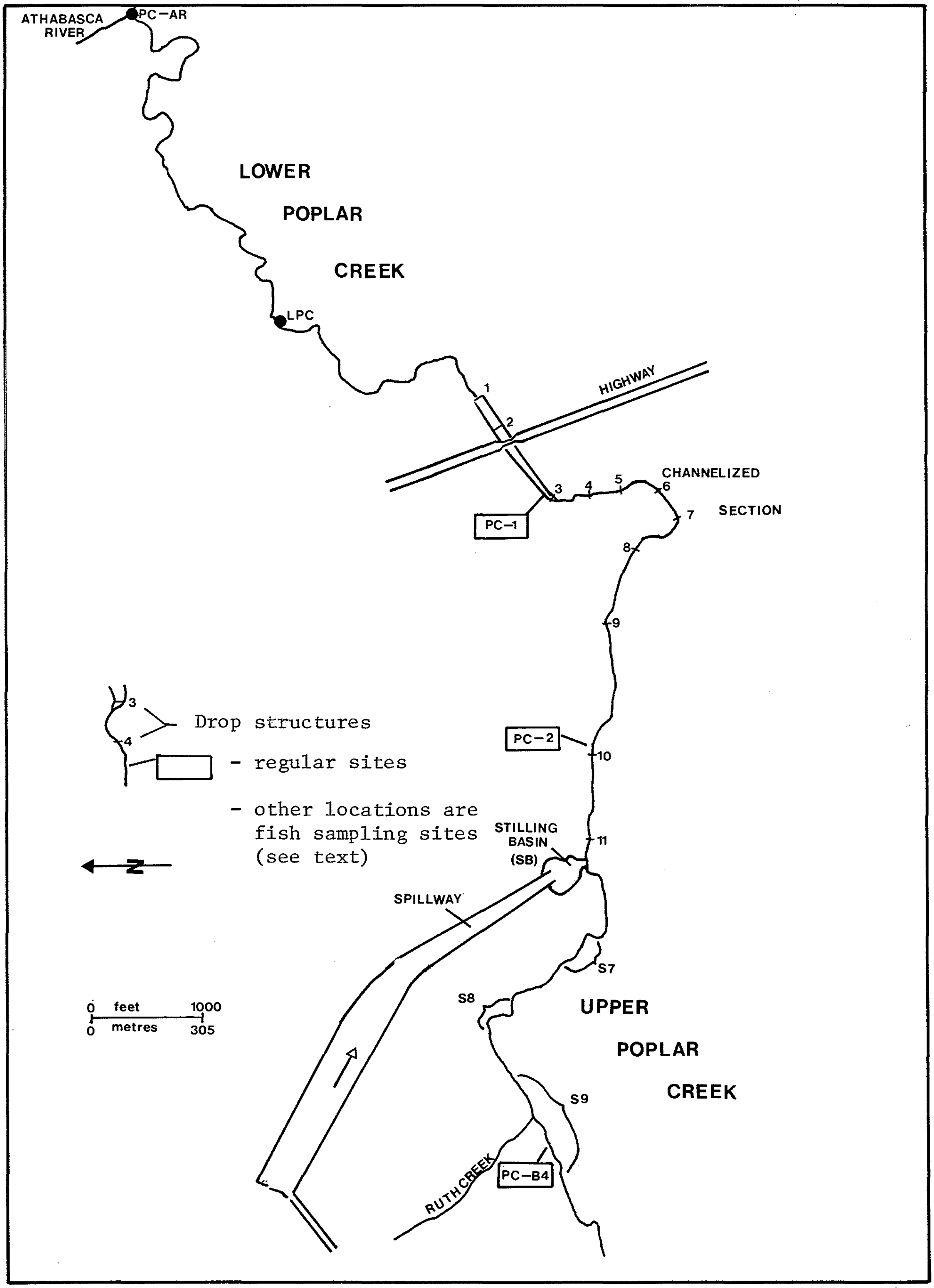


Figure 53. Sampling locations in Poplar Creek, 1977.

at least one transect was sampled in each of the adjacent pools and riffles.

The sampling program for fish was divided into a spring monitoring, a summer inventory and a fall inventory. The spring monitoring was designed to check fish presence, relative abundance and breeding conditions every few days during April-May when spring spawners might have been using Poplar Creek. This sampling was done by electrofishing and gillnetting. Summer and fall inventories were carried out over two days each, using seines, gillnets and electrofishing to determine what species were in the creek and their relative abundance. The fall survey was carried out when the spillway was shut off for modifications, therefore, flow remaining in the creek at that time was derived solely from the original Poplar Creek. A summary of dates, sampling locations and sampling effort is contained in Table 68. The channelized portion of Poplar Creek had ready access, moderate depths, a variety of habitats and obstructions where fish could be expected to concentrate. As a result, much sampling effort was expended there, especially during spring monitoring. Electrofishing was used anywhere wading was possible at the sampled sites, with special attention paid to obstructions to fish passage and areas providing escape cover. Seining was carried out in pools and some riffles, the water depths sampled being up to 1 m deep. Gill nets, set in pools in depths up to 1.5 m, were either 2½ or 3½ inch (64 or 89 mm) stretched mesh.

Sacrificing of fish was kept to a minimum. Stomachs of sacrificed fish were generally retained for content analysis.

Table 68. Locations and times of fish collections in Poplar Creek, 1977.

	Locations[1]													
	PC-AR	LPC	DS-1	DS-2	DS-3	DS4-6	DS-7	DS-10	DS-11	SB	UPC-SB	UPC-S7	UPC-S8	UPC-S9
April 14	A	A		A										
15	EF	EF	EF	EF	EF	EF			——	—— EF ——	——			
20	A			A					——	—— A ——	——			
				A	——	—— A ——	——							
			EF	EF	EF	EF								
26-27	A		——	——	—— A ——	——	——		——	—— A ——	——			
	EF		EF	EF	—— EF ——	——								
	[2]GN			GN		—— EF ——	——	GN						
May 2,3						—— A ——	——		——	—— A ——	——			
			—— EF ——	——	EF	—— EF ——	——	EF	EF	EF	EF			
6			EF	EF	EF		EF	—— EF ——	——	EF	EF			
11-12			EF	EF	EF	EF	EF	—— EF ——	——	EF	EF	EF		
				GN						GN				
18										A				
			—— EF ——	——	EF	EF	EF	—— EF ——	——	EF	EF	EF		
June 29										A				
July 25-26			EF	EF	EF	EF	EF	EF	EF		EF	EF	EF	EF
			S	S	S		S	S		S	S	S		
				GN						GN				
Sept. 19-20	A		—— EF ——	——	EF	EF	EF	—— EF ——	——	EF	EF	EF	EF	EF
				GN		A	A			GN				
			S	S	S			S		S	S	S		

[1] Refer to map of sampling locations. UPC refers to Upper Poplar Creek.

[2] a 30-min. set of 20 m, both 63.5 & 89 mm mesh (2½ and 3½ inch, resp.)

A - Angling: mean angling time - 20 man-minutes, range 5-60 minutes

EF - Electrofishing: mean shocking time - 133 seconds, range 30-330

S - Seining: mean - 2 hauls of about 15 m

GN - Gillnetting: overnight set of 10 m of 63.5 (2½) or 89 mm (3½ inch) mesh each time, unless noted.

RESULTS AND DISCUSSION

The lower two to three miles of Poplar Creek has been previously described as a small, brownwater stream of moderate alkalinity (RRCS, 1975; Noton and Chymko, 1977). The stream was meandering and slow in its lowermost two miles, with sand-silt substrates and much driftwood and deadfall. Farther upstream, creek gradient increased, and sand, gravel and rubble substrates were common. Fish were present but low in abundance, and benthos was typical of a clean-water-stream situation. During construction of the Beaver Creek Diversion System, much of the lower reach of the creek was channelized to accomodate increased flows without excessive erosion. The two lowermost sampling sites (PC-1 and PC-2) were situated in this section, and site PC-B4 was upstream of all disturbances at a site that had been sampled in 1974 and 1975. As a result of channelization and flow augmentations, downstream of the spillway there has been a change in the thermal and ice regime, an increase in benthic invertebrate populations, and the appearance of a more diverse and abundant fish fauna. The situation existing in the creek in 1977 is described more fully in the following.

Physical and chemical parameters

Flows in Poplar Creek during the summer have been augmented by spillway discharges from the Beaver Creek Diversion system (Figure 54). Water first began to flow over the spillway in July of 1976, and shortly after that heavy rains produced peak flows in lower Poplar Creek which were more than five times as large as peak flows observed in 1974-75. During the summer of 1977, flows in lower Poplar Creek were about 2-3 times the flow observed prior to the addition of spillway discharge to the creek. The spillway was shut off from early September to early October, 1977, for alterations that would permit a fall drawdown of the water level in Poplar Creek Reservoir. By lowering the reservoir level in fall, winter flow over the spillway will not be necessary.

Upper Poplar Creek was covered with up to 1 m of overflow ice when examined on March 30, 1977. Such overflow ice regularly occurs on small creeks in winter but is quite variable from year to year. March investigations in 1974, for example, revealed only a very thin covering of ice but up to a metre of snow cover on the creek (RRCS, 1975). While upper Poplar Creek was ice covered this March, the creek below the spillway was largely ice free as a result of early spring discharges from the spillway. On November 18 of

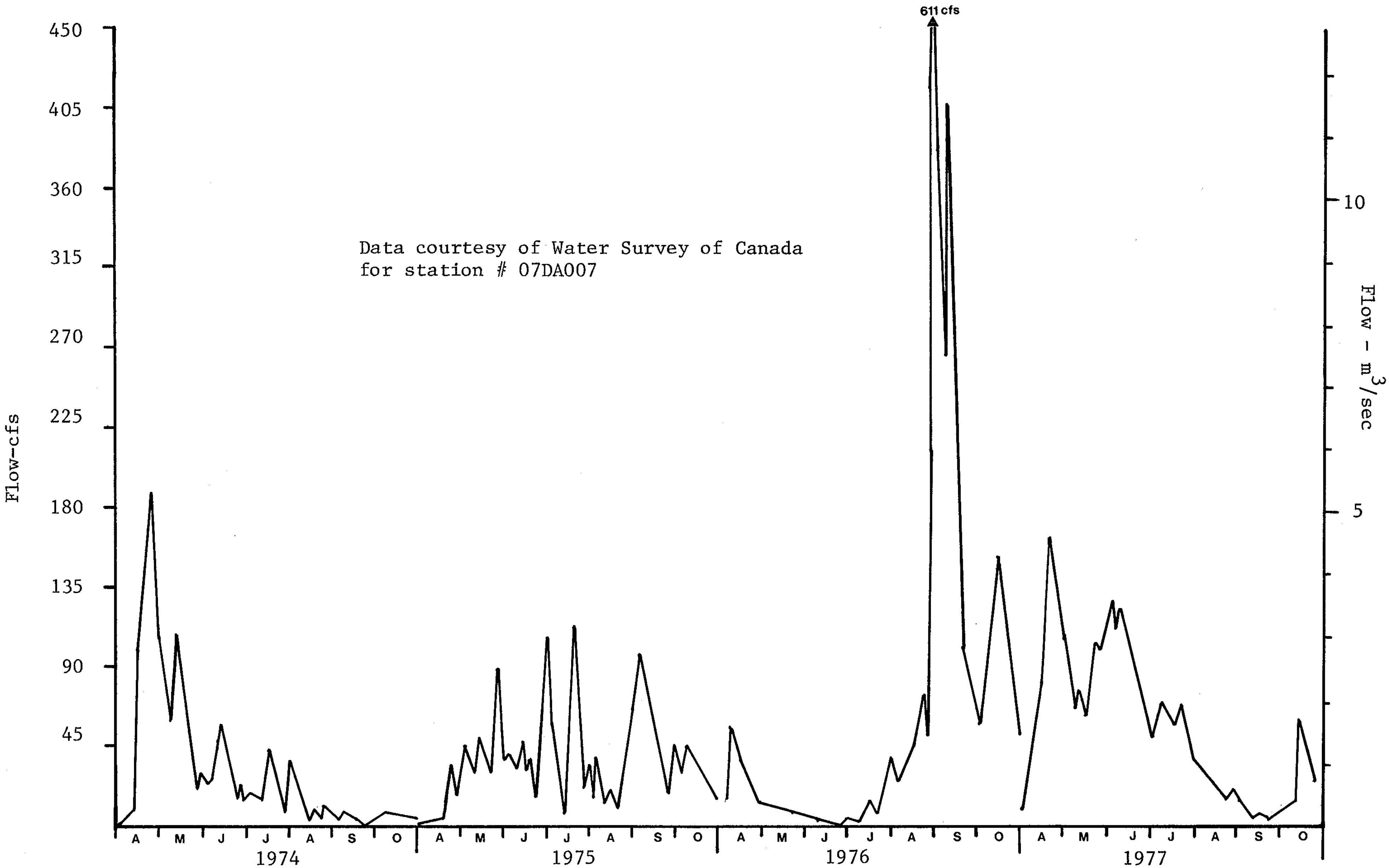


Figure 54. Summer flows in Poplar Creek, 1974-77.

1977, the upper reach was covered with up to 15 cm of ice except in some riffles. Below the spillway confluence, however, only the quieter pools were covered by a thin ice layer. Creek temperatures reached a recorded maximum of 23^{o}C on July 27 at station PC-2 (Table 69). Temperatures at the lower two sites were often slightly higher than at site PC-B4 and also higher than were recorded in 1974 and 1975 (the recorded maximum was 20^{o}C in both years). The lower creek is now more exposed to sunlight, and the spillway may facilitate heat exchange with the air. These factors may have allowed creek water to warm more easily than in the past.

Dissolved oxygen (Table 69) ranged from 85 to 107% saturation during the study and was regularly in the 89-100% range. Differences between the stations were not evident nor was there any appreciable difference from levels recorded in 1975 when saturation was usually in the 89-102% range (Noton and Chymko, 1977). The lower reach of the creek was never ice covered during the study, and it is not known if the creek was as well oxygenated through the winter as it was previous to diversion. Although Poplar Creek Reservoir was not well oxygenated, aeration of the water passing over the spillway apparently was thorough since summer oxygen levels at nearby station PC-2 were consistently close to saturation. Further, on March 30, 1977, oxygen saturation in the spillway canal was found to be only 2% but was 86% in water that had flowed over the spillway and was entering the creek. Similarly, on April 15 when the canal leading to the spillway was 30% saturated, oxygen concentration at site PC-1 was 98% of saturation.

Temperature and oxygen levels measured during the drift study in late June are placed in Table 70. The values indicate that both parameters underwent a greater diurnal fluctuation in the lower reach than in upper Poplar Creek. Also, in the lower reach, the fluctuation was greater than in 1975. At site PC-1, oxygen underwent a 33% saturation differential (2.1 mg/l), and temperature ranged 8 Celsius degrees over the 24 hour study. At site PC-B4 this year and at B4 and B1 in June and September, 1975, there was only a 12% saturation variation (1.0 mg/l) and a temperature range of 4 Celsius degrees. Heat exchange in the spillway may account for this greater diurnal temperature fluctuation observed in lower Poplar Creek in 1977. The greater oxygen variation may be caused by an increased oxygen demand exerted by organically rich reservoir water and nocturnal respiration of the increased benthic biomass. Changes in the benthos will be discussed later.

Table 69. Temperature and oxygen levels in Poplar Creek, 1977.

	March	April				May						June	July		Aug.	Sept.	Oct.	Nov.
	30	14	20	26	27	2-3		6	11-12	18	31	29	25	27	27	22	14	18
Station PC-1																		
Temp. (°C)	1.0	4.0	2.5	6	3.5		8.0		14.8		14.0	18.5	22.0	22.0	11.0	11.0	6.5	0
Oxygen (% Sat.)	94	98	94	99			95				89	94		94	89	85	98	101
Oxygen (mg/l)	12.30	11.9	12.0	11.4		10.4					8.5	8.1		7.6	9.2	8.7	11.2	13.7
Station PC-2																		
Temp. (°C)	1.0					9.5	9.0	10.0	15.0	8.5	17.0	18.5		23.0	13	11	6.5	0
Oxygen (% Sat.)	90						94				97	89		88	93	78	98	107
Oxygen (mg/l)	11.95					10.1					8.3	7.8		7.1	9.0	8.0	11.1	14.6
Station PC-B4																		
Temp. (°C)	0.5						9.0				16.0	15.5		20.0	11.0	10.5	3.0	0
Oxygen (% Sat.)	93						94				89	94		93	93	93	97	89
Oxygen (mg/l)	12.35					10.1					8.2	8.6		7.8	9.5	9.6	12.1	12.2

Measurements with thermometer and azide - Winkler method.

Table 70. Temperature and oxygen during drift studies in Poplar Creek, June 23-24, 1977.

Time (MDT)	Temp. °C	Oxygen mg/l	Oxygen % saturation
		Stn. PC-1	
1715	23	8.1	100
2145	21.5	7.3	89
0100	15.5	6.3	67
0515	15	6.9	73
0945	17	7.6	84
1320	21	8.4	100
		Stn. PC-B4	
1735	19	8.1	94
2150	19	8.0	93
0105	18	8.0	90
0505	15	7.8	83
0900	15	8.0	85
1300	15.5	8.1	87

The results of regular chemical analysis of Poplar Creek water samples are in Table 71. Of the two sites below the spillway, only PC-1 was sampled for all regular water quality parameters since significant differences in water quality were not expected between sites PC-1 and PC-2. This was confirmed by the temperature, oxygen, pH and alkalinity measurements which were very similar between the two sites (Table 71). Many of the parameters at both stations had high values in March, followed by much lower concentrations in early May, a pattern that also occurred in most of the other water bodies in the diversion system. Water quality in Poplar Creek below the spillway reflected conditions in both Poplar Creek Reservoir and upper Poplar Creek since flow was a composite of both. Filtrable residue and phosphorus parameters seemed to be a combination of levels from both parent water bodies. Turbidity, pH and suspended-solids levels resembled those of upper Poplar Creek, and alkalinity, ignition loss and nitrogen parameters were similar in concentration to those in the reservoir. Alkalinity and filtrable residue at PC-1 were the only components that differed noticeably in value from measurements made in 1975; however, these differences were not great. Water quality at Site PC-B4 was very similar to that of 1975.

pH was very similar at all three stations this year, averaging 8.1 in the open season, with somewhat lower levels in March. In 1975, pH averaged 8.0 over the same period. Alkalinity at PC-B4 was more variable and was somewhat lower than at PC-1. Filtrable residue was also more variable at PC-B4 than at PC-1, but turbidity and suspended solids were essentially similar at both stations. Both parameters were highest in spring but by the end of June had declined to lower and fairly stable levels. TOC concentrations averaged 31 and 33 mg/l at PC-1 and PC-B4 respectively. They ranged from 21 to 42 mg/l at both stations with highest levels in August and September. TOC was remarkably similar in concentration and fluctuation to TOC levels in other areas of the diversion system and to Poplar Creek in 1975. Ignition loss from PC-1 samples resembled that of the reservoir more than that of PC-B4 as did nitrate - nitrogen (NO_3 + NO_2 - N) concentrations and to a lesser extent total Kjeldahl nitrogen. Orthophosphate-phosphorus concentrations were very similar at the two stations in the creek and resembled levels measured in the diversion system lakes, although stream concentrations were somewhat higher in summer and lower in March. Levels recorded in 1975 were of the same magnitude. Total phosphorus was also very similar between stations and between water bodies.

Table 71. Chemical characteristics of Poplar Creek, 1977.

	March 30	May 3	May 31	June 29	July 27	Aug. 27	Sept. 22	Oct. 14	Nov. 18
				PC-1					
pH	7.5	7.9	8.1	8.1	8.3	8.1	8.0	8.1	8.3
pp alkalinity	0	0	0	0	0	0	0	0	0
Total alkalinity	170	139	134	154	154	166	190	169	185
Turbidity (NTU)	4.5	16.0	11	4.4	4.7	1.3	3.1	4.1	11
Suspended solids	8.2	2.8	23.5	1.5	1.0	1.5	<0.5	14.4	12.0
Total organic carbon	27	21	25	36	32	42	42	22	28
$NO_3 + NO_2$ - N	0.32	0.08	0.035	0.115	0.050	0.078	0.027	0.081	0.217
Total Kjeldahl - N	12.1	10.6	0.2	0.2	0.2	0.3	0.6	0.8	0.6
Ortho PO_4 - P	0.180	0.061	<0.016	0.025	<0.016	0.028	<0.016	0.030	0.023
Total P	0.406	0.076	0.044	0.064	0.098	0.049	0.051	0.055	0.052
Reactive SiO_2	5.9	6.4	4.0	5.0	6.2	4.7	5.5	6.9	9.4
Filtrable residue	525	232	222	270	240	310	360	104	294
Ignition loss	230	80	68	78	104	100	96	48	124
				PC-2					
pH	7.5	7.7	8.1	8.1	8.3	8.2	7.8	8.0	8.0
pp alkalinity	0	0	0	0	0	0	0	0	0
Total alkalinity	172	140	133	151	155	167	186	170	187
				PC-B4					
pH	7.6	7.9	8.0	8.1	8.2	8.2	8.0	8.2	8.0
pp alkalinity	0	0	0	0	0	0	0	0	0
Total alkalinity	368	94	98	136	145	171	190	142	175
Turbidity (NTU)	6.0	18.0	24	8.7	5.4	6.2	2.2	3.5	4.8
Suspended solids	17.8	22.4	41.0		<0.5	5.0	<0.5	1.2	<0.5
Total organic carbon	21	26	28	36	37	42	42	31	30
$NO_3 + NO_2$ - N	0.87	0.09	<0.03	<0.03	0.038	<0.03	<0.016	<0.016	0.023
Total Kjeldahl - N	4.3	7.0	0.1	0.2	0.1	0.1	0.2	0.6	
Ortho PO_4 - P	0.140	0.030	<0.016	0.022	0.023	0.029	<0.016	<0.016	<0.016
Total P	0.423	0.052	0.060	0.068	0.092	0.047	0.051	0.048	0.047
Reactive SiO_2	14.3	3.2	3.6	4.0	4.7	6.5	5.6	4.2	5.5
Filtrable residue	545	202	190	278	290	340	390	272	376
Ignition loss	190	74	44	70	146	78	165	120	236

Results in mg/l except pH and turbidity. Alkalinities as $CaCO_3$.

Reactive silicate was quite variable in concentration (Table 71) at the two Poplar Creek stations but was of the same general level at both.

Seasonal water sample analyses at PC-B4 and PC-1 are in Table 72. True colour did not show a consistent pattern between stations but was similar in intensity to the other brown waters of the diversion system. Oil and grease concentrations were in the range of 6-57 mg/l but did not reach levels as high as in some samples from other sites in the system. Concentrations of phenols were quite low, never exceeding 0.003 mg/l, and chemical oxygen demand ranged from 45 to 103 mg/l. Hardness (as $CaCO_3$) was in the 66-138 mg/l range. Sodium and calcium were the major cations, and concentrations were fairly similar between the two sites except in the spring when calcium values were noticeably higher at PC-B4 than PC-1. Sodium was less concentrated than calcium in the spring, but values were similar in the summer and fall. Bicarbonate was clearly the dominant anion. Chloride ranged from 12 to 37 mg/l and was similar in concentration to what it was in 1975 (Noton and Chymko, 1977). Concentrations of metals in seasonal samples this year were fairly similar to levels measured in 1975 although lead, nickel and aluminum values were mostly lower this year. Except for slightly higher levels of iron at site PC-B4, metal concentrations were very similar at PC-B4 and PC-1 in 1977.

Substrate samples collected from the three stations in July (Table 73) were low in organic compounds, similar to the upper Beaver Creek samples. Stream substrates accumulate much less organic debris than do lakes because of scouring of the light debris by the current. Of the metals, copper, chromium, lead, zinc and cobalt were two to four times more concentrated at the two sites in the channelized portion of the creek than at site PC-B4. The significance of this was not clear since substrate variability in the upper reach can not be assessed from the data. Substrate samples from PC-1 and PC-2 were very similar in metal content. Substrate metals in upper Beaver Creek samples (Table 7) were generally much higher than those in Poplar Creek samples.

Physical Habitat

The addition of upper Beaver Creek flows to Poplar Creek via the diversion system and spillway has been accompanied by channelization of much of the creek downstream from the stilling basin (Figure 55). This channelization and the increased flows have combined to produce distinct changes in the habitat of Poplar Creek. For purposes of discussion it is best to consider the creek

Table 72. Results of seasonal water analysis, Poplar Creek, 1977.

	PC-1 May 3	PC-1 July 27	PC-1 Oct. 14	PC-B4 May 3	PC-B4 July 27	PC-B4 Oct. 14
True color (APHA)	220	90	75	100	150	130
Oil and grease	8.20	14.4	18	17.8	56.8	6.2
Phenols	<0.001	<0.001	0.003	0.001	<0.001	<0.001
C.O.D.	103	45	99	52	55	-
Hardness[1]	66	115	77	138	117	80
Na	2.99	42.4	19.2	4.07	46.4	24.5
Mg	4.8	9.4	5.0	12.0	10.8	7.5
Ca	18.5	30.5	22.8	35.7	28.9	19.7
K	0.7	1.7	1.2	2.6	0.4	1.0
Cl	12	21	17	20	37	18
SO_4	6	4	5	10	6	6
Fe	0.89	0.40	0.61	1.28	0.94	0.70
Cu	0.006	0.009	0.019	0.007	0.01	0.015
Cr	0.02	<0.01	0.03	0.04	<0.01	0.03
Pb	0.03	<0.02	0.05	0.03	<0.02	0.05
Zn	0.005	0.009	0.052	0.023	0.011	0.064
Ni	<0.02	<0.02	0.03	<0.02	<0.02	0.02
Co	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Al	<0.1	0.2	0.2	0.3	0.3	0.2
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B	0.107	0.193	0.167	0.247	0.146	0.157

Results as mg/l unless noted.

[1] Ca & Mg hardness, as $CaCO_3$.

Table 73. Results of substrate analysis, Poplar Creek, July 27, 1977.

	PC-1	PC-2	PC-B4
% organic	4	3	4
% inorganic	96	97	96
Fe	11481	13523	11879
Cu	7.1	8.2	3.8
Cr	23.4	26.9	9.6
Pb	55.5	63.9	16.3
Zn	27.5	29.8	17.0
Ni	7.6	10.4	8.9
Co	10.7	14.4	4.6
Al	18808	24850	13888
Cd	7.9	9.4	6.0

Results are by weight of air dried samples. Metals as ppm.

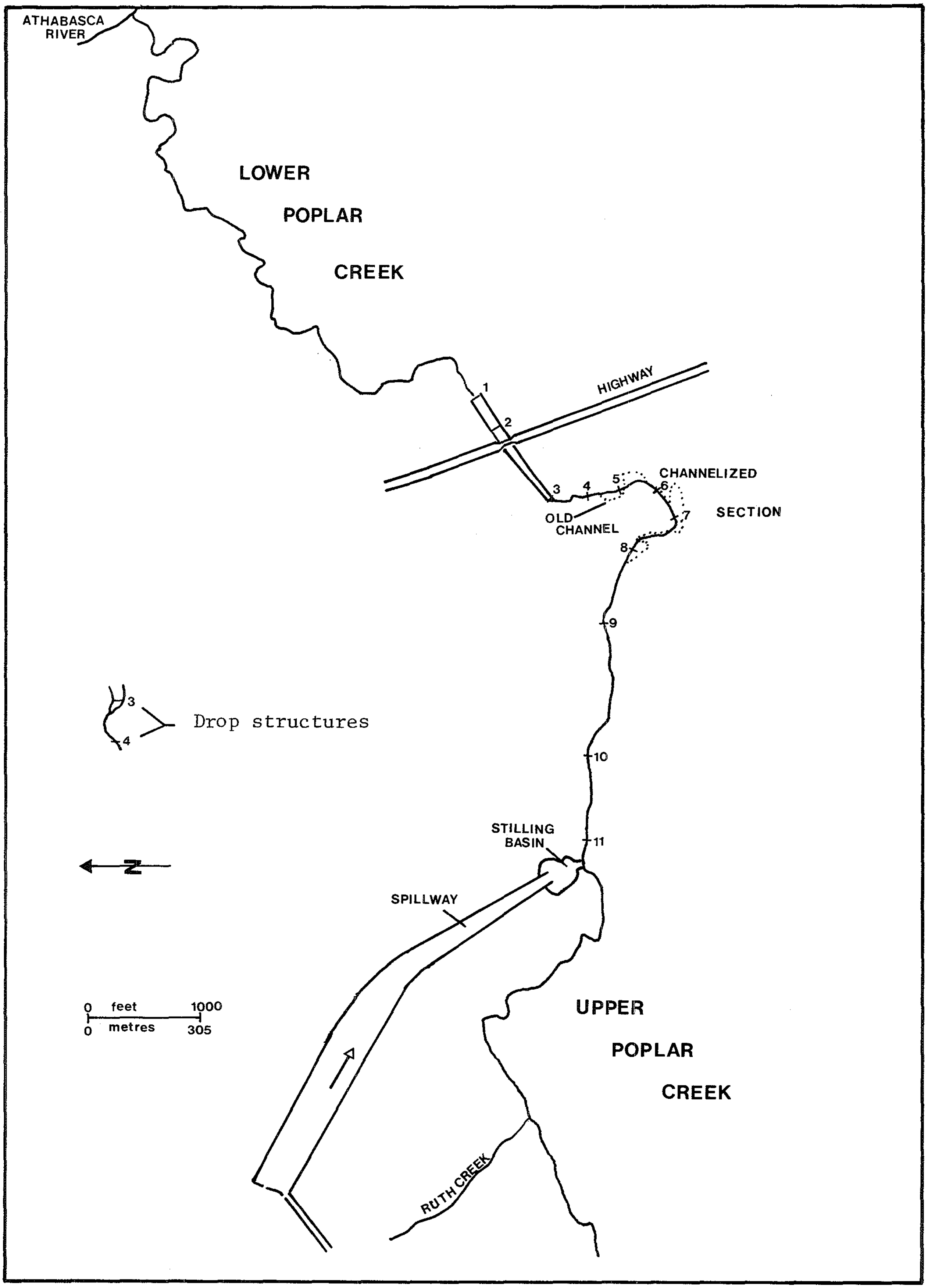


Figure 55. Habitat features of Poplar Creek, 1977.

in four sections: the stilling basin, upper Poplar Creek, the channelized section, and lower Poplar Creek (downstream of the channelization). The habitat of upper Poplar Creek was essentially unaffected by the diversion system, except for a rise in water level for about 100 m upstream from the stilling basin confluence. This was caused by ponding of water behind drop structure # 11 (Figure 55).

Streamflows at the time of sampling (September 21) were low as a result of the spillway's being dammed. The low flow was contributed solely by Poplar Creek, and although it facilitated habitat assessment, such low flows were not typical of the summer flow regime. The stream would normally be somewhat deeper and wider during the summer months but will be even shallower and narrower during winter since present plans are for preventing flow over the spillway in winter.

The stilling basin is an oblong pond (Figure 55, Plate 7) of about 0.5 ha (1.25 acres) in area. Its basin is bowl shaped, up to 2 m deep during spillway shutoff, and the substrate is mostly boulders and rubble. Sand-silt occurred in some places as well, notably in the backwaters where the spillway enters. Water level in the basin was as much as 0.5 m higher during times of maximum flow over the spillway.

To contend with the added flow, Poplar Creek has been channelized from the stilling basin confluence to just below the highway bridge (Figure 55). The stream channel has been straightened, widened and/or deepened; the banks and channel lined with rip-rap in many places; and eleven drop structures (weirs or low dams) of rubble and boulders have been constructed to control the water's descent (Plate 9). In the upstream portion of the channel, the drop structures are fairly far apart, separated by long, deep pools of sand-silt substrate (Plate 8), but near the highway bridge the channel is more intensively structured. There the drop structures are more frequent because of the higher stream gradient, and the banks and channel are almost completely lined with boulder and rubble (Plate 9). The channelized section widens near the bridge and ends at drop structure # 1 where water enters the old creek channel.

The habitat characteristics of the channelized section are described in Table 74. The new channel differed from the natural channel it replaced in width, pool-riffle ratio, type of substrate, bank cover and bank stability. Also, the old stream contained considerable amounts of driftwood and deadfall which were not abundant in the new channel. Accomodation of flows from the

Table 74. Characteristics of pools, riffles and drop structures in the channelized section of Poplar Creek, 1977.

	Pools	Riffles	Drop Structures
# of transects	18	10	11
Total length - m(ft)	1313 (4308)	378 (1240)	161 (529)
Mean length - m(ft)	119 (392)	42 (138)	14.6 (48)
Mean width - m(ft)	19 (63)	15.9 (52)	17.6 (58)
Mean depth - cm(in)	75 (29)	19.5 (8)	NA[1]
Total surface area - ha(ac)	2.49 (6.15)	0.6 (1.49)	0.28 (0.7)
% of total length of channelized section	71	20	9
Substrate % in:			
Boulder	11	61	91
Rubble	8	20	9
Gravel	3	4	
Sand/Silt	78	15	

[1] The low flow at sampling time was mostly percolating through the boulder substrate.

diversion system required a wider channel to be constructed, and the drop structures and riffles have decreased the percentage of pool habitat. Previously sand-silt was the only substrate in this reach, but boulders and rubble now account for 37% of the bottom material (Table 75). Bank vegetation is much less abundant than before, but banks are more stable, many being composed of rip-rap.

Habitat in this section typically consists of a repetition of drop-structure, riffle and pool. The drop structures make up about 9% of the total length of the channelized creek, and there is about a 1.2 m drop between each structure. In summer, flow over these structures was usually turbulent and cascading (Plate 9), but during periods of low flow the water mostly percolated through the boulders. As a result, water depth in these structures was quite variable.

Downstream of each drop structure, the habitat generally graded into a riffle in which the water was turbulent and rippled but not foaming. These riffles formed 20% of the length of the channelized creek and contained more rubble, gravel and sand-silt than did the drop structures (Table 74). There are nine sections of riffle, one at the downstream side of each of drop structures # 3 through # 11.

Pools occur below each drop structure and riffle where the water backs up behind the next drop structure. Table 74 contains the average characteristics of the eleven pools in this section, but more variability existed in their characteristics than in those of the drop structures and riffles. Pools downstream of drop structure # 7 are shorter, shallower and wider and contain more boulder and rubble substrates than those upstream. Upstream pools are long and narrow, with natural sand-silt forming most of their substrate (Plate 8).

Lower Poplar Creek, below the channelized section, is a slow-flowing meandering stream containing much driftwood and deadfall. The eight transects sampled there showed that sand-silt was the major substrate type, as it was in 1974 (Table 75). Widths and depths measured this year were not as great as those obtained in July, 1974 because of lower streamflows in September 1977. Although the 1974 data was from a larger reach of the creek, that reach was fairly homogeneous, and the data may still be compared to that collected this year in lower Poplar Creek. Pool-riffle proportions have not changed measurably,

Table 75. Summary of habitat characteristics of Poplar Creek, 1974 and 1977.

	1974 'Lower section'[1]	'Lower Poplar Creek'	1977 Channelized section
# of transects	17	8	39
Length - km(mi)	4.25 (2.64)	2.29 (1.42)	1.85 (1.15)
Gradient - %(ft/mi)	0.3 (17)	0.1 (7)	0.6 (30)
Mean width - m(ft)	5.9 (19.4)	4.7 (15.4)	18.2 (59.7)
Mean depth - cm(in)	76 (30)	64 (25)	63 (25)
Total surface area - ha(ac)	2.51 (6.2)	1.07 (2.65)	3.38 (8.35)
Habitat % in:			
Pools	88	88	71
Riffles	12	12	20
Drop structures			9
Substrate % in:			
Boulder			26
Rubble			11
Gravel			3
Sand/Silt	100	100	60
Bank vegetation - %:			
Forest	30	44	
Brush	47	56	12
Open	23		88
Stable banks - %:	82	100	97

[1] Includes reach of stream from mouth to present stilling basin confluence.

and allowing for lower streamflows, width and depth appear to be similar to 1974 for most of this section. It would appear that most of the channel of lower Poplar Creek has not been noticeably affected by the increased flows; however, for about 200 m immediately downstream of drop structure # 1, some channel enlargement appeared to be occurring. This was too short a section to show up in the transect data, but inspection revealed a relatively deep channel and numerous recent bank slumpings. Apparently, channel enlargement due to increased flows was occurring in a short reach immediately below the channelized creek. It is not known whether this channel enlargement will progress downstream.

Benthic macroinvertebrates

Three benthic invertebrate samples were collected on each sampling date with a Hess-type cylinder sampler at PC-B4, PC-2 and PC-1 (Figure 53). The substrate at PC-B4 was unchanged from previous years and consisted of a sand-gravel base with rubble and a few boulder-size rocks (up to 30 cm in width). At PC-2 and PC-1 the substrate comprised gravel, rubble and boulders which had been laid down during stream-channel alterations. Much of the material in the stream bed consisted of large rocks more than 15 cm in width, but the actual substrates sampled were basically similar to the substrate at PC-B4. The latter site, however, had a greater variety of rock forms (i.e., round, angular, flat, etc.).

As a result of the selectivity of benthic samplers and the heterogeneity of stream benthic communities, considerable variability normally occurs in the numbers of organisms collected in stream benthic samples. In Poplar Creek, the mean coefficients of variation (standard deviation/mean x 100) in total numbers within each three-sample set collected during 1977 at PC-B4, PC-2 and PC-1 were 40%, 62% and 44% respectively. Many investigators have documented the high variability of benthic samples, and as Hynes (1970) notes, "... all quantitative estimates of the numbers or biomass of animals on stream beds are, at best, only very rough estimates". In the present study, the three samples per site, collected at about four week intervals, were considered to give a general indication of the abundance and seasonal trends in the zoobenthos.

The effects of the Beaver Creek diversion on Poplar Creek include the introduction of reservoir water, with its different physical, chemical and biological properties, into the creek system. There have been few studies on the effects of impoundments on streams, but there are undoubtedly major changes involved with such impoundments for at least certain distances downstream. The effects vary with the nature of the water and its release (epilimnetic versus hypolimnetic; stable discharge versus variable discharge, etc.). Spence and Hynes (1971) noted that a hypolimnetic release into the Grand River, Ontario caused downstream differences "comparable with those occurring after mild organic enrichment". They documented higher numbers of filter feeders such as simuliid and hydropsychid larvae as well as increases in numbers of chironomids, mayflies (*Baetis* and *Caenis*), coleopterans (*Optioservus*) and amphipods (*Hyalella azteca*). They attributed these downstream changes to an increase in the amount of detritus, a lag in the rise of early summer water temperatures, lower maximum summer temperatures and alterations of other factors.

Hynes (1970) points out that many studies around the world have demonstrated that filter-feeding organisms such as larval Simuliidae, Hydropsychidae, and Polycentropidae are particularly abundant downstream of lakes. Cushing (1963) studied the Montreal River in Saskatchewan and observed that in the sections below "a series of productive lakes" there were larger populations of mayflies (*Baetis*) as well as filter-feeding trichopteran larvae (Hydropsychidae). In Mary Gregg Creek below Mary Gregg Lake, Alberta, abundance of *Simulium* was high immediately below the lake and decreased downstream (Chymko, 1977). Robertson (1967) noted that in the summer the benthic fauna in the Wandering River, Alberta, was more abundant downstream of a lake than it was upstream.

The composition of the Poplar Creek zoobenthos at the sampling sites is presented in Table 76. Several genera and taxa were observed exclusively upstream or downstream of the spillway, but in most of these instances the sample size was very low. Only for the coelenterate *Hydra* and the gastropod *Gyraulus* was the sample size large enough to conclude that these organisms occurred almost exclusively downstream of the spillway. The occurrence of *Hydra* was undoubtedly related to a plankton food source. Many taxa, although not occurring exclusively downstream or upstream, showed notable differences in abundance between these areas. These are discussed below.

Since the level of identification was only to the generic level or higher, many changes may not have been detected even though they may have occurred. This would be particularly true for the Chironomidae which were identified to sub-family and tribe levels. In 1975 thirty-six chironomid genera were identified in Poplar Creek samples, and there were undoubtedly many species

Table 76. Composition of the benthos at the sampling sites in Poplar Creek, 1977.

	PC-B4	PC-2	PC-1
COELENTERATA-*Hydra*		X	X
OLIGOCHAETA	X	X	X
HIRUDINEA		X	X
NEMATA	X	X	X
CRUSTACEA-Ostracoda	X	X	X
ARACHNOIDEA-Hydracarina	X	X	X
INSECTA			
COLLEMBOLA		X	X
EPHEMEROPTERA			
Ameletus	X		X
Baetis	X	X	X
Caenis	X	X	X
Cinygmula	X	X	X
Ephemerella	X	X	X
Heptagenia	X	X	X
Leptophlebia		X	X
PLECOPTERA			
Alloperla	X		X
Arcynopteryx	X	X	X
Isogenus	X		
Nemoura	X	X	X
HEMIPTERA-Corixidae			
ODONATA-Anisoptera	X	X	X
TRICHOPTERA			
Arctopsyche			X
Brachycentrus	X	X	X
Ceraclea			
Cheumatopsyche	X	X	X
Glossosoma	X	X	X
Hesperophylax	X		
Hydropsyche	X	X	X
Lepidostoma			X
Neureclipsis	X	X	X
Ochrotrichia	X		X
Oxyethira	X		
Psychomyia		X	X
Rhyacophila	X	X	X
Wormaldia	X		X
pupae	X	X	X
unidentified			X
COLEOPTERA			
Agabus		X	
Deronectes			X
Donacia	X		
Galerucella			X
Gyrinus			X
Haliplus		X	
Heterlimnius	X	X	X
Narpus			X
Optioservus	X	X	
Rhantus			X
DIPTERA			
Ceratopoginidae	X	X	X
Chironomidae			
Chironominae			
Chironomini	X	X	X
Tanytarsini	X	X	X
Diamesinae	X	X	X
Orthocladiinae	X	X	X
Tanypodinae	X	X	X
Culicidae			
Chaoborus	X		X
Dolicopodidae	X	X	
Empididae	X	X	X
Muscidae	X		
Rhagionidae			
Atherix variegata		X	
Simuliidae			
larvae	X	X	X
pupae	X	X	X
Stratiomyidae		X	
Tabanidae	X	X	
Tipulidae-*Dicranota*	X	X	X
MOLLUSCA			
Gastropoda			
Ferrissia rivularis			X
Gyraulus		X	
Helisoma		X	X
Physa		X	X
Pelecypoda			
Sphaerium		X	

within these genera. Changes at the generic and species levels would almost certainly have occurred between upstream and downstream locations.

The raw data for the numbers of various taxa in the Poplar Creek benthic samples are placed in Appendices 14-16. Figures 56 and 57 show the abundance and community composition on a major group basis respectively.

Chironomidae

Chironomid larvae were one of the most numerically important groups in Poplar Creek. Orthocladiinae, Chironominae (both Chironomini and Tanytarsini), Tanypodinae and Diamesinae occurred in the stream. The Diamesinae were collected only occasionally and in low numbers. Figure 58 presents the seasonal counts of the major types of chironomids, and it was evident that the Orthocladiinae were the dominant group. Also, the abundance of all the groups was higher at the two downstream sites than at the upstream location, most likely as a result of organic input from the reservoir. Of the two downstream sites, PC-2 tended to have higher chironomid larval densities than PC-1, except in the fall when for unknown reasons densities were high at PC-1. The reason for the generally higher level at PC-2 was not clear. Most of the Orthocladiinae and Chironominae are algae or algae-detrital feeders (Oliver, 1971), and it is possible that more organic material was available at the site closer to the spillway. Tanypodinae tend to be carnivorous, and their abundance is probably associated with higher numbers of available prey, which would include other chironomids.

The trends in total abundance of Chironomidae was basically a reflection of the fluctuations in abundance of Orthocladiinae. Populations at the downstream sites were generally low in the spring and early summer (less than 5000/m^2). They subsequently increased in late August and reached recorded summer maxima of 35,000/m^2 and 15,000/m^2 at PC-2 and PC-1 respectively. The counts declined in September and October to about 4000-5000/m^2 but then increased in November, particularly at PC-1 where a maximum density of 44,000 individuals/m^2 was recorded. The majority of these individuals were early instars of the Orthocladiinae. At PC-B4 numbers were low in the spring. During most of the summer and fall numbers at PC-B4 were in the 1,000 to 4,000/m^2 range but they increased in November to about 10,000/m^2.

Simuliidae

Simuliid larvae were much more abundant at stations below the spillway, undoubtedly as a result of organic particulate matter entering the stream

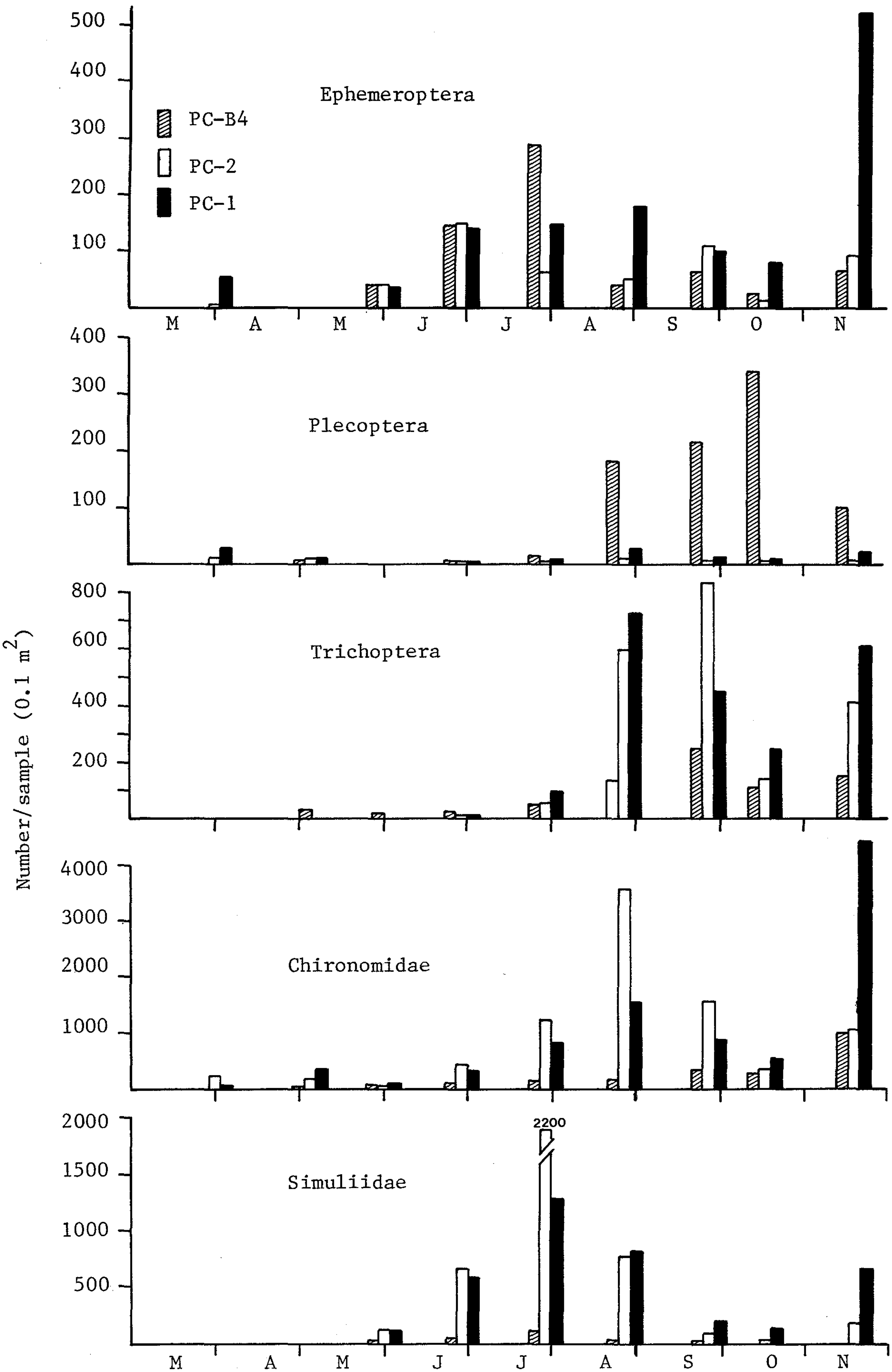


Figure 56 . Abundance of the major benthic groups in Poplar Creek in 1977. Each value is the mean of three Hess samples.

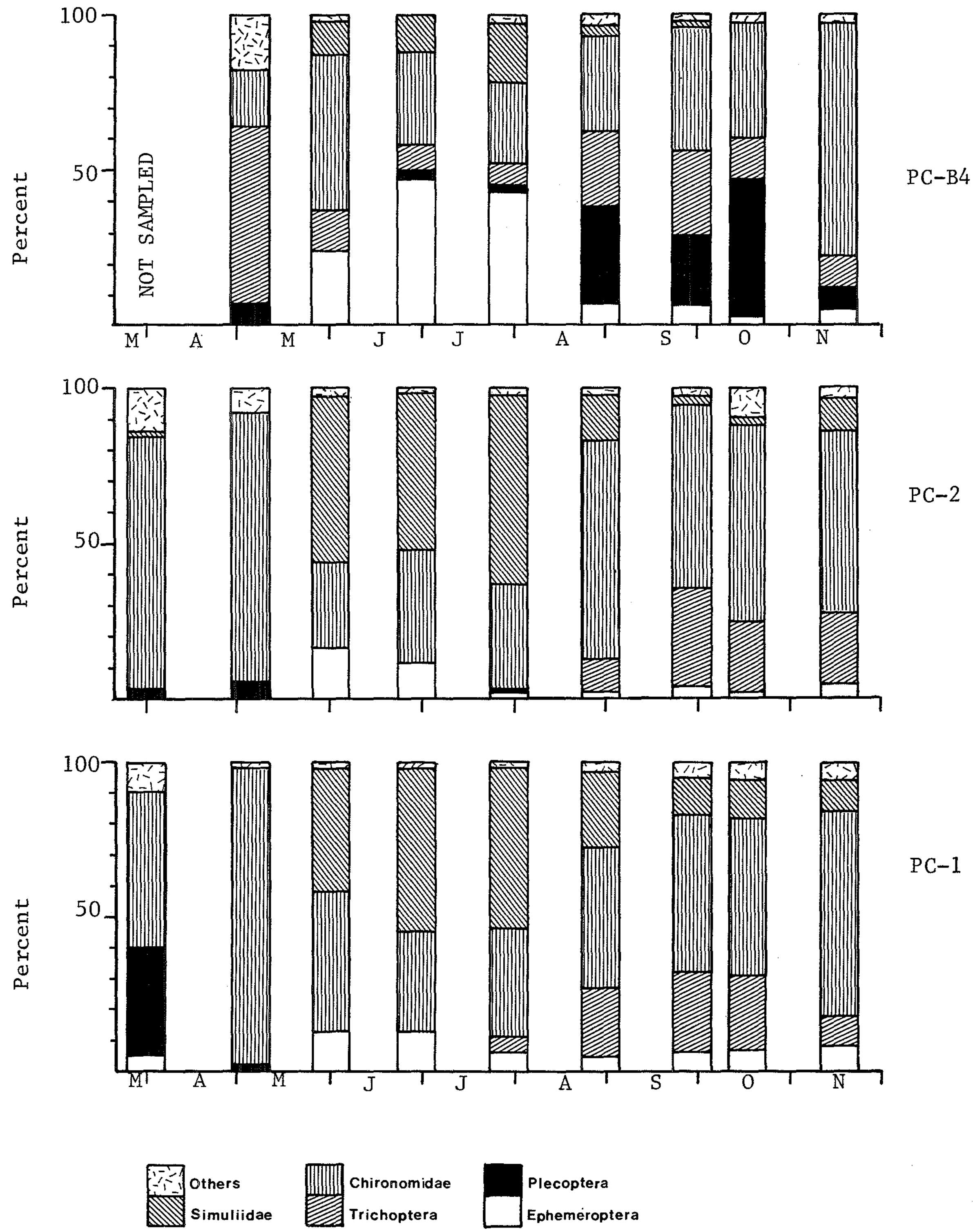


Figure 57. Numerical composition of the benthos in Poplar Creek in 1977.

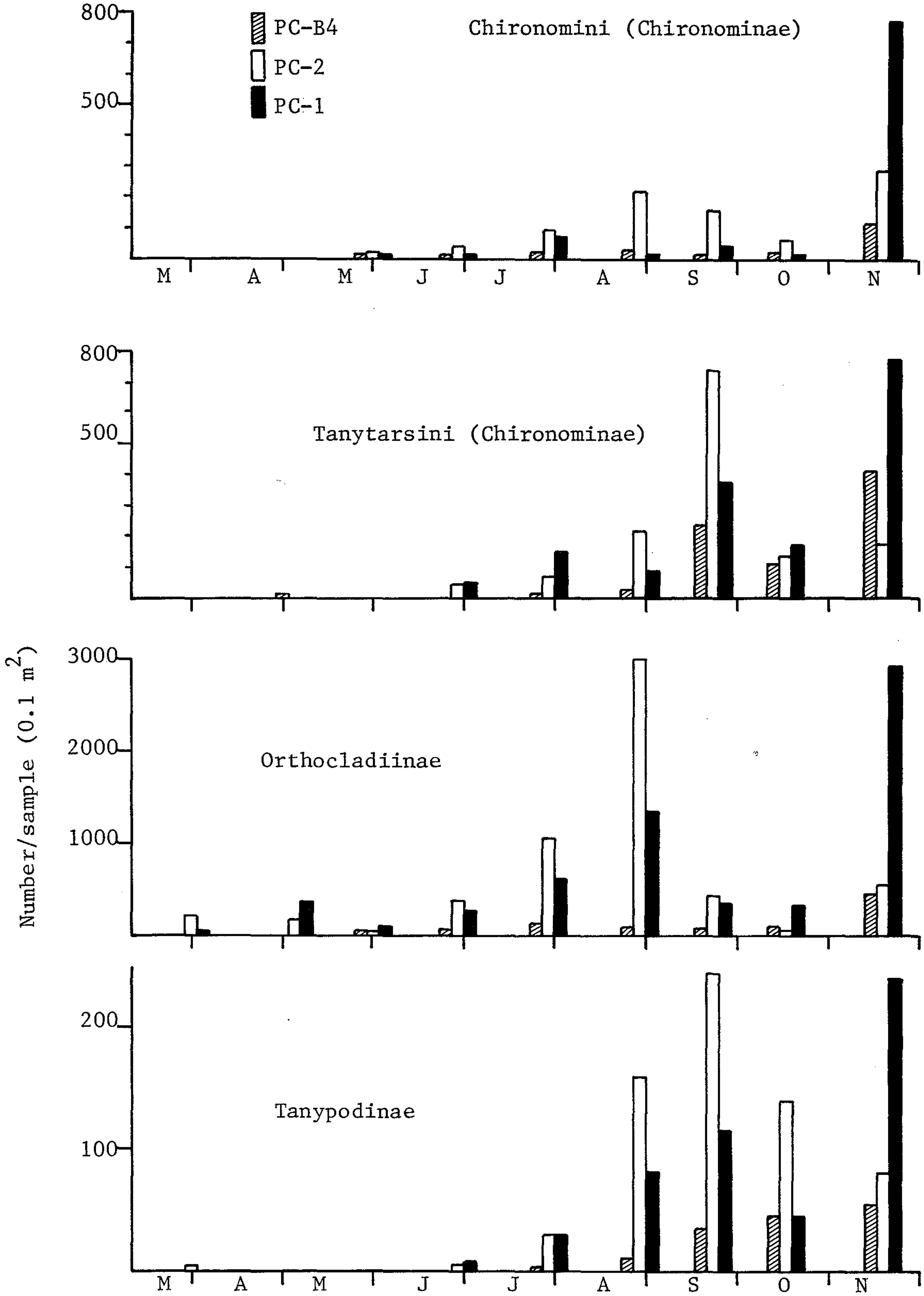


Figure 58. Abundance of Chironomidae in Poplar Creek in 1977. Each value is the mean of three Hess samples.

from the reservoir. Numerous simuliid larvae were observed in midsummer attached to substrates in shallow water around the wave-washed shore of the stilling basin. These larvae are filter feeders, and increased concentrations below lakes has been well documented (Hynes, 1970). Representative larvae and pupae were identified as *Simulium vittatum* (D. A. Craig, pers. comm.), and this was apparently the predominant species in summer in Poplar Creek. Sommerman *et al.*, (1954) considered this species characteristic of lake outflows, and Spence and Hynes (1971) noted *S. vittatum* as the only simuliid below a dam on the Grand River, Ontario.

At the downstream sites, abundance began to increase around late May, and a summer maximum was reached around late July, recorded densities being about 13,000/m^2 and 22,000/m^2 at PC-1 and PC-2 respectively. The numbers subsequently declined but then increased in November at which time small early instars predominated. At PC-B4 the maximum abundance of simuliid larvae was slightly over 1,000/m^2. As at the downstream sites, this maximum occurred during the late July sampling period.

The pattern of development of the blackfly larvae was difficult to determine. A wide distribution of larval instars was present at most times, which could indicate overlapping generations or the presence of several species. Pupae were present from late May to late September but their numbers were greatest in the late June to late August period.

Trichoptera

Filter-feeding trichopterans notably *Hydropsyche* and *Cheumatopsyche*, also showed higher densities at sites below the spillway. As with the filter-feeding simuliid larvae, many studies have documented the success of net-spinning caddisflies below lakes and impoundments (Hynes, 1970; Hynes and Spence, 1971; Cushing, 1963).

Both *Cheumatopsyche* and *Hydropsyche* were similar in abundance at PC-2 and PC-1, and total trichopteran numbers were a reflection of their density (Figure 56 and 59). At these downstream sites trichopteran populations were low through the spring and summer but increased markedly in the late August-September period. At that time counts of the two genera were in about the 250 to 500/m^2 range with total trichopteran abundance in the 500 to 800/m^2 range. Numbers declined in October but increased in late November (except for *Cheumatopsyche* at PC-1).

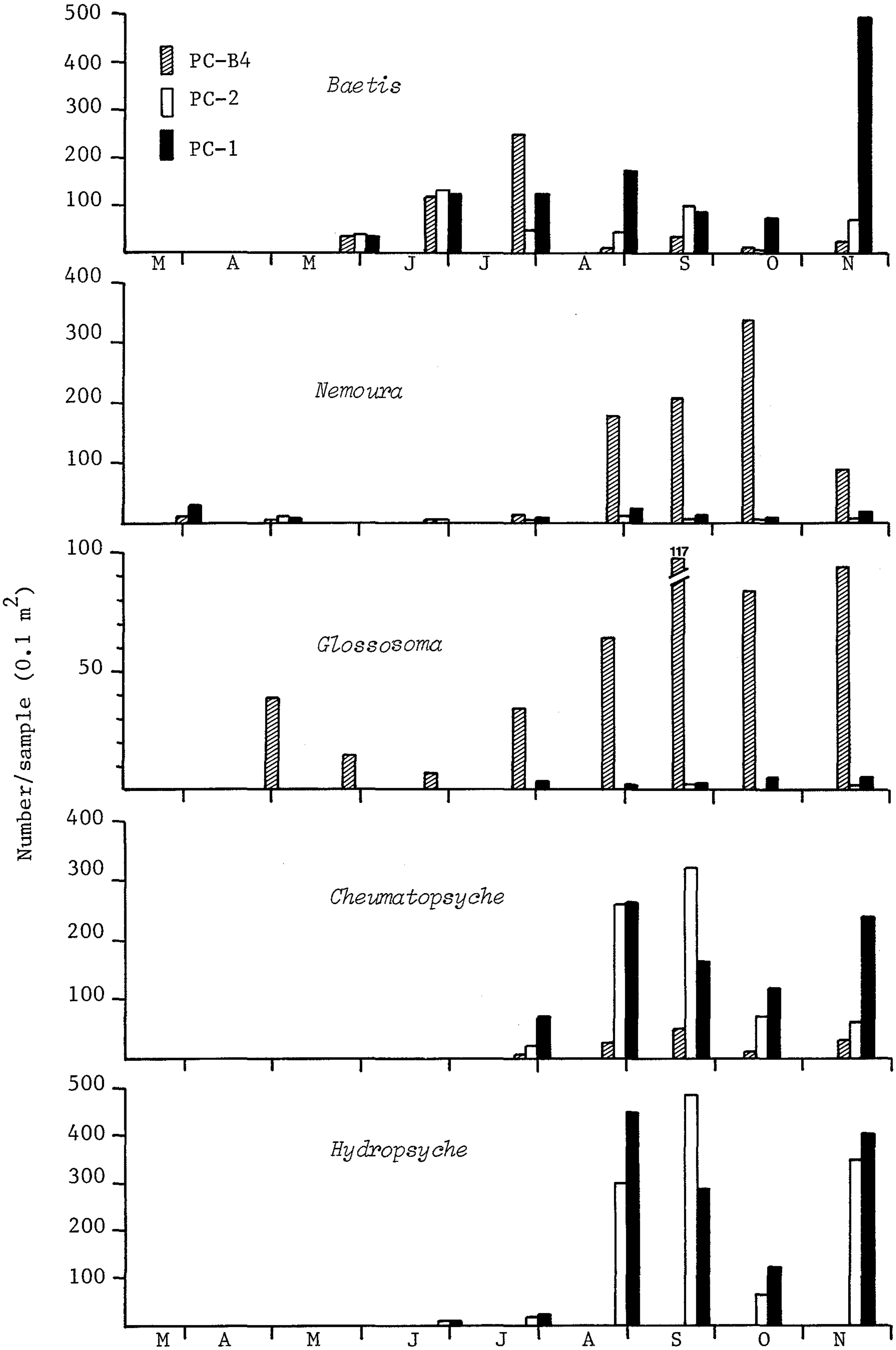


Figure 59. Abundance of selected benthic insects in Poplar Creek in 1977. Each value is the mean of three Hess samples.

The seasonal cycles of *Hydropsyche* and *Cheumatopsyche* were not clear. When populations increased in August, there was a wide range in size of larvae. Clifford (1969) observed the same pattern with *Cheumatopsyche analis* and *Hydropsyche* in the Bigoray River, Alberta. He attributed these variations in size to prepupal aestivation in the spring, after which some of the larvae pupate, emerge and reproduce while some become active larvae again. As a result many different sizes of larvae were present at one time.

Neureclipsis was another net-spinning caddisfly collected in Poplar Creek. It was not very abundant and was almost entirely confined to the sites below the spillway (Appendices 14-16). The Philopotamidae, the family to which *Neureclipsis* belongs, are carnivores that filter small animals from the current (Hynes, 1971), and the distribution of *Neureclipsis* probably reflected the higher particulate content of the water entering from the spillway. The remaining caddisflies that occurred below the spillway were present in low numbers and were minor components of the fauna.

At PC-B4, as at the downstream sites, trichopteran larvae tended to be most abundant in the late summer and fall. *Glossosoma* was the dominant genus although *Cheumatopsyche* and *Hydropsyche* were well represented, their combined abundance being similar to that of *Glossosoma*. *Glossosoma* was rarely collected at sites other than PC-B4.

The seasonal abundance of *Glossosoma* larvae is presented in Figure 59. In the spring and early summer most of the population was pupating and numbers gradually decreased, presumably due to emergence. In late July and August numbers increased, and the population consisted mostly of growing larvae. By fall most of the population was pupating.

Ephemeroptera

The Ephemeroptera were a relatively minor component of the benthos at the sites downstream of the spillway but were quite important at PC-B4 in the June-July period. *Baetis* was by far the dominant genus at all sites, and total numbers of Ephemeroptera were a reflection of its abundance (Figures 56 and 59). *Heptagenia* and *Ephemerella* consistently occurred at all sites in low numbers.

At PC-B4 counts of *Baetis* increased in the spring and early summer, reaching a recorded maximum in late July. At that time many of the nymphs were mature, and the subsequent decline by late August was presumably due to emergence. The populations remained low for the remainder of the season. The 1977 trends were similar to those in pre-diversion years (RRCS, 1975; Noton and Chymko, 1977), particularly in the magnitude and timing of the summer peaks in numbers.

At the downstream sites there were no consistent trends in seasonal abundance. The density of mayfly nymphs was in the 500 to 1500/m^2 range through much of the season. At PC-1 in November *Baetis* showed a very large increase due to an influx of small individuals.

Plecoptera

Like the Ephemeroptera, the Plecoptera were a minor component of the benthic communities downstream of the spillway but were important at PC-B4 at certain times. *Nemoura* completely dominated the stonefly fauna with interpretable patterns occurring only at PC-B4. At this site numbers were low through spring and most of the summer, but in late August and early fall numbers increased, presumably due to egg hatches. In late November counts apparently declined (Figure 59). The dynamics of the summer and fall period were very similar to those observed in 1974 and 1975. In the previous years, however, numbers were higher in early spring prior to an emergence in May-June; this is the emergence period reported by Radford and Hartland-Rowe (1971) for all species of *Nemoura* collected in several Alberta streams. There was a very small population of about 50 individuals/m^2 present on May 3 this year, and on May 31 it had virtually disappeared. It is possible that the majority of emergence occurred prior to the May 3 sampling date, or that winter mortality had been very high.

The low abundance of Plecoptera below the spillway was quite noteable. They were the only major insect group that was well represented upstream but low in numbers downstream. Temperature was an unlikely factor in this difference since it was well within the range of natural streams. It is possible that the food available in the downstream sites may not be suitable for herbivores or detritivores such as *Nemoura*. There would, however, seem to have been adequate food for carnivorous species such as *Arcynopteryx*, *Isogenus* and *Alloperla*, but these genera were essentially absent below the spillway. Spence and Hynes (1971) observed a similar absence of stoneflies below a dam on the Grand River, Ontario. They thought that oxygen depletion in the Aufwuchs community (the community of attached organisms) was likely to be a most critical factor for stoneflies since they are known to be very sensitive to slight decreases in oxygen. Nocturnal respiratory rates in heavy aufwuchs communities can cause oxygen depletion within the community (McIntire, 1966). At the sampling sites below the spillway the aufwuchs community was well developed, and nocturnal oxygen depletion in this community could be a factor in the absence of stoneflies. In the June 23-24 drift study, oxygen concentration and saturation was lowest at PC-1 during the night (Table 70), an indication that the respiratory demand at PC-1 was higher than at PC-B4.

Total Abundance and Seasonal Community Composition

Except for one occasion when numbers were slightly higher at PC-B4 than PC-2, the sites downstream of the spillway had higher densities than the upstream site (Figure 60). This was undoubtedly a result of the organic input in the form of phytoplankton, zooplankton, bacteria, protozoa, detritus, particulate organics, etc., from the reservoir system to the creek. The rock rubble substrate present below the spillway provided a suitable physical habitat for benthic organisms, and it was not unreasonable to expect, given this allochthonous energy input, that populations would be high. Nutrient enrichment from the reservoir system could be a factor that would also increase stream productivity; however, phosphate and nitrate values in the outflowing reservoir water were not significantly higher than in upper Poplar Creek water (see Table 71).

Seasonal trends in total densities at PC-2 and PC-2 were very similar to one another and differed from the trends at PC-B4. At the downstream sites, abundance was low in the spring and early summer, being about 2500 individuals/m^2. They subsequently increased due to higher simuliid and chironomid (mostly Orthocladiinae) numbers, with recorded values reaching a summer maximum of about 35,000 to 50,000 individuals/m^2 in late August. Populations decreased in the fall, reaching a low in October of about 5,000 to 10,000 individuals/m^2, then increased again in November due to higher chironomid numbers. This was particularly evident at PC-1 where the total density in November was around 65,000 individuals/m^2. At PC-B4 abundance was low in the spring, being about 1000 to 2000 individuals/m^2 but then gradually increased. During the summer, density was about 5,000 to 10,000 individuals/m^2 but increased in the fall to about 14,000 individuals/m^2. This increase, although not as notable as at the downstream sites, also involved chironomid larvae.

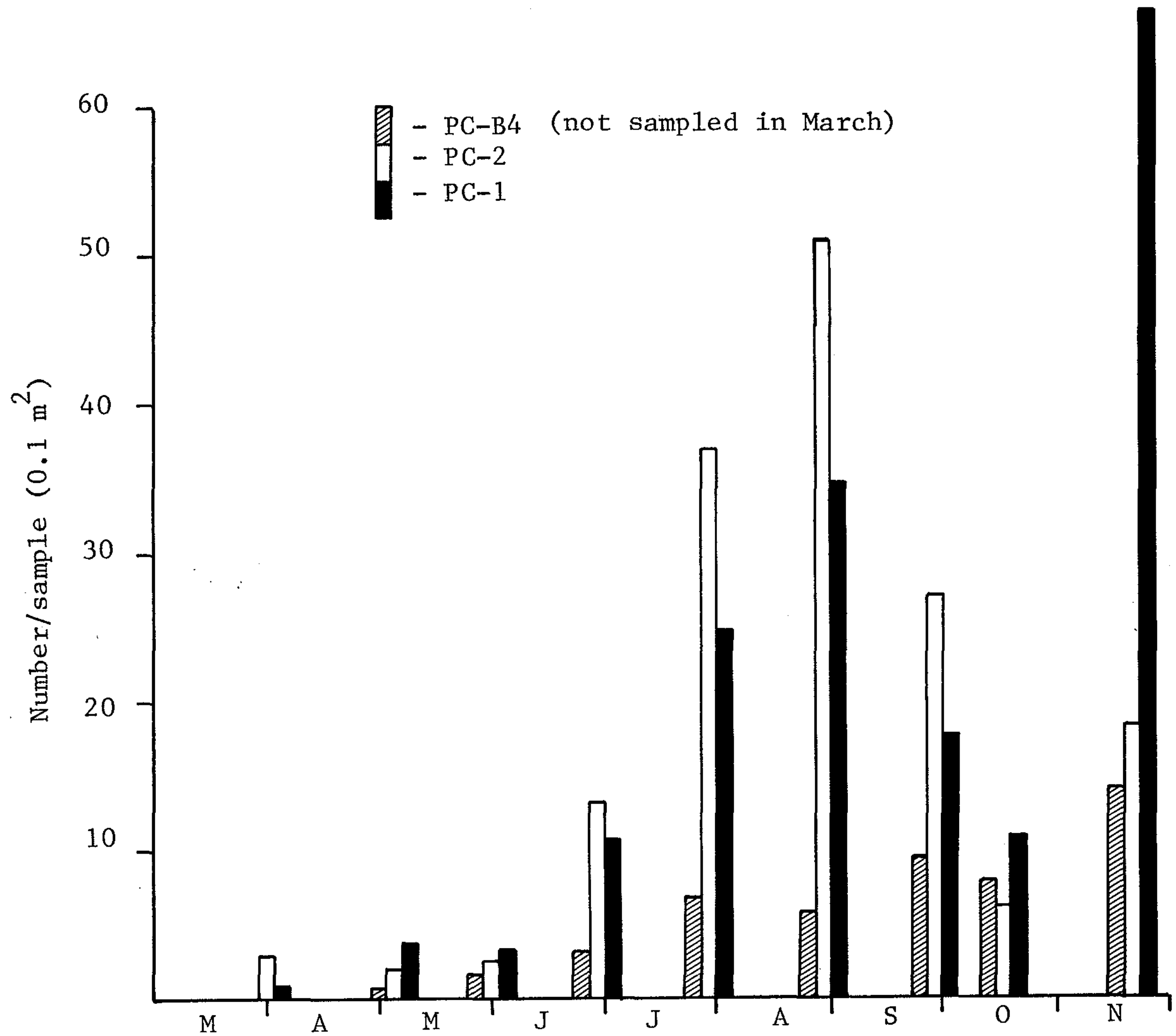


Figure 60. Total abundance of the benthos in Poplar Creek in 1977. Each value is the mean of three Hess samples.

Table 77 presents the average abundance of the major groups as well as some of the upstream versus downstream differences based on these averages. Because of the large temporal variations in abundance, both in total numbers and individual group abundance, these average values should not be construed as general levels of abundance during the season. They should be used as an indication of the relative numerical importance of the various groups.

Average total abundance was about three times higher at the downstream sites than at PC-B4. It is evident that the increase in total abundance at the sites downstream of the spillway largely comprised three groups (Figure 56 and Table 77). In order of importance they were: Chironomidae, Simuliidae and Trichoptera which accounted for, respectively, about 60%, 30% and 10% of the downstream increase.

The marked decline and subsequent increase in abundance at PC-2 and PC-1 in the fall deserves special comment, since it involved the Chironomidae, Simuliidae and Trichoptera, the most numerically important groups in the benthos. On September 11, the spillway was shut-off for structural modifications at which time the flow at PC-2 and PC-1 was greatly reduced. On October 9, it was reopened, and flow subsequently increased. The creek was sampled on September 22 and October 14, and it is possible that the combination of flow alterations and sampling schedule could have affected the numbers collected.

Stream organisms show differences in distribution across a stream due to variations in factors such as current speed and substrate. It is possible that under the reduced flow conditions, substrates could have been sampled that were previously in deeper water and may have contained fewer organisms. The reopening of the spillway could also have contributed to a decrease in abundance in the October samples in the following ways:

1) As the flow increased, substrates that were previously exposed would have been flooded. Since the depth to which a Hess sampler can effectively work is limited, the October samples could have been collected from areas that were recently flooded and had not yet been fully recolonized.

2) The sudden high flows could have constituted a flood which may have washed away invertebrates.

Table 77. Comparison of major groups of benthic macroinvertebrates at the Poplar Creek sampling sites, based on average[1] seasonal abundance. Values expressed as number/m^2.

	PC-B4	PC-2	PC-1	PC-2 Factor of Change[2]	PC-2 % Contribution to Total Difference[3]	PC-1 Factor of Change[2]	PC-1 % Contribution to Total Difference[3]
EPHEMEROPTERA	840	660	1510	- 1.27	-1	+1.8	+4
PLECOPTERA	1080	50	120	-21.6	-8	-9.0	-6
TRICHOPTERA	980	2560	2700	+2.6	+12	+2.8	+11
CHIRONOMIDAE	2830	10710	11380	+3.8	+59	+4.0	+56
SIMULIIDAE	280	5050	4770	+18.0	+35	+17.0	+29
OLIGOCHAETA	20	260	100	+13.0	+2	+5.0	+1
OTHERS	170	350	930	+2.0	+1	+5.5	+5
TOTAL	6200	19640	20575	+3.2		+3.3	

[1] calculated from the sampling period May 3 to November 18, 1977. March 30 excluded because of lack of samples at PC-B4.

[2] "factor of change" refers to the increase or decrease in numbers relative to PC-B4.

[3] "% contribution to total difference" refers to the portion of the difference accounted for by an individual group.

3) During the period of shutdown the stilling basin did not flow into the creek. Oxygen levels decreased in the basin to at least 4 ppm, and when this poorly oxygenated water was subsequently pushed into Poplar Creek, it may have induced some benthic invertebrates to leave the substrate.

The higher values in November may have occurred because of effective recolonization of the areas that showed reduced numbers in October. The high values involved young instars of Chironomidae, Simuliidae and Trichoptera, and it is possible that eggs hatched at that time in response to environmental alterations caused by the spillway operations, or that they hatched naturally.

The composition of the benthos was very similar at PC-2 and PC-1 (Figure 57). At these sites chironomids were usually the most important group, with the Orthocladiinae being the dominant sub-family. Although chironomids were generally important, simuliid larvae were co-dominants in the June-July period. Trichopteran larvae never dominated but were well represented in the late summer-fall period at which time their numbers were highest.

At PC-B4, chironomid larvae, basically Orthocladiinae, were important components of the community but did not dominate to the extent observed at downstream sites. Ephemeroptera, almost entirely *Baetis*, were very important in the June-July period. In late summer and fall Plecoptera (*Nemoura*) and Trichoptera (*Glossosoma*) were well represented. Blackfly larvae were never a major component of the benthos at this site. As at the downstream sites, they were most abundant in the June-July period.

Comparisons with pre-diversion conditions

Figure 61 presents total abundance at PC-B4 in the three study years. Sampling regimes varied among the years; only one sample was taken every two weeks in the 1975 study although three samples were taken every four weeks in 1974 and 1977. Considering this, there did not appear to be marked differences between years in the spring and summer abundance of benthos. In 1977, however, counts at this site in the fall were higher than in 1975. The major cause of this increase was a greater abundance of Chironomidae. The exact reason for the appearance of such high numbers was not clear, but it is not unusual for stream benthos to vary considerably from year to year (Hynes, 1970). Flows in 1977 were less than in previous years, and the biological community may reflect this.

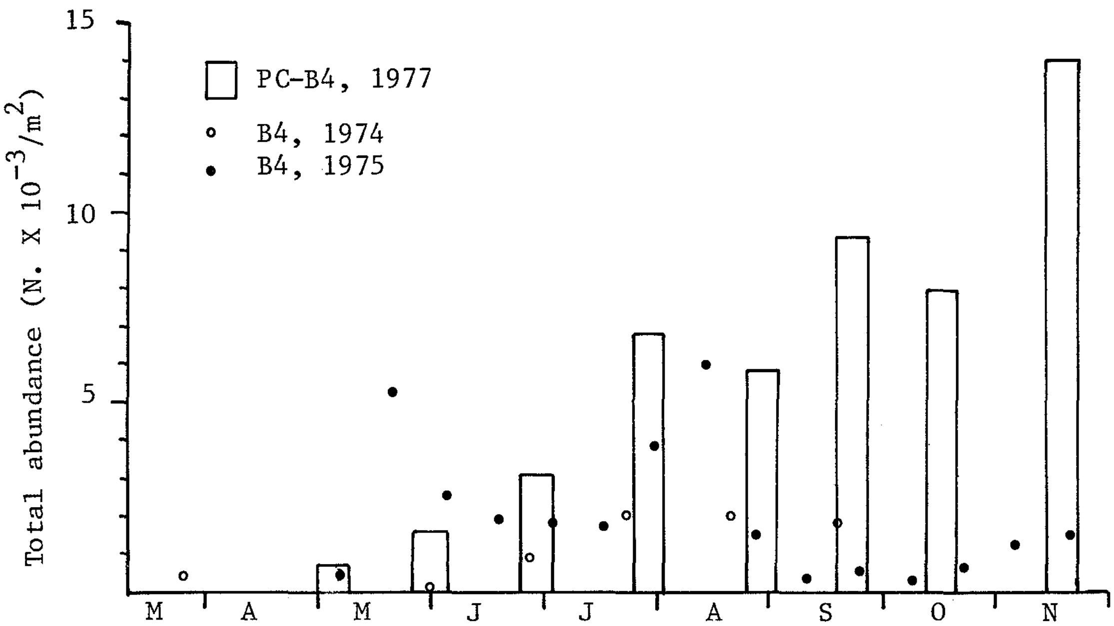


Figure 61. Total abundance of benthos at the upstream sampling site in Poplar Creek in the three study years. Site B4 in 1974 and 1975 was the same as PC-B4 in 1977.

In 1974 and 1975, under pre-diversion conditions, there were two sites, B2 and B1, in approximately similar positions to PC-2 and PC-1, respectively. These pre-diversion sites were eliminated by stream channel alterations. Site B1 was about 200-300 m upstream of Site PC-1, and the substrate consisted of sand-silt. For purposes of comparison with upstream sites, a gravel-rubble riffle would have been the preferred habitat to sample, however, such areas were not present in that section of the channel. Sand-silt substrates generally contain less numerous and less diverse benthic communities than do gravel or rubble stream beds (Hynes, 1970), and in both pre-diversion study years, Site B1 had a relatively low concentration of benthos. Densities were less than $250/m^2$ and were usually around $100/m^2$. Chironomid and non-simuliid dipteran larvae dominated the benthos; mayflies, stoneflies and caddisflies were rare.

Site B2 was slightly upstream of PC-2 and about 5 m downstream from where the stilling basin flows into Poplar Creek. In 1974, and until about June 1975, this site was a riffle similar to the upstream site B4 (called PC-B4 in 1977). After June 1975, construction activities at the spillway changed the nature of the site. At that time, sediment began to accumulate as a result of deeper water, reduced current velocities and silt input to the stream (Noton and Chymko, 1977). This had the effect of converting the substrate from a riffle type to one more similar to a pool sand-silt type, such as was found at Site B1. This was reflected in the zoobenthos which changed from a community similar to that of Site B4 to a community similar to Site B1.

The physical habitat of Poplar Creek below the spillway was tremendously modified during construction of the diversion system, and there is little value in detailed comparisons between old and new sites. The abundance of benthos on gravel, rubble and boulder substrates in the new channel was one to two orders of magnitude higher than on the sand-silt substrates in the old channel. Formerly, sand-silt substrates occupied almost the entire stream bed whereas in 1977, 40% of the channelized section of creek comprised gravel, rubble and boulder (Table 74). As a result, there would be considerably more zoobenthos in the creek under the modified conditions.

Drift

The 24-hour drift study was conducted on June 23 and 24, 1977, at PC-B4 and PC-1. The drifting organisms were grouped into four major categories: benthic organisms (further divided into Ephemeroptera, Diptera, and others); terrestrial and semiaquatic arthropods; zooplankton; and fish. The densities of these groups and their component taxa, collected in the two nets at each site are presented in Tables 78 and 79. Figure 62 shows the diurnal distribution and counts of the major groups in 1977. Table 80 presents summarized information on the density of the major groups in the 1975 and 1977 drift studies.

Plankton Drift

Zooplankton

The most striking feature of the 1977 drift study was the magnitude of zooplankton in the drift at PC-1. These organisms entered the natural stream drift via the spillway and completely dominated the drift at this site. Numerically they accounted for almost all the organisms collected (99%), and their composition and abundance is presented in Table 81. Cladocera was the most abundant group, composing 86% of the total zooplankton collected. *Daphnia pulicaria* was the dominant cladoceran species, representing 63% of the zooplankton, and the next most abundant species, *Bosmina longirostris*, made up 14%. *Daphnia galeata mendotae* and *Ceriodaphnia affinis* accounted for about 6% and 3% respectively, but *Chydorus sphaericus* was extremely rare (less than 0.1%). Cyclopoida made up about 10% of the zooplankton, *Mesocyclops edax* being the dominant species, and the Calanoida, which contributed about 4% of the total, were dominated by *Diaptomus leptopus*. The conchostracan *Lynceus brachyurus* accounted for less than 1% of the zooplankton, but due to its large size, it could have been important as a food source for fish.

Several of the zooplankton species were slightly more abundant in the early morning. *Daphnia pulicaria, D. galeata mendotae, Diaptomus leptopus* and *Mesocyclops edax* all showed maximum abundance in the 0500 to 0700 set. A nocturnal migration in which surface numbers reach a maximum some time between sunset and sunrise is common among zooplankton species (Hutchinson, 1967). At this time organisms would be most likely to be carried into the creek via the spillway.

Crustaceans were relatively uncommon in the 1975 study and were very rare at PC-B4 in the 1977 study. Amphipods, ostracods and harpacticoid copepods can be considered benthic, but cyclopoid copepods have both planktonic and benthic species. Although not identified to species, the cyclopoids collected in the drift at Site B4 in 1975, had large, robust bodies typical of benthic forms. Of the numerous cyclopoids collected at PC-1 in 1977, all specimens

Table 78. Density of drifting organisms at PC-B4, June 23-24, 1977. Results expressed as mean number/m^3 during the set.

	Set 1 1735-1920		Set 2 2150-2335		Set 3 0105-0305		Set 4 0505-0710		Set 5 0900-1130		Set 6 1300-1505		MEAN	%
	T	B	T	B	T	B	T	B	T	B	T	B		
BENTHIC ORGANISMS														
NON-INSECTS														
Nemata														
Nematomorpha		0.32			0.02	0.02							0.003	<1
Oligochaeta	0.09			0.11	0.02	0.04	0.06				0.06	0.02	0.033	<1
Hirudinea														
Amphipoda					0.04								0.003	<1
Harpacticoida														
Ostracoda														
Mollusca														
Hydracarina					0.08	0.02	0.04						0.012	<1
TOTAL	0.09	0.32		0.11	0.16	0.08	0.10				0.06	0.02	0.051	<1
INSECTS														
Ephemeroptera	2.30	6.98	0.51	0.80	24.96	21.43	4.20	3.45	1.09	0.63	1.04	1.16	5.710	41
Odonata					0.02								0.002	<1
Plecoptera		1.29					0.06	0.04	0.02		0.02		0.126	1
Hemiptera									0.02				0.002	1
Coleoptera														
larvae	0.09	0.32					0.02	0.02			0.02	0.02	0.041	<1
adults			0.05		0.02	0.04							0.009	<1
Trichoptera		0.32			0.29	0.25	0.28	0.10	0.07	0.03	0.16	0.06	0.130	1
Diptera														
Chironomidae	2.83	9.21	0.97	1.93	5.94	2.72	2.05	1.59	0.67	0.78	0.82	1.24	2.563	22
Simuliidae	0.62	0.63	0.26	0.80	4.85	3.86	2.63	1.89	0.58	0.58	0.50	0.62	1.485	13
others			0.05		0.02	0.02	0.04	0.02					0.015	<1
TOTAL	5.84	18.73	1.84	3.53	36.10	28.32	9.28	7.11	2.45	2.02	2.56	3.10	10.083	87
TOTAL BENTHIC ORGANISMS	5.93	19.05	1.84	3.64	36.26	28.40	9.38	7.11	2.45	2.02	2.62	3.12	10.134	87
TERRESTRIAL AND SEMIAQUATIC ARTHROPODS														
Collembola					0.02								0.002	<1
Araneae					0.04	0.02							0.005	<1
Insecta	0.18	1.59	0.05	0.57	0.37	0.62	0.14	0.04	0.15	0.07	0.14	0.12	0.337	3
TOTAL	0.18	1.59	0.05	0.57	0.43	0.64	0.14	0.04	0.15	0.07	0.14	0.12	0.344	3
PISCES					2.55	2.68	4.74	3.51	0.02	0.05	0.04	0.04	1.137	10
TOTAL DRIFT	6.11	20.64	1.89	4.21	39.24	31.72	14.26	10.66	2.62	2.14	2.80	3.28	11.62	

Table 79 . Density of drifting organisms at PC-1, June 23-24, 1977. Results are expressed as number/m^3 during the set.

	Set 1 1715-1915		Set 2 2130-2330		Set 3 0100-0300		Set 4 0500-0710		Set 5 0900-1120		Set 6 1300-1505		MEAN	%	% (excluding zooplankton)
	T	B	T	B	T	B	T	B	T	B	T	B			
BENTHIC ORGANISMS															
NON-INSECTS															
Nemata															
Nematomorpha															
Oligochaeta	0.05		0.05	0.05		0.10	0.37	0.09	0.04	0.17	0.15	0.29	0.113	<1	1
Hirudinea															
Amphipoda															
Harpacticoida															
Ostracoda															
Mollusca															
Hydracarina	0.50	0.20	0.30	0.20	0.15	0.35	0.33	0.23	0.09		0.29	0.10	0.228	<1	2
TOTAL	0.55	0.20	0.35	0.25	0.15	0.45	0.70	0.32	0.13	0.17	0.44	0.39	0.341	<1	3
INSECTS															
Ephemeroptera	0.91	1.01	0.45	0.61	14.70	13.18	1.35	1.68	0.39	0.48	0.24	1.07	3.006	<1	23
Odonata															
Plecoptera	0.15	0.05		0.15	0.15	0.30		0.09					0.074	<1	1
Hemiptera	0.86	0.51	0.71	0.40	0.61	0.51	0.79	0.33	0.52	0.17	0.49	0.24	0.512	<1	4
Coleoptera															
larvae	0.05	0.05			0.05		0.05						0.017	<1	<1
adults															
Trichoptera		0.05		0.05	0.05				0.04	0.09	0.05		0.028	1	<1
Diptera															
Chironomidae	1.76	3.63	1.41	3.08	8.94	6.82	3.45	4.43	1.17	2.08	0.97	2.28	3.335	<1	26
Simuliidae	0.66	1.46	0.56	0.81	2.27	1.78	1.12	1.86	0.43	1.73	0.29	0.49	1.122	<1	9
others						0.05							0.004	<1	<1
TOTAL	4.39	6.76	3.13	5.10	26.77	22.64	6.76	8.39	2.55	4.55	2.04	4.08	8.098	<1	62
TOTAL BENTHIC ORGANISMS	4.94	6.96	3.48	5.35	26.92	23.09	7.46	8.71	2.68	4.72	2.48	4.47	8.439	<1	65
TERRESTRIAL AND SEMIAQUATIC ARTHROPODS															
Collembola															
Araneae				0.05									0.004	<1	<1
Insecta	0.81	0.91	0.30	0.76	2.89	0.86	1.77	0.84	0.26	0.74	0.49	0.49	0.927	<1	7
TOTAL	0.81	0.91	0.30	0.81	2.89	0.86	1.77	0.84	0.23	0.74	0.49	0.49	0.931	<1	7
ZOOPLANKTON															
Cladocera	2330	2899	2974	2557	2954	3201	3899	4889	3699	2954	3085	2257	3142	85	
Calanoida	57	76	95	152	114	227	331	248	74	81	40	73	131	4	
Cyclopoida	247	133	171	114	398	322	507	619	387	633	418	364	359	10	
Conchostraca	13	22	34	37	29	40	44	60	18	31	4	6	28	<1	
Chaoborinae	0.20	0.05	0.15	0.05	0.66	0.35	1.16	0.33					0.246	<1	
	2647	3130	3274	2860	3496	3790	4782	5816	4178	3699	3547	2700	3660	99	
PISCES	4.64	4.04	4.09	2.07	6.87	5.20	3.92	2.42	2.64	2.03	3.64	3.20	3.731	<1	28
TOTAL DRIFT	2658	3142	3282	2868	3533	3820	4795	5828	4184	3706	3554	2708	3673		
NON-ZOOPLANKTON DRIFT	7.59	1.96	2.02	8.28	2.34	19.50	5.31	8.30	3.58	6.49	3.61	8.16	12.75		

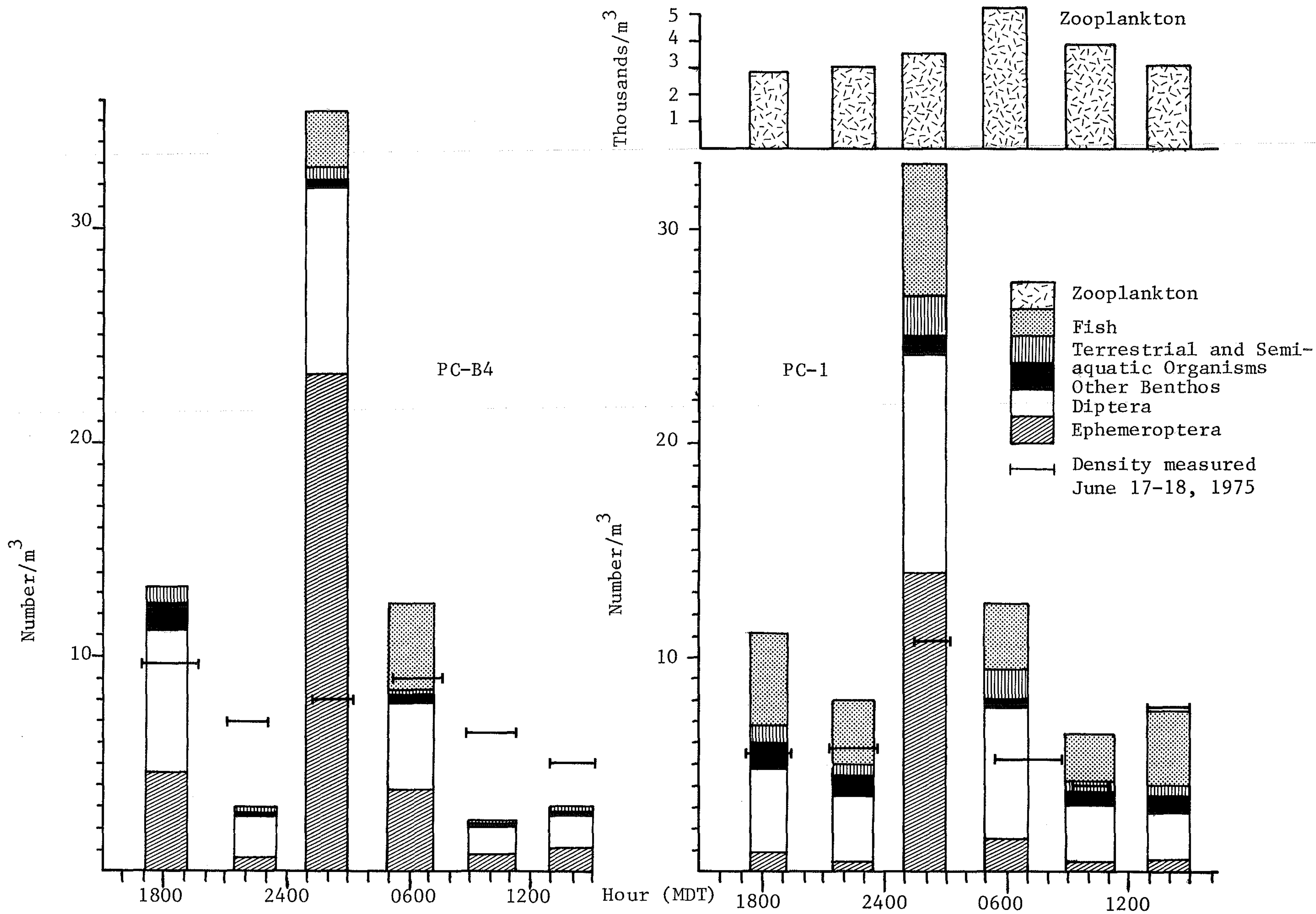


Figure 62. Density of drifting organisms in Poplar Creek, June 23 and 24, 1977.

Table 80. Summary of drifting organisms in Poplar Creek in 1975 and 1977. Results are a combination of both nets and are expressed as mean number/m^3 during the set.

Site B4 (= PC-B4), June 17 and 18, 1975

	Set 1 1705-1945	Set 2 2115-2305	Set 3 0115-0310	Set 4 0510-0730	Set 5 0910-1100	Set 6 1310-1510	MEAN	% OF TOTAL ORGANISMS COLLECTED
BENTHIC ORGANISMS								
EPHEMEROPTERA	2.15	2.59	3.83	2.16	1.61	1.29	2.27	28.02
DIPTERA	3.58	2.27	2.70	3.15	2.30	2.17	2.70	33.33
OTHERS	2.60	2.74	1.11	3.73	1.99	1.66	2.31	38.52
TOTAL	8.33	7.60	7.64	9.04	5.90	5.12	7.28	89.87
TERRESTRIAL AND SEMIAQUATIC ARTHRO-PODA	1.94	0.64	0.40	0.60	0.72	0.46	0.78	9.63
PISCES	0.01	0.03	0.03	0.08	0.01	0.06	0.04	0.50
TOTAL	10.28	8.27	8.07	9.72	6.63	5.64	8.10	

Site PC-B4, June 23 and 24, 1977

	Set 1 1735-1920	Set 2 2150-2335	Set 3 0105-0305	Set 4 0505-0710	Set 5 0900-1130	Set 6 1300-1505	MEAN	% OF TOTAL ORGANISMS COLLECTED
BENTHIC ORGANISMS								
EPHEMEROPTERA	4.64	0.65	23.20	3.82	0.86	1.10	5.71	49.14
DIPTERA	6.64	2.00	8.72	4.11	1.31	1.59	4.06	34.94
OTHERS	1.21	0.09	0.41	0.31	0.12	0.18	0.38	3.27
TOTAL	12.49	2.74	32.33	8.24	2.24	2.87	10.15	87.35
TERRESTRIAL AND SEMIAQUATIC ARTHRO-PODA	0.88	0.31	0.53	0.09	0.10	0.13	0.34	2.93
PISCES			2.61	4.12	0.04	0.04	1.13	9.72
TOTAL	13.37	3.05	35.48	12.45	2.38	3.04	11.62	

Continued . . .

Table 80. Concluded.

Site B1 (= PC-1), June 17-18, 1975

	Set 1 1710-1935	Set 2 2120-2310	Set 3 0130-0310	Set 4 0520-0915	Set 5 0925-1105	Set 6 1320-1510	MEAN	% OF TOTAL ORGANISMS COLLECTED
BENTHIC ORGANISMS								
EPHEMEROPTERA	2.29	2.28	6.57	1.73	1.41	1.63	2.65	40.33
DIPTERA	1.70	1.96	2.62	1.70	1.64	2.80	2.07	31.51
OTHERS	0.52	0.75	0.95	1.67	0.83	1.73	1.07	16.29
TOTAL	0.51	4.99	10.14	5.10	3.88	6.16	5.79	88.13
TERRESTRIAL AND SEMIAQUATIC ARTHROPODA	0.87	0.78	0.66	0.43	0.25	1.47	0.74	11.26
PISCES	0.06			0.05	0.02	0.09	0.04	0.61
TOTAL	5.44	5.77	10.80	5.58	4.15	7.72	6.57	

Site PC-1, June 23 and 24, 1977

	Set 1 1715-1915	Set 2 2130-2330	Set 3 0100-0300	Set 4 0500-0710	Set 5 0900-1120	Set 6 1300-1505	MEAN	% OF TOTAL ORGANISMS COLLECTED	% OF TOTAL ORGANISMS COLLECTED (excluding zooplankton)
BENTHIC ORGANISMS									
EPHEMEROPTERA	0.96	0.53	13.94	1.51	0.43	0.65	3.00	0.08	22.90
DIPTERA	3.88	3.03	10.43	6.18	2.71	2.02	4.71	0.13	35.95
OTHERS	1.11	0.86	0.63	0.40	0.56	0.81	0.73	0.02	5.57
TOTAL	5.95	4.42	25.00	8.09	3.70	3.48	8.44	0.23	64.42
TERRESTRIAL AND SEMIAQUATIC ARTHROPODA	0.86	0.56	1.87	1.30	0.49	0.49	0.93	0.02	7.10
ZOOPLANKTON	2888	3067	3643	5299	3938	3123	3660	99.65	
PISCES	4.34	3.08	6.03	3.17	2.34	3.42	3.73	0.10	28.47
TOTAL	2899	3075	3676	5312	3945	3130	3673		
TOTAL (excluding zooplankton)	11.15	8.06	32.90	12.56	6.53	7.39	13.1		

Table 81. Summary of zooplankton in the Poplar Creek drift at PC-1, June 23-24, 1977. Results expressed as mean number/m^3 during the set.

	SET 1 1715-1915		SET 2 2130-2330		SET 3 0100-0300		SET 4 0500-0710		SET 5 0900-1120		SET 6 1300-1505			
	T	B	T	B	T	B	T	B	T	B	T	B	MEAN	%
CLADOCERA														
Bosmina longirostris	95	133	284	322	360	265	210	301	1141	779	1533	892	526	14.38
Ceriodaphnia affinis		95	38	38	208	133	52	106	92	162	179	91	100	2.72
Chydorus sphaericus		19										18	3	0.08
Daphnia galeata mendotae		57	114	38	284	170	385	638	313	162	159	127	204	5.57
Daphnia pulicaria	2235	2595	2538	2159	2102	2633	3252	3844	2153	1851	1214	1129	2309	63.08
													3142	85.83
COPEPODA														
CALANOIDA														
nauplii														
Diaptomus leptopus	57	76	95	152	114	227	314	248	37	65	40	18	120	3.29
Diaptomus oregonensis							17		37	16		55	10	0.28
													130	3.57
CYCLOPOIDA														
nauplii														
Cyclops bicuspidatus thomasi	95	38	95	57	57	38	35	53	37	130	119	146	75	2.05
C. navus	19	19	19		19		17	35	37				14	0.38
Mesocyclops edax	133	76	57	57	322	284	455	531	313	503	299	218	271	7.40
													360	9.83
CONCHOSTRACA														
Lynceus brachyurus	13	22	34	37	29	40	44	60	18	31	4	6	28	0.77
CHAOBORINAE														
Chaoborus	0.20	0.05	0.15	0.05	0.06	0.35	1.16	0.33					0.24	0.01
TOTAL	2547	3130	3274	2860	3495	3790	4721	5816	4178	3699	3547	2700	3661	

counted in subsamples were planktonic forms, and it appeared that benthic types of cyclopoids were rare or absent in the drift at that station.

Algae

Unconcentrated phytoplankton samples were collected from PC-B4 and PC-1 on July 27, 1977, to investigate the algae occurring in the drift upstream and downstream of the spillway. Algal counts from the two sites and from site PCR-1 in Poplar Creek Reservoir are in Table 82. The algal drift was quite different at the two locations in the creek. Total counts were less than 100 cells/ml at PC-B4 but were moderately high (about 1500 cells/ml) at PC-1. The species prevalent at each site were also quite different, and it appears that the assemblage of drifting algae at PC-1 was unrelated to that at PC-B4. The density of drifting algae at PC-B4 in 1977 was similar to that found at two sites sampled in the creek in August and September of 1975 (Noton and Chymko, 1977) and appeared typical for a stream receiving no major inflows from standing water.

The drifting algae at PC-1 resembled the phytoplankton collected from Poplar Creek Reservoir on July 29 (Table 82) except for the numerous blue-green algae found in the reservoir which were rare at PC-1. It appeared that the colonial blue-green algae that entered the creek via the spillway were removed from the water mass before reaching site PC-1. The fate of the blue-green algal cells is not known; however, other algae were not noticeably reduced in numbers of species or cell densities between the reservoir and site PC-1 (Table 82).

Non-plankton Drift

Excluding the zooplankton, the abundance and composition of the drift at PC-1 was roughly similar to that at PC-B4. Benthic organisms were the major non-zooplankton drift at PC-1 (64%) and dominated the drift at PC-B4 (87%) (Table 80). Mean drift densities (individuals/m^3) of benthic organisms were similar at the two sites, being 10.2 at PC-B4 and 8.4 at PC-1, and mayflies and dipterans were the most abundant groups. The mayflies were almost entirely *Baetis*; the dipterans included Chironomidae and Simuliidae, the former group being more abundant.

Fish were the next most important group and were almost exclusively sucker fry. Mean abundance and percent contribution were about three times

Table 82. Algae in water samples from Poplar Creek and Poplar Creek Reservoir, July, 1977.

	Algal density - cells/ml		
	July 27		July 29
	PC-B4	PC-1	PCR-1-Top*
Cyanophyta			
Anabaena flos-aquae		+	20,942
Aphanizomenon flos-aquae		+	8,267
Bacillariophyceae			
Cocconeis	+		
Pennate diatoms (unident. further)	+	53	48
Stephanodiscus	+	+	72
Synedra		18	
Flagellates			
Cryptomonas		70	72
Dinobryon		35	72
Euglena	+		
Rhodomonas		88	
Trachelomonas		18	
Unident. flagellates	+	53	72
Chlorophyta			
Ankistrodesmus		176	96
Chlamydomonas		35	
Closterium	+		
Coccoid forms (unident. further)	+	35	72
Crucigenia		+	96
Oocystis		88	
Pandorina morum	+		
Pediastrum		70	192
Scenedesmus		281	862
Tetraedron minimum	+		
Ultraplankton		527	599
Total cells/ml		1,546	31,461

+ Occurred in quantities too low for enumeration
* From Appendix 11

higher at PC-1 than PC-B4 ($3.73/m^3$ versus $1.13/m^3$ and 28% versus 10%, respectively) which may reflect more spawning in the portion of the stream below the spillway. The fry exhibited a more marked diurnal periodicity at the upstream site, being collected almost entirely in the 0100 to 0700 period. At the downstream site, they were consistently collected throughout the sampling period although the greatest number occurred in the 0100 to 0300 set. The reasons for the more marked periodicity at PC-B4 were not clear. In a study of the Bigoray River in Alberta, Clifford (1972) also observed a nocturnal drift pattern for white sucker fry.

The terrestrial and semiaquatic arthropods were the least abundant major group, composing 3% of the drift at PC-B4 and 7% of the non-zooplankton drift at PC-1. Terrestrial insects (mostly chironomids) were dominant, with low numbers of Araneae (spiders) and Collembola.

Diurnal patterns were similar between the two sites (Figure 61). *Baetis* exhibited a very marked periodicity and was much more abundant in the middle of the night (0100 to 0300). This pattern was observed in 1975 (Noton and Chymko, 1977), but for uncertain reasons the magnitude of night activity was much higher in 1977. Other observers have also documented a night-active pattern for *Baetis* (Hynes, 1970; Clifford, 1972). The dipterans were also more active at night although the pattern was less notable than for *Baetis*. Both the Chironomidae and Simuliidae exhibited this trend. For unknown reasons this night-active pattern was not discernable for the Chironomidae in 1975 and was less noticeable for the Simuliidae.

The mean density (individuals/m^3) of the benthic invertebrate drift at PC-B4 (10.2) was slightly higher than at PC-1 (8.4), even though the benthos at PC-2 and PC-1 was about three to four times more abundant than at PC-B4. In 1975, a similar discrepancy between drift densities and benthic standing crops occurred when drift densities of bottom organisms were similar at Site B4 and B1 even though the former site had much higher standing crops. Waters (1972), in a review of the literature, stated that there is no direct, linear relation between benthic invertebrate drift and standing crop. It has been suggested that drift is a function of production in excess of stream-bottom carrying capabity; thus, a habitat with higher standing crops may not contribute more organisms to the drift because the habitat can hold more organisms before a drift response occurs. In Poplar Creek this excess production hypothesis implies that the number of organisms in excess of stream bottom carrying capacity was similar between the sites.

Summary

The mean densities of the major groups are in Table 83. The major change in the drift after diversion was the very high numbers of zooplankton that occurred downstream of the spillway. In 1977, zooplankton accounted for more than 99% of the total drift at PC-1. Another important difference that occurred was the collection of greater numbers of fish fry in 1977. More fish were utilizing the stream in 1977 (to be discussed later), and the increased abundance of fry suggests that more spawning has occurred in the creek. However, a direct relationship can not be inferred here since it was not known when peak fry emergence occurred in either year.

Terrestrial and semiaquatic arthropods showed no obvious difference between sites and years. Benthic invertebrate drift was basically similar between upstream and downstream sites in both study years even though standing crops were very different between sites. In 1975, the benthic densities were much higher at the upstream site compared to the downstream site, but in 1977, the opposite was true. As mentioned, the amount of drift is not necessarily proportional to benthic standing crop.

Stilling Basin Zooplankton

Quantitative zooplankton samples were collected on the regular sampling dates at the point where the stilling basin entered Poplar Creek. In September the spillway was shut off, and no sample collected; and the contents of one sample from late June were lost. The composition and abundance of this zooplankton is presented in Table 84.

As expected, seasonal trends in abundance and composition of this zooplankton basically followed the events in Poplar Creek Reservoir. Populations were low in late winter and early May but increased in late May due to the spring cyclopoid pulse (*Cyclops bicuspidatus thomasi* and *Cyclops vernalis*). A late June sample was not available, but since total abundance had declined in the reservoir at this time, it is likely the number of organisms going through the spillway also decreased. Maximum numbers entering the creek occurred in late July and late August and involved *Bosmina longirostris* and *Diaptomus oregonensis*. In the fall the numbers were lower, at which time *D. oregonensis* was completely dominant.

Table 83. Summary of mean densities (individuals/m^3) of the major groups in the 1975 and 1977 drift studies of Poplar Creek. Values in brackets indicate percent.

		Benthos	Terrestrial and Semiaquatic Arthropods	Zooplankton	Fish	Total
1975	Site B4	7.28 (90)	0.78 (10)		0.04 (<1)	8.10
1977	Site PC-B4	10.15 (87)	0.34 (3)		1.13 (10)	11.62
1975	Site B1	5.79 (88)	0.74 (11)		0.04 (1)	6.57
1977	Site PC-1	8.44 (<1) (64[1])	0.93 (<1) (7[1])	3660 (100)	3.73 (<1) (28[1])	36.73 (13.10[1])

[1]excluding zooplankton

Table 84. Abundance of zooplankton at the outlet of the stilling basin, 1977. Values expressed as numbers/m^3.

	March 30	May 12	May 31	July 29	Aug. 26	Oct. 14	Nov. 18
CLADOCERA							
Bosmina longirostris			2,941	29,411	34,314	197	
Ceriodaphnia affinis				294	1,569		
Daphnia pulicaria						98	
Daphnia parvula			4,608				
Diaphanosoma leuchtenbergianum				392	98	197	
TOTAL CLADOCERA			7,549	30,097	35,981	492	
COPEPODA							
CALANOIDA							
nauplii			196	13,333	2,941		
Diaptomus oregonensis							
copepodite			294	4,803	10,392	590	
adult				3,627	3,725	13,077	7472
TOTAL CALANOIDA			490	21,763	17,058	13,667	7472
CYCLOPOIDA							
nauplii		728	4,902	1,961		197	
copepodite (unidentified)			16,176	294	98	197	
Cyclops vernalis							
copepodite		300	2,745				
adult			1,569				
Cyclops bicuspidatus thomasi							
copepodite			4,020				590
adult	0.20	39	294				
Cyclops navus							
copepodite		35					
Mesocyclops edax							
copepodite				686			
adult				98			
TOTAL CYCLOPOIDA	0.20	1102	29,706	3,039	98	394	590
TOTAL ZOOPLANKTON	0.20	1102	37,745	54,899	53,137	14,553	8062

As might be expected, the composition of the zooplankton in the spillway drift did not exactly correspond with the zooplankton composition at the main stations in the reservoir. Vertical and horizontal distributions in the reservoir, as well as different susceptibilities to physical damage, would have affected the composition of the zooplankton entering the creek via the stilling basin.

Fish

General

As previously discussed, Poplar Creek has been channelized downstream of the spillway and now accomodates two to three times the flow of pre-diversion conditions. The habitat in the channelized section has changed from a meandering, slow-flowing, stream with sand-silt substrates to one with a direct channel containing a heterogeneous substrate of boulders, rubble, gravel and sand-silt. Not unexpectedly, fish have exploited the new habitat and were present in greater numbers than in the original stream. The new substrates are suitable for the spawning of at least some species, and the depth and turbidity of the water apparently provides adequate cover for the larger fish in the absence of overhanging banks and vegetation. The drop structures in the channelized bed may provide some hindrance to fish movement by creating torrential flow, but their boulder composition also provides larger interstices which have very low current velocities. Measurements taken on May 3 in the main chute of drop structure # 7 (which had one of the highest velocities) revealed that while the current ranged up to 2.9 m/sec at the surface, velocities near boulders were about 1.4 m/sec and were too low to measure between boulders on the bottom. Fish can probably take advantage of these current irregularities in moving upstream, and all species collected in the creek, except walleye, were found upstream of at least some drop structures. Walleye were only taken at the base of drop structure # 1 and at the Poplar Creek - Athabasca River confluence area.

Implementation of the diversion has augmented the food available to fish in the channelized section of the creek. This was a result of the improved habitat for benthos and the input of plankton in spillway flows. The boulder, rubble and gravel substrates deposited during channelization provide a more stable and heterogeneous habitat for benthos than did the predominantly sand-silt substrates previously. The plankton entering from Poplar Creek Reservoir constitute a food source for benthic invertebrates and to at least some extent for fish; the larger zooplankton in particular may be utilized by fish.

The fish community has responded fairly rapidly to the new environment, and in 1977 fish were more numerous and diverse in Poplar Creek than they had been in 1974 or 1975 prior to diversion. Most of the fish must have come from the Athabasca River although brook sticklebacks and fathead minnows, the most abundant species present, probably entered Poplar Creek via the spillway from Poplar Creek Reservoir. Although sampling efforts in 1974 and 1975 (RRCS, 1975; Noton and Chymko, 1977) were not as great as in 1977, a two day July electrofishing survey in each of those years did not capture as many fish as a similar survey this year (Table 85).

Increased fish abundance appeared to extend up Poplar Creek above the spillway confluence. Although this upper reach has not been affected by the diversion, brook sticklebacks, fathead minnows and lake chub occurred as far up as station PC-B4 (Figure 53); and grayling and white suckers were more abundant in the vicinity of S7 than they had been in past years. The former three species were not collected from the creek at all in past years.

Fifteen species of fish were collected in Poplar Creek this year as compared to only five in 1974-75. Sticklebacks, fathead minnows and lake chub were the most abundant species encountered (Table 86), with white and longnose suckers next. Grayling and pike were common in the creek in 1977, and a number of other species (Table 86) were occasionally collected as well. Only one specimen each of spottail shiners and yellow perch were collected.

The species occurring in Poplar Creek were similar to those found by McCart *et al.*, (1977) in adjacent sections of the Athabasca River. Goldeye, flathead chub and slimy sculpin were not collected in Poplar Creek although the first two species were quite abundant in the main river. Goldeye and flathead chub apparently were not moving into Poplar Creek in significant numbers, or if they were, they were staying in the lowest reach of the creek where sampling was not intensive. Sculpins may have been present in the creek but not collected because of their close adherence to the substrate.

Mountain whitefish, finescale dace and fathead minnows were not reported from the Athabasca mainstem by McCart *et al.*, (1977) although mountain whitefish have been taken in other tributaries of the river (Robertson, 1970; Griffiths, 1973; RRCS, 1974b). Finescale dace may not be abundant in the area but do occur in the Athabasca drainage (Paetz and Nelson, 1970).

Table 85. Numbers of fish sampled electrofishing in July of 1974, 75, 77, in Poplar Creek.

Species	1974[1]	1975[2]	1977
Arctic grayling	2	2	10
Northern pike			1
White sucker	2	5	10
Longnose sucker	2		38
Lake chub (larger specimens)			6
Burbot		1	

[1] RRCS, 1975

[2] Noton and Chymko, 1977

Table 86. Species of fish collected in Poplar Creek in 1977 and their relative abundance.

Very abundant - 100 or more collected each survey

Brook stickleback - *Culaea inconstans* (Kirtland)

Fathead minnow - *Pimephales promelas* (Rafinesque)

Lake chub - *Couesius plumbeus* (Agassiz)

Abundant - about 10 to 100 collected each survey

* White sucker - *Catostomus commersoni* (Lacepede)

* Longnose sucker - *C. catostomus* (Forster)

Common - about 3 to 10 collected each survey

* Arctic grayling - *Thymallus arcticus* (Pallas)

* Northern pike - *Esox lucius* (Linnaeus)

Occasional - 1 or 2 collected each survey or several only once

Lake whitefish - *Coregonus clupeaformis* (Mitchill)

Mountain whitefish - *Prosopium williamsoni* (Girard)

Finescale dace - *Chrosomus neogaeus* (Cope)

Yellow walleye - *Stizostedion vitreum vitreum* (Mitchill)

Trout-perch - *Percopsis omiscomaycus* (Walbaum)

* Burbot - *Lota lota* (Linnaeus)

Rare - only 1 collected in total

Spottail shiner - *Notropis hudsonius* (Clinton)

Yellow perch - *Perca flavescens* (Mitchill)

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* Also observed in 1974-75.

Brook sticklebacks, fathead minnows, lake chub

Brook sticklebacks and fathead minnows were the most abundant fish encountered in Poplar Creek in 1977. They were taken mostly in seine hauls (Table 87) in all reaches of the creek except for the lower section and mouth. In these areas sampling was less intensive, however, and both species may occur there in, at least, some abundance. Neither species had been collected in the creek in past years, and they have probably entered via the spillway from Poplar Creek Reservoir since they are not common in the Athabasca River proper (McCart *et al.*, 1977). Successful passage over the spillway seems possible for small fish such as these since they could probably avoid excessive damage in the thin sheet of water flowing down the spillway. Gas supersaturation in the stilling basin probably was not a problem for fish because the water does not plunge to a great depth, the normal cause of this problem (Harvey and Cooper, 1962), but instead mixes in a turbulent eddy within a metre of the surface.

Sticklebacks and fathead minnows were taken on all occasions when fish were collected, from April through September, and have moved upstream in the creek, being taken at Station PC-B4 in late June. Small young of the year of both species (15-17 mm total length) were collected in June and July, but it was not known if they were produced in the creek or entered from Poplar Creek Reservoir.

Lake chub are a common species in the vicinity of the study area. They have been collected regularly in Beaver Creek (Table 10) and were reported as common in the Athabasca River (McCart *et al.*, 1977). They were found to be very abundant in Poplar Creek and were collected by electrofishing and seining throughout the study and at most locations in the creek. Although present in upper Beaver Creek and Beaver Creek Reservoir, they were not observed to be in Ruth Lake or Poplar Creek Reservoir, and had not been collected in Poplar Creek in 1974 or 1975. Therefore the population in the creek probably originated in the Athabasca River. Individuals collected in 1977 were 20 to 80 mm long; the smallest individuals appeared to be young of the year, indicating that some reproduction was occurring in the creek.

White suckers

White suckers were the most abundant larger fish collected and were successfully spawning in the creek. This species is common in the area and

Table 87. Relative abundance of small fish in seine hauls from Poplar Creek, July and September, 1977.

	Location[1]							
	DS-1	DS-2	DS-3	DS-7	DS-10	SB	UPC-SB	UPC-S7
July 25-26								
Brook stickleback	A	A	A	C	O	A	O	C
Fathead minnow			C	C	O	A	O	
Lake chub				O		A		
White sucker						C		
Longnose sucker						O		
Unidentified suckers	A	A	C	A	C		O	C
Arctic grayling			O					O
Lake whitefish			R					
Trout-perch	C							
Spottail shiner	R							
Yellow perch			R					
Sept. 20								
Brook sticklebacks	C	C	A		C	A	O	C
Fathead minnow			A		C	C	O	C
Lake chub	O	O	A		C	C		O
White sucker						A		
Longnose sucker						A		
Unidentified suckers	C	C	A		C		O	C
Arctic grayling			R					
Finescale dace						O		

A - abundant
C - common
O - occasional
R - rare

[1] Refer to map of sampling locations. UPC refers to Upper Poplar Creek.

has been found in sizeable numbers in the past in both Beaver Creek (RRCS, 1973) and the Muskeg River (RRCS, 1974b), two other tributaries of the Athabasca River. Over 100 large individuals (greater than 150 mm FL) and numerous smaller ones were collected during 1977 (Appendix 17). Most fish were released, but representative individuals were sacrificed to assess maturity and food habits. This species was collected from March to September, when fish collections ceased. It was apparently not abundant before late April since only two individuals were collected prior to April 26. Fish over 150 mm FL were collected, by electrofishing, in all habitats sampled although in lower frequencies in pools. Gill nets caught white suckers in pools, especially the stilling basin, and smaller specimens were taken in seine hauls throughout the creek. The species seemed to be abundant and broadly distributed through the lower 3 km of Poplar Creek, and has probably invaded the creek from the Athabasca River. The number of white suckers collected in previous years was not as high as in 1977 (Table 85).

Table 88 contains observations on the occurrence of spawning individuals of white suckers in Poplar Creek. Ripe individuals were first observed on May 11, when the water temperature had reached 17^{o}C after a period of warm weather. They may have occurred there somewhat before that date since the creek had last been sampled on May 6. Most ripe fish were in the upper reaches, around the stilling basin and section S7 (Figure 53), and were probably spawning in both areas since substrates there contained much gravel and rubble substrate. Young of the year and juvenile white suckers were collected throughout the creek in July and September by seining (Table 87).

Longnose suckers

Longnose suckers are a common fish in the Athabasca drainage, being abundant in collections from the mainstem Athabasca (McCart *et al.*, 1977) and tributaries (RRCS, 1973; 1974b). They were collected regularly in 1977 in Poplar Creek by electrofishing and seining and were almost as abundant as white suckers. About 90 individuals (over about 150 mm FL) were collected of which most were released. Appendix 17 contains length-weight information from a representative sample of these fish, the largest of which was 567 g in weight. There was a fairly continuous distribution in size of collected fish, down to individuals of about 30 mm FL. Small individuals including some young of the year were collected with seines. These smaller fish were not

Table 88. Incidence of ripe white suckers in Poplar Creek, spring 1977.

Date	Midday Water Temperature °C	Number of live fish examined	Number ripe
April 15	4	1	-
20	3	-	-
26	6	10	-
27	4	1	-
May 2	9.5	9	-
6	10	3	-
11	17	18	8♂♂ 1♀
12	12	1	1♂
18	7	5	2♂♂

as abundant as the young of white suckers. This species has undoubtedly moved into Poplar Creek from the Athabasca River since it only occurred in low numbers in the creek prior to the diversion.

Longnose suckers were taken in most areas sampled in the creek, from early May through September, when collections ceased. None, however, were obtained at the mouth, and only one or two individuals were observed upstream of the stilling basin confluence. This species was most frequently collected at the drop structures. Use of the creek in the open season by longnose suckers appeared to be primarily for feeding although a small amount of spawning may have occurred as well. No ripe individuals were collected in the spring, but a few young of the year were taken in the creek in September. This species apparently did not use the creek for spawning as much as did white suckers.

Arctic grayling

Although widespread and often common in Athabasca River tributaries, arctic grayling apparently are not collected in great numbers in the main river itself (McCart *et al.*, 1977). They were commonly collected in Poplar Creek in 1977, being taken with gill nets, seines and electrofishing throughout the channelized creek bed and up to area S7. Grayling were first collected on April 20 and were still present when the creek was last sampled for fish on September 20. Scales were used to determine ages, and all age classes up to and including age 6 were encountered among the 31 grayling collected. Mean lengths and weights observed for each age class are presented in Table 89.

Grayling collected this year were probably originating in the Athabasca River. Pre-diversion populations did not appear to be as high as that sampled this year (Table 85), consequently these fish were probably moving in from the main river. Four young of the year were collected in 1977 (Table 89) indicating that some spawning was occurring in the creek; however, this would appear to be quite limited. Only four young-of-the-year grayling were collected in all the seining carried out (Table 68) and this age class of grayling must have been uncommon in the creek. No ripe individuals were taken in spring, and only two fish older than two years of age were collected in that season.

Table 89. Summary of age and growth data for arctic grayling collected in Poplar Creek, 1977.

Age	n	Mean Fork Length (& Range) mm	Mean Weight (& Range) g
*0	4	66 (61 - 78)	
*1	6	91 (84 - 101)	
1	4	139 (125 - 151)	51 (30 - 85)
2	3	194 (170 - 220)	94 (57 - 113)
3	8	261 (228 - 305)	248 (142 - 397)
4	2	298 (275 - 320)	397 (340 - 454)
5	1	320	397
6	3	366 (359 - 370)	634 (596 - 681)
	31		

* Measurements taken on formalin-preserved specimens.

It would appear that grayling used Poplar Creek in the open season primarily for feeding. Stomachs of two six-year-old males, gill netted at drop structure # 1 in September, contained mostly Simuliidae larvae, which were very abundant in the benthos, and a few Corixidae, Despite the fact that arctic grayling were regularly collected in this study, several conversations with anglers through the summer revealed that grayling were not commonly angled in the creek in 1977.

Northern pike

Northern pike are broadly distributed throughout the Athabasca oil sands region and in the immediate vicinity of the study area are common in the Athabasca River (McCart *et al.*, 1977) and the Muskeg River system (RRCS, 1974b). They were common in Poplar Creek, with 32 individuals being collected this summer by electrofishing, gillnetting and angling (Appendix 17). Although no creel census was attempted, anglers frequently reported catching pike in the creek. These pike are probably originating in the Athabasca River since only one or two individuals have been observed in Poplar Creek in past studies.

Table 90 contains a summary of age and size information for pike collected this year. Ageing was done with scales; however, crowding of annuli made this difficult, and ages must be considered tentative at present. It was notable that no fish less than an estimated 4 years of age was taken. Extensive seining carried out in July and September failed to collect young pike even though such seining occasionally captured larger pike. Larger pike were taken from late April to September inclusive, throughout the channelized creek and in the stilling basin. None were taken upstream of the stilling basin confluence nor were any collected in the lower reaches. The fish collected ranged from 227 to 1759 g.

Many of the pike taken in April and May were in or close to spawning condition. Of 14 examined, 2 were sacrificed and found to be gravid females. The remaining 12 were released after a check for emission of eggs or milt: 7 emitted no sex products, but 4 were ripe males, and 1 was a ripe female. This occurrence of adults in spawning condition contrasts with a lack of pike young of the year in Poplar Creek in 1977. Very little submerged vegetation of any kind was present in Poplar Creek or the stilling basin when an inspection was made on May 12. Pike normally require such vegetation for

Table 90. Summary of age and growth data for northern pike collected in Poplar Creek, 1977.

Age (Est.)	n	Mean Fork Length (& Range) mm	Mean Weight (& Range) g
[1]4	1	310	227
5	5	492 (475 - 515)	987 (851 - 1192)
6	5	450 (355 - 510)	647 (425 - 851)
7	7	495 (470 - 555)	1021 (738 - 1475)
8	6	553 (485 - 600)	1168 (823 - 1504)
9	5	590 (510 - 678)	1478 (1021 - 1759)
10	2	540 (485 - 595)	1050 (851 - 1248)
11	1	520	993
	32		

[1] No fish younger than 4 years were collected.

spawning although in its absence they have been reported to spawn on unvegetated substrates (Fabricius and Gustafson, 1958). Whether these fish spawned on bare substrates in Poplar Creek, left the creek before spawning or resorbed their eggs is not known. In the absence of pike young of the year, it must be assumed that spawning was not successful in Poplar Creek in 1977.

Stomach contents of six pike taken in spring were examined, and brook sticklebacks were the most common food item at the time (Table 91). The abundant small fish in the creek (sticklebacks, young suckers, cyprinids) probably provided a ready food supply for pike throughout the summer, and pike may be utilizing Poplar Creek as a feeding area. In spring they may be entering the creek in search of spawning areas.

Occasional species

Six species of fish, walleye, lake whitefish, mountain whitefish, burbot, trout-perch and finescale dace were collected only occasionally in the creek (Table 86). Walleye were never encountered upstream of drop structure # 1. Their use of Poplar Creek appeared to be concentrated in the lower reach and the creek mouth (Appendix 17). A ripe male was taken at the latter location on April 27. Sports fishermen, at least occasionally, caught walleye throughout the summer in the creek below drop structure # 1 and at the creek mouth. This species has been collected in the Athabasca River (McCart *et al.*, 1977), in the Muskeg River (RRCS, 1974b) and in the Beaver Creek - Athabasca River confluence (RRCS, 1973) in the past and is fairly well distributed throughout the area. Its use of Poplar Creek was probably restricted to feeding since adults in spawning condition were not taken within the creek, although one was found in the confluence. The significance of that specimen was uncertain although a similar occurrence has been reported from the Beaver Creek - Athabasca River confluence in the past, where numerous walleye in spawning condition were observed at the mouth but apparently did not enter Beaver Creek (RRCS, 1973).

Six lake whitefish (Appendix 17) were collected in pools in the creek in spring and fall, by electrofishing and gillnetting . As well, a one year old was seined on July 26 at drop structure # 3. Two females collected in the fall were mature fish and were developing eggs but were not considered likely to spawn in fall, 1977. Use of Poplar Creek by this species would seem to have been only occasional and perhaps for feeding. Of three stomachs examined from fall-collected fish, two were empty and the third

Table 91. Stomach contents of northern pike from Poplar Creek, 1977.

Date	Location	Weight g	Food Items			
			Brook stickleback	Fathead minnow	Unidentifiable fish	Fish eggs*
April 27	DS-2	1475	30		13	
May 11	DS-2	1248	3			+
	DS-2	993			1	
	DS-2	1504	15	1	5	+
May 12	DS-2	851	5		1	
	SB	1731			1	

* Likely those of consumed fish

contained Corixidae and immature stages of Dytiscidae, Simuliidae, Trichoptera and Ephemeroptera. Lake whitefish have not been reported as common in tributaries to the Athabasca River in this area but were found to be abundant in the main river itself by McCart *et al.*, (1977).

Mountain whtefish have been reported from the oil sands area in the past (Robertson, 1970; Griffiths, 1973; RRCS, 1974b) but were not taken from the Athabasca River by McCart *et al.*, (1977). Four individuals were collected from Poplar Creek in the spring of 1977 (Appendix 17). Their use of Poplar Creek was difficult to assess; however, being primarily bottom feeders (Paetz and Nelson, 1970), they may have been utilizing benthic invertebrates in the creek as a food source.

Burbot were occasionally collected in Poplar Creek. They were taken at the mouth in spring and in the channelized creek bed in fall. These piscivorous fish may have been utilizing the creek as a feeding area since the numerous sticklebacks and cyprinids in the stream could provide a ready food supply. Burbot have been collected previously by McCart *et al.*, (1977) in the Athabasca River, and in Beaver Creek by three investigators (Robertson, 1970; RRCS, 1971; RRCS, 1973). One specimen had been collected in Poplar Creek previously (Noton and Chymko, 1977).

Trout-perch which are fairly common in the Athabasca River (McCart *et al.*, 1977) were collected at the Poplar Creek - Athabasca River confluence on April 15 and just above drop structure # 1 on July 25. They would appear to have been frequenting the creek on an occasional basis. Finescale dace, of which 6 individuals were collected on September 21 in the stilling basin, are not commonly reported from the area. No other individuals of this species were collected during the study. Spottail shiners and yellow perch were rare species, being represented in Poplar Creek collections by only one fish each. They were both taken in seine hauls on July 26.

Overwintering

Prior to construction of the diversion system, Poplar Creek was well oxygenated in winter (Noton and Chymko, 1977), and the presence of adult suckers and grayling upstream of large beaver dams (considered impassable to fish) indicated that these fish were able to overwinter in the creek. In Poplar Creek below the spillway confluence, no measurements of oxygen under the ice cover have yet been made; however, some evidence indicated there may have been a considerable oxygen demand in that section of the stream which could imply winter oxygen depletion. Diurnal measurements, taken during the drift study in June, showed a marked decline in dissolved oxygen overnight (discussed previously), and during spillway shut off in September oxygen had fallen to about 40% saturation (4 mg/l at 12^{o}C) in the stilling basin about 2 weeks after flow had ceased. Since present plans call for the spillway to be shut off during the winter, there will not be a sizeable flow of oxygenated water entering the creek from the spillway in winter, and all flow in the channelized creek bed will be from upper Poplar Creek. Such flows are very low in winter, and the possibility exists that they would be inadequate to replenish oxygen deficits that may develop in the channelized creek. Benthic biomass was observed to increase and accumulate during the open season in 1977, and such high benthic standing crops would probably exert a considerable oxygen demand during the winter.

If any oxygen deficiency were to develop in the lower reaches of Poplar Creek, fish would probably attempt to avoid such unfavourable conditions by simply moving downstream and entering the Athabasca River. Observations made in September, however, during spillway shut off, indicate that the drop structures impeded fish movement at low flow. Several of these structures had no surface flow at the time, but water was percolating through crevices in them. These interstices did not appear to be large enough to allow passage of all sizes of fish. Several individuals of pike, grayling, white sucker and lake whitefish, considered too large to pass such obstructions, were captured from the pools between the drop structures at that time.

One other observation is pertinent to the overwintering of fish in the creek. On April 14, 1977, more than 50 dead and partially decomposed fish were observed accumulated in the rock and wire mesh of drop structure # 2. Most of these appeared to be white suckers, but individual burbot, grayling and whitefish were also observed. The exact cause and time of their death was unknown; however, water ceased flowing over the spillway in late winter, and a possible explanation for the fish mortality is that oxygen had been severely depleted in lower Poplar Creek with the resulting reduced flows.

In summary, several things indicate that the winter conditions of lower Poplar Creek may not be safe for fish:

- low oxygen content may occur under low flow conditions
- larger fish, at least, can not pass all the drop structures under low flow conditions

- winter discharge from the spillway is not intended, therefore low flows will result
- fish did not leave the creek prior to spillway shut-off in 1977
- dead fish were observed in the creek in spring, 1977, subsequent to a period of low flow

DIVERSION CANALS

Two diversion canals have been excavated in the Beaver Creek Diversion System to facilitate the flow of water from Beaver Creek to Poplar Creek (Figure 63). They are situated between Beaver Creek Reservoir and Ruth Lake (Sections A and B), and between Ruth Lake and Poplar Creek Reservoir (Sections C and D). The canals were of variable widths and depths (Table 92), but in general were fairly shallow. Most of their banks and substrate were soft organic material (muskeg), and clumps of this peat-like material was lodged through sections B and C. Section A was narrower than sections B and C and cut through gravel over much of its length. The banks and substrates were primarily gravel and sand-silt with lesser amounts of peat. Some submergent aquatic macrophytes (mostly *Potamogeton berchtoldii*) had established in this section, but in other parts of the canals, aquatic macrophytes, other than shoreline emergents, were rare. Section D was much narrower than the rest of the canal system because it consisted of only the original pilot ditch which had not subsequently been widened. It went through the large stand of emergent macrophytes at the north end of Poplar Creek Reservoir.

The current in the canals was not great although it varied with depth and width of the channel. Data on water depth presented in Table 92 were collected during September when flows and water levels were low.

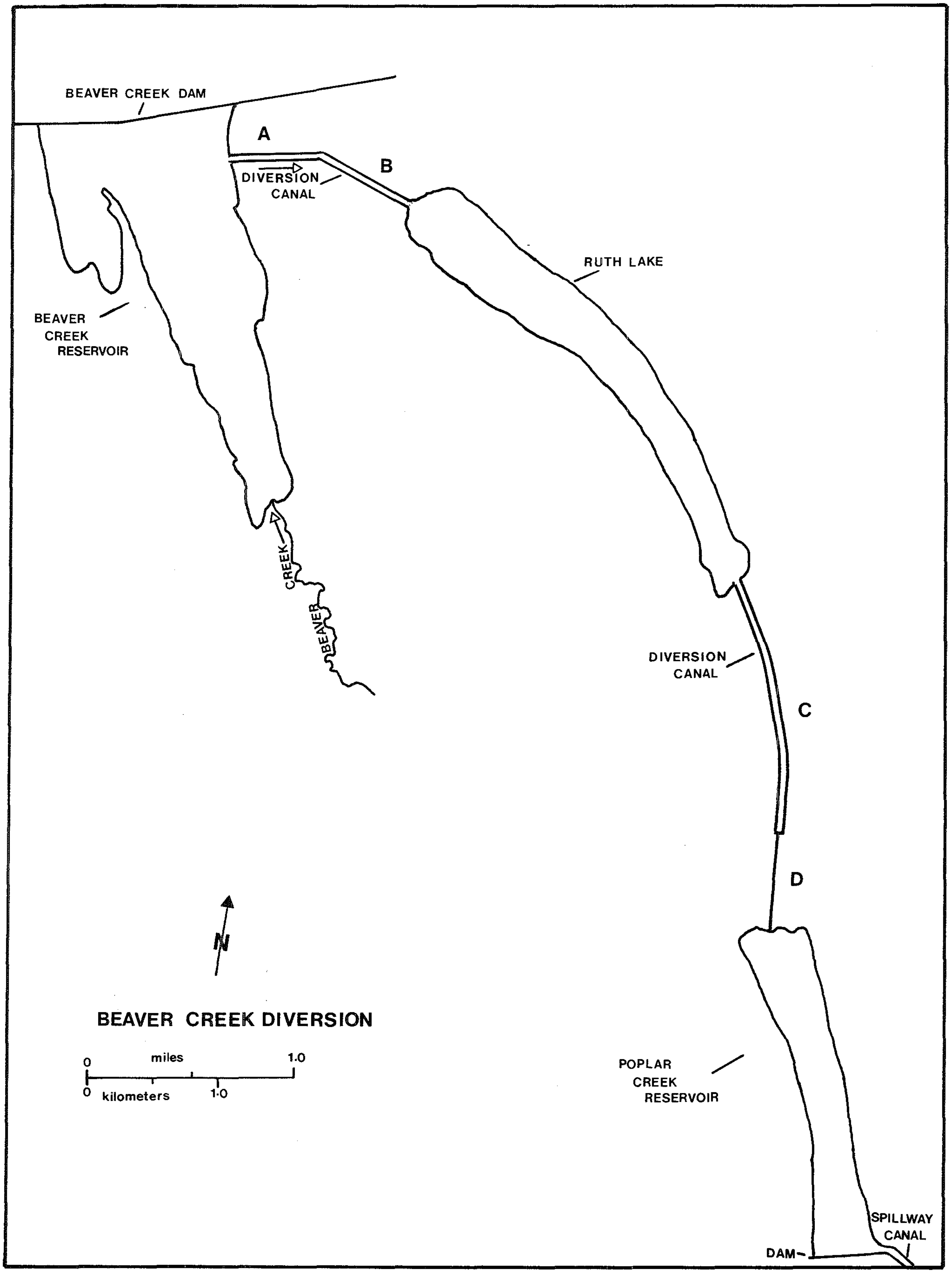

Figure 63. Outline of canals in the Beaver Creek Diversion System.

Table 92. Characteristics of the diversion canals in the Beaver Creek diversion system, 1977.

Section[1]	Channel Width m (ft)	Channel Length m (ft)	Water Depths[2] cm (in)
A	15-18 (50-60)	670 (2200)	20-50 (8-20)
B	30 (95)	914 (3000)	0-50 (0-20)
C	23-30 (75-100)[E]	2621 (8600)	0-50 (0-20)[E]
D	5 (15)[E]	1036 (3400)	0-30 (0-12)[E]

[1] See outline of canals

[2] Observed Sept. 22-23, 1977

[E] Estimated

GENERAL DISCUSSION

The system

The Beaver Creek Diversion system involves two creeks, two reservoirs, a series of diversion canals, and Ruth Lake. Both creeks are brown-water streams, and upper Beaver Creek has strongly influenced the water quality of the three lakes in the system. The recently created reservoirs showed the influence of the flooded basins they occupy, and Ruth Lake has undergone considerable change since diversion, especially in its water quality and plankton communities. Although the flows of Beaver Creek were large enough to determine the basic nature of water quality in the lakes, the flushing rates in 1977 did not appear to strongly influence the plankton communities in them. The influence of the diversion system lakes on water that entered Poplar Creek via the spillway was also apparent, and the biota of Poplar Creek has responded noticeably to the flows received from Poplar Creek Reservoir. The new and modified habitats in the diversion system have already been colonized by a varied community of organisms but most likely will continue to show changes in their physical, chemical and biological characteristics as they evolve.

The pH was only slightly higher in Ruth Lake and Poplar Creek than in the other water bodies, but alkalinity, filtrable residue and TOC were similar in each part of the system. Turbidity and suspended solids were higher in the creeks than in the lakes, but oil and grease concentrations and loss on ignition were somewhat higher in the lakes than in the creeks. Both ignition loss and oil and grease concentrations are measures of the organic content of the water, and high concentrations in standing waters may reflect both the development of plankton and the leaching of compounds from the newly flooded substrates in the two reservoirs. Nutrients (N, P) may also be leaching from flooded sediments, however, during summer, nutrients were apparently being removed from solution in the lakes since concentrations declined to less than those of the creeks. This probably was a result of biotic processes.

Streamflows in 1977 were apparently lower than average, and in years of normal flow there would probably be an even stronger influence of Beaver Creek on the diversion system lakes as a result of higher flushing rates. This would particularly affect the plankton since they would tend to be flushed from standing waters.

Concentrations of sodium and chloride ions increased to some extent in summer and fall in the system lakes and in Poplar Creek. Similar increases were not observed in upper Beaver Creek, therefore the increases in the system lakes may have been related to the discharge of saline minewater to Beaver Creek Reservoir.

Although thermal stratification occurred in the deep areas of Poplar Creek Reservoir, Beaver Creek Reservoir developed only weak temperature gradients, and Ruth Lake was essentially isothermal. Some increase in temperature was apparent in lower Poplar Creek as a result of warm surface water from the reservoir passing over the spillway and because of increased exposure of the channelized creek to sun and wind. Both Poplar and upper Beaver Creek had oxygen concentrations near saturation during the open-water season, but Ruth Lake and the reservoirs were noticeably undersaturated during the same period, even in their surface waters (Figure 64). All three lakes were almost anaerobic in March, 1977.

The exact cause of the oxygen undersaturation in the lakes can not be determined from the largely descriptive data available. Lakes high in dissolved humic compounds are often undersaturated and it is known that some of the oxygen demand arises from the chemical and photochemical oxidation of these compounds (Wetzel, 1975). The brown colour of the lakes in the diversion system indicated that they may contain high concentrations of such compounds.

Oxygen saturation was usually higher in Ruth Lake than in the reservoirs and this may reflect several factors. The recently flooded substrates in the reservoirs may be exerting a greater oxygen demand than the Ruth Lake sediments which have been in contact with an overlying water column for a considerably longer period than the reservoir substrates. The higher saturation in Ruth Lake may also reflect greater photosynthetic oxygen production by the higher phytoplankton crop (Figure 64) and more extensive macrophyte community. As for the reservoirs, Beaver Creek Reservoir generally contained higher cell densities than Poplar Creek Reservoir and oxygen saturation was also slightly higher in Beaver Creek Reservoir (Figure 64). This suggests that while oxygen-demanding substances were removing oxygen from the water, the phytoplankton community was replenishing it in proportion to the community's density.

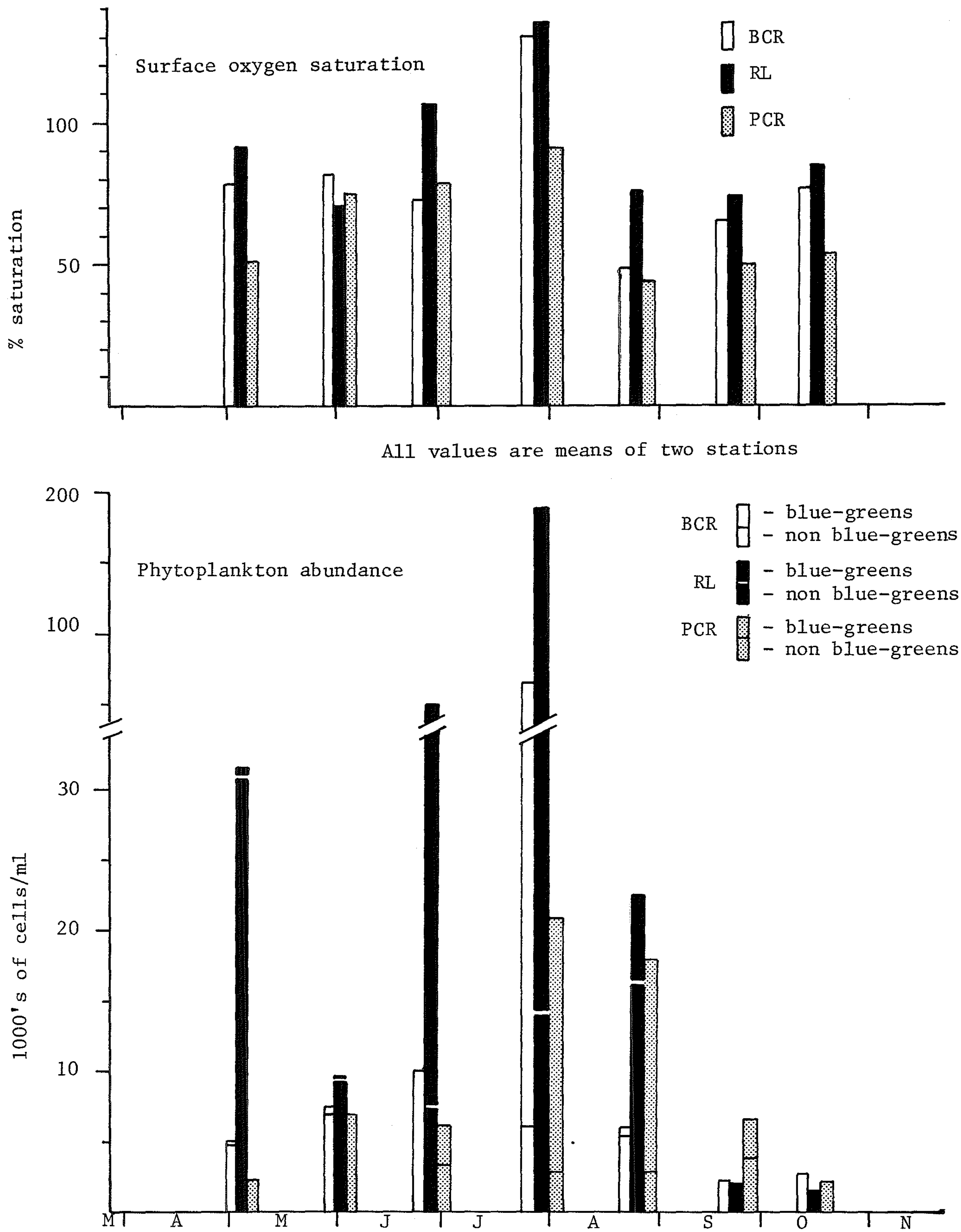

Figure 64. Phytoplankton abundance and oxygen saturation in Beaver Creek Reservoir, Ruth Lake, and Poplar Creek Reservoir, during the open season, 1977.

The general ranking of the lakes in order of decreasing phytoplankton abundance in 1977 was Ruth Lake, Beaver Creek Reservoir and Poplar Creek Reservoir. This ranking corresponds to increasing mixing depths of the water bodies, and, as has been discussed earlier, the depth of the mixing zone in combination with water turbidity may be an important determinant of phytoplankton abundance in the lakes of the system. The significance of mixing depth and turbidity in influencing phytoplankton populations has been discussed by Murphy (1962). Nutrients were fairly high in concentration throughout the system and were in excess of levels typical of eutrophic conditions (discussed below); however, except for floating blue-greens which can resist vertical mixing, phytoplankton only attained densities consistent with eutrophy in Ruth Lake where water depth was low, and the whole water column was probably in the trophogenic zone. In the two reservoirs, phytoplankton may have been spending significant amounts of time circulated below the trophogenic zone, which was shallow because of the turbid and coloured nature of the water. Consequently, algal growth may have been suppressed, preventing the algae from fully utilizing the nutrients available. In addition to having lower cell densities, the phytoplankton communities in the reservoirs contained fewer genera (43 and 47) than did the assemblage in Ruth Lake (58 genera).

Flushing probably was not a major factor influencing plankton populations in 1977 since Ruth Lake, the shallowest basin, had the highest flushing rate but also had the highest phytoplankton densities. Although suppression of phytoplankton through mixing below the trophogenic zone was the simplest explanation for the low algae densities in the deeper lakes, many other factors may have been involved that can not be assessed from the mostly descriptive data available. For example, zooplankton tended to be lowest in Ruth Lake, and consequently, phytoplankton may have flourished there under relatively low grazing intensity from zooplankton. Alternatively, zooplankton abundance in Ruth Lake may have been suppressed by the dense assemblage of blue-green algae that occurred in midsummer. The exact relationships can not be determined without further research.

Wetzel (1975; p. 353) indicates that eutrophic lakes normally contain more than 0.03 mg/l total phosphorus and about 1 mg/l or more of total nitrogen. The lakes in the diversion system in 1977 contained approximately 0.05 to 0.11 mg/l of total phosphorus during the open season and from about 0.3 to 0.7 mg/l in March. Total Kjeldahl nitrogen plus nitrate (NO_3 + NO_2)

nitrogen concentrations in 1977 were about 0.2 - 0.9 mg/l during the ice-free season but much higher in March and May (8-20 mg/l).

The aquatic macrophyte communities in the three lakes were probably not in an equilibrium state when surveyed in 1977. Colonization of the two new impoundments by aquatic plants is, very probably, still proceeding. Emergent plants were not abundant in the reservoirs and can be expected to expand in both their abundance and distribution. The submergent and floating-leafed species assemblage presently established in the two reservoirs (primarily *Potamogeton berchtoldii*, *Ceratophyllum demersum*, *Myriophyllum exalbescens*, *Utricularia vulgaris* and *Sparganium* sp.) was fairly similar in composition and may reflect the ability of certain aquatic plants to colonize new water bodies. Only *M. exalbescens* and *U. vulgaris* were prevalent in the established Ruth Lake macrophyte community. This community has undergone some change subsequent to the diversion and may continue to evolve to accomodate the changes in Ruth Lake's water level and chemical regime. The establishment of aquatic vegetation in the reservoirs will be strongly influenced by fluctuations in water level, particularly in Poplar Creek Reservoir where fall drawdown is planned. Lowered water levels over winter have been shown to have drastic consequences for aquatic vegetation elsewhere (Beard, 1973).

As mentioned in the sections on methods, discussions of abundance and seasonal trends of zooplankton in the system must be general for two basic reasons: the four week sampling interval may have missed some important events in zooplankton periodicity, and the different depths of the various lake stations make volumetric comparisons difficult.

Table 93 lists the zooplankton collected in the three water bodies at the open-water stations, and Table 94 lists the number of *common*[1] species in the major zooplankton groups. In a survey of fourteen large, central Alberta lakes, it was found that the number of common species in the major groups was usually: Rotifera - 8 or 9, Cyclopoida - 1 to 4, Calanoida - 1 or 2, Cladocera - 5 or 6 (D. N. Gallup, unpublished data). This situation is similar to that observed in the water bodies in the Beaver Creek Diversion System. The species observed there are common in Alberta lakes with the

[1]common is defined here as species that were observed in more than very low numbers on a few occasions.

Table 93. Zooplankton collected at the open water stations in Beaver Creek Reservoir, Ruth Lake and Poplar Creek Reservoir in 1977.

	Beaver Creek Reservoir	Ruth Lake	Poplar Creek Reservoir
CONCHOSTRACA			
Lynceus brachyurus Muller	X[1]	X[1]	X[1]
CLADOCERA			
Bosmina longirostris (Muller)	X	X	X
Ceriodaphnia affinis Lilljeborg	X	X	X
Ceriodaphnia lacustris Birge			X
Ceriodaphnia reticulata (Jurine)	X[1]		
Chydorus sphaericus (Muller)	X	X	X
Daphnia galeata Sars *mendotae* Birge			X
Daphnia magna Straus	X[1]		
Daphnia parvula Fordyce			X
Daphnia pulicaria Forbes	X	X	X
Daphnia rosea Sars	X	X[1]	X[1]
Diaphanosoma leuchtenbergianum Fischer	X	X	X
COPEPODA			
CALANOIDA			
Diaptomus leptopus Forbes	X	X	X
Diaptomus oregonensis Lilljebora		X	X
CYCLOPOIDA			
Cyclops vernalis Fischer	X	X	X
Cyclops bicuspidatus thomasi Forbes	X	X	X
Cyclops navus Herrick	X	X	X
Macrocyclops albidus (Jurine)	X[1]		
Mesocyclops edax (Forbes)			X
ROTIFERA			
Asplanchna	X	X	X
Brachionus calyciflorus (Pallas)	X[1]		X[1]
Brachionus	X		
Conochilus unicornis (Rousselet)	X	X	X
Filinia longiseta (Ehrenberg)	X	X	X
Hexarthra	X	X	X
Keratella cochlearis (Gosse)	X	X	X
K. quadrata (Muller)	X	X	X
Nothalca		X[1]	
Polyarthra	X	X	X
Synchaeta	X	X	X
Platyias			X[1]
Testudinella			X[1]

[1] denotes "uncommon" species, defined here as species which were only observed as a few individuals during counting procedures on two or three dates.

Table 94. Number of "common"[1] species in the major zooplankton groups in Beaver Creek Reservoir, Ruth Lake, and Poplar Creek Reservoir in 1977.

	ROTIFERA	CYCLOPOIDA	CALANOIDA	CLADOCERA
Beaver Creek Reservoir	9	3	1	6
Ruth Lake	8	3	2	5
Poplar Creek Reservoir	8	4	2	8

[1]"common" refers to species that 1) were consistently observed during the study, or 2) were present on a few occasions in high numbers. Species observed in very low numbers on a few occasions were considered "uncommon" or "rare". Species consistently occurring in low numbers were considered "common" but low in abundance.

exception of *Daphnia parvula*. This species occurred in Poplar Creek Reservoir and has not been recorded in many localities in Alberta. Brooks (1957) described *D. parvula* as reaching into central southern Canada, and Anderson (1974), in a survey of 340 lakes and ponds in Alberta and British Columbia, observed *D. parvula* in only one water body. Why it occurred in Poplar Creek Reservoir is not known.

Figure 65 presents the total number and dominant types of rotifers at the time of sampling in the three water bodies. Total numbers were lowest in late March and tended to be highest in the August-September period. Seasonal trends of dominant types were most similar in Beaver Creek Reservoir and Ruth Lake. In these water bodies *Filinia longiseta* was completely dominant in March and existed in very low oxygen concentrations (less than 1 ppm). Through spring and summer *Keratella cochlearis* and *K. quadrata* were the most important rotifers, and in the fall *Polyarthra* dominated. In Poplar Creek Reservoir, as in the other two water bodies, *F. longiseta* was present in late March under low oxygen concentrations, was still dominant in late spring but was succeeded by *Conochilus unicornis* in late May. In late June *Polyarthra* dominated, but from late July onward *Keratella cochlearis* was generally the most important rotifer.

The graphs of individual species' abundances (Figure 66 and 67) and of community composition (Figure 68) give a general picture of seasonal dynamics of the crustacean zooplankton. Although total numbers were low in late March and early May, cyclopoid copepods dominated the crustacean zooplankton in all three water bodies. In early June cyclopoids had increased in numbers and were still dominant. By late June their numbers had decreased in all the water bodies, but they were still an important component of the communities in Ruth Lake and Poplar Creek Reservoir. In Ruth Lake and Beaver Creek Reservoir *Cyclops vernalis* appeared to be the dominant cyclopoid in spring, but in Poplar Creek Reservoir both *C. vernalis* and *C. bicuspidatus thomasi* were abundant.

As cyclopoids decreased in June, cladocerans became more important. *Daphnia* species were dominant in the two reservoirs in late June: *D. pulicaria* and *D. rosea* in Beaver Creek Reservoir, *D. pulicaria* and *D. galeata mendotae* in Poplar Creek Reservoir. In Ruth Lake, at this time, cyclopoids were still important, but *Bosmina longirostris* and *Diaphanosoma leuchtenbergianum* were also abundant. In all water bodies in late July *Bosmina* was present in high numbers and dominated the crustacean zooplankton. As cladocerans declined

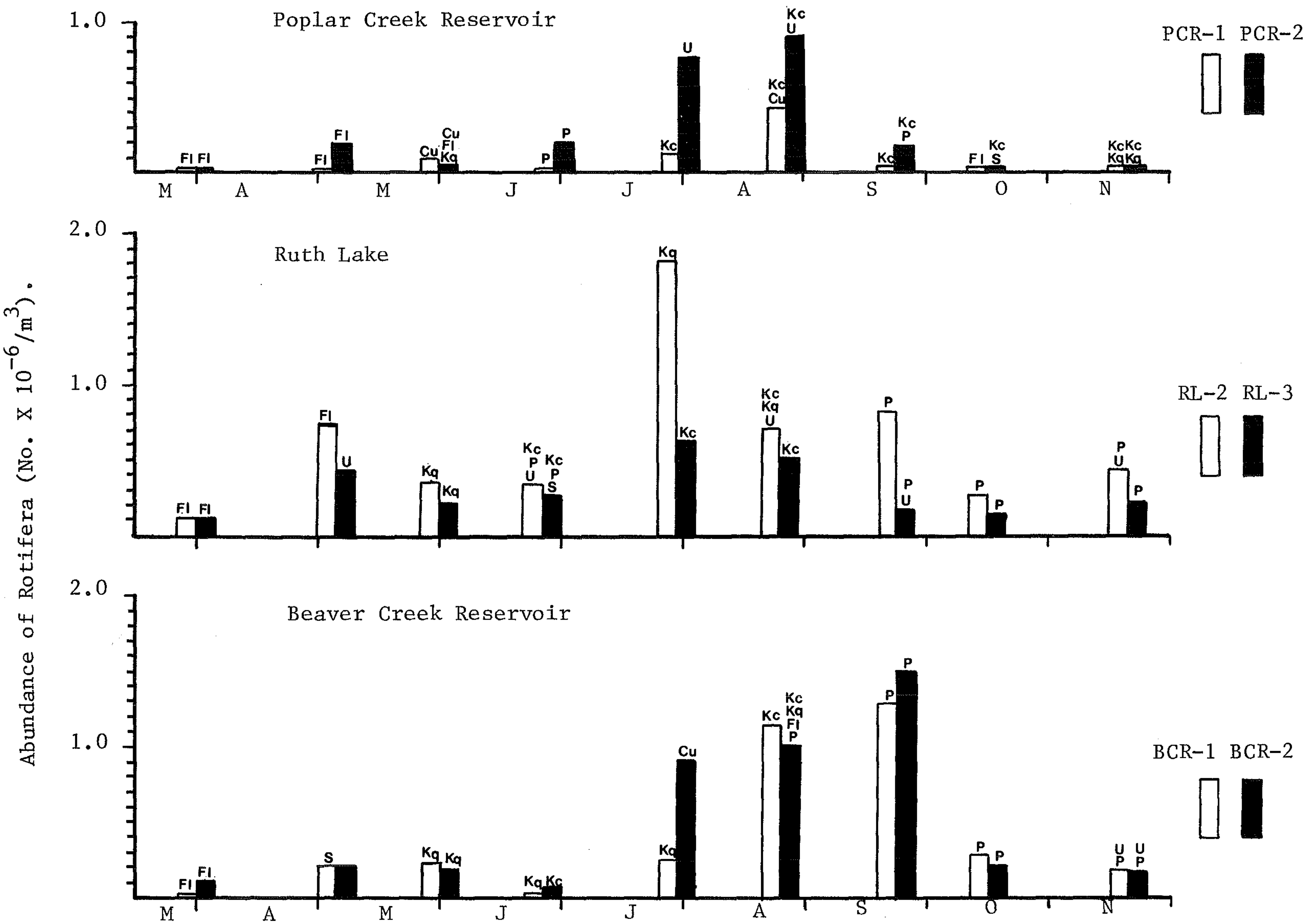

Figure 65 . Abundance of Rotifera in the three water bodies in 1977. Letters at the top of each bar indicate dominant types. Cu = *Conochilus unicornis*, Fl = *Filinia longiseta*, Kc = *Keratella cochlearis*, Kq = *K. quadrata*, P = *Polyarthra*, S = *Synchaeta*, U = unidentified.

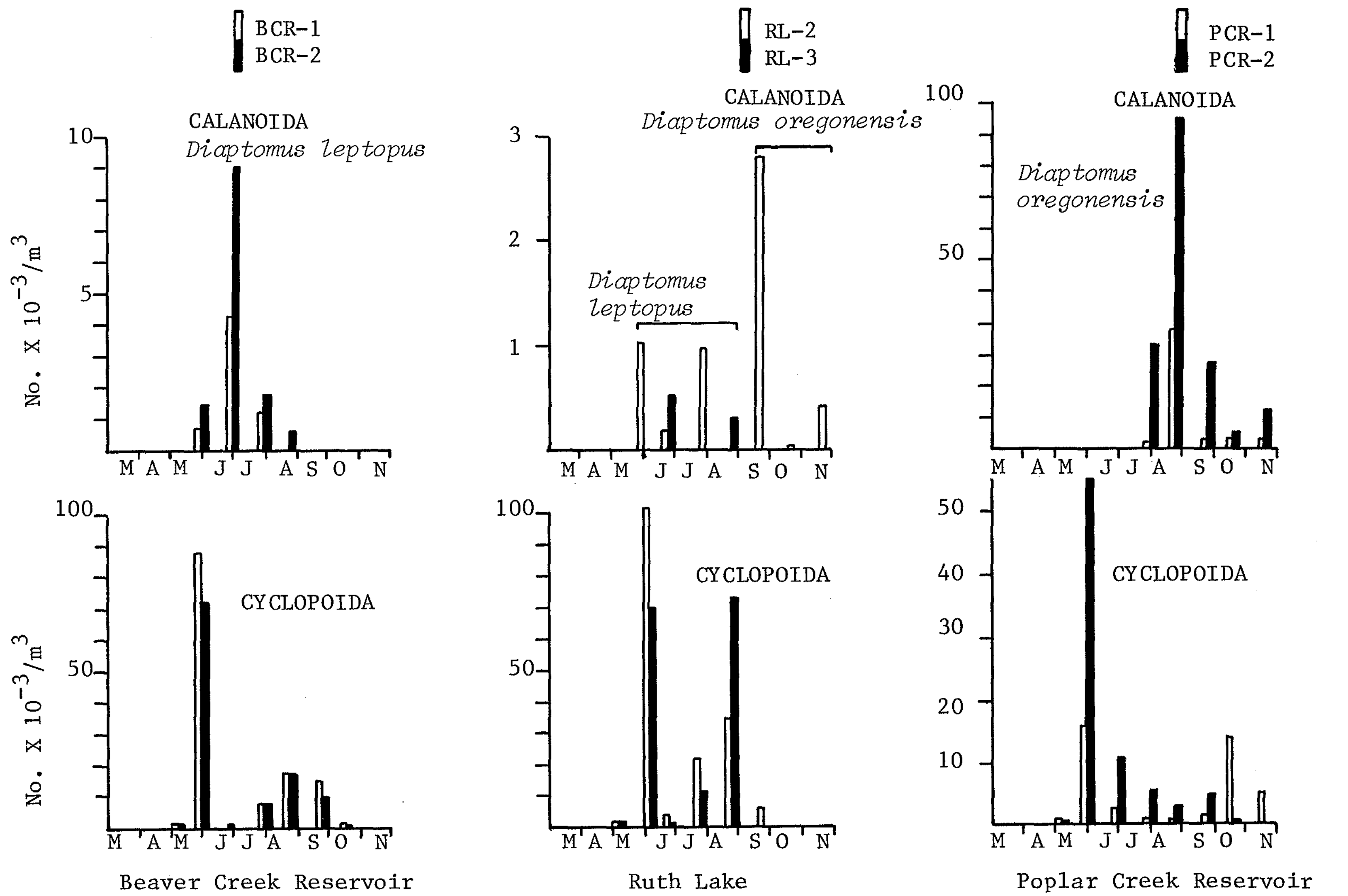

Figure 66. Abundance of Calanoida and Cyclopoida in the three water bodies. Values are the sum of copepodite and adult stages.

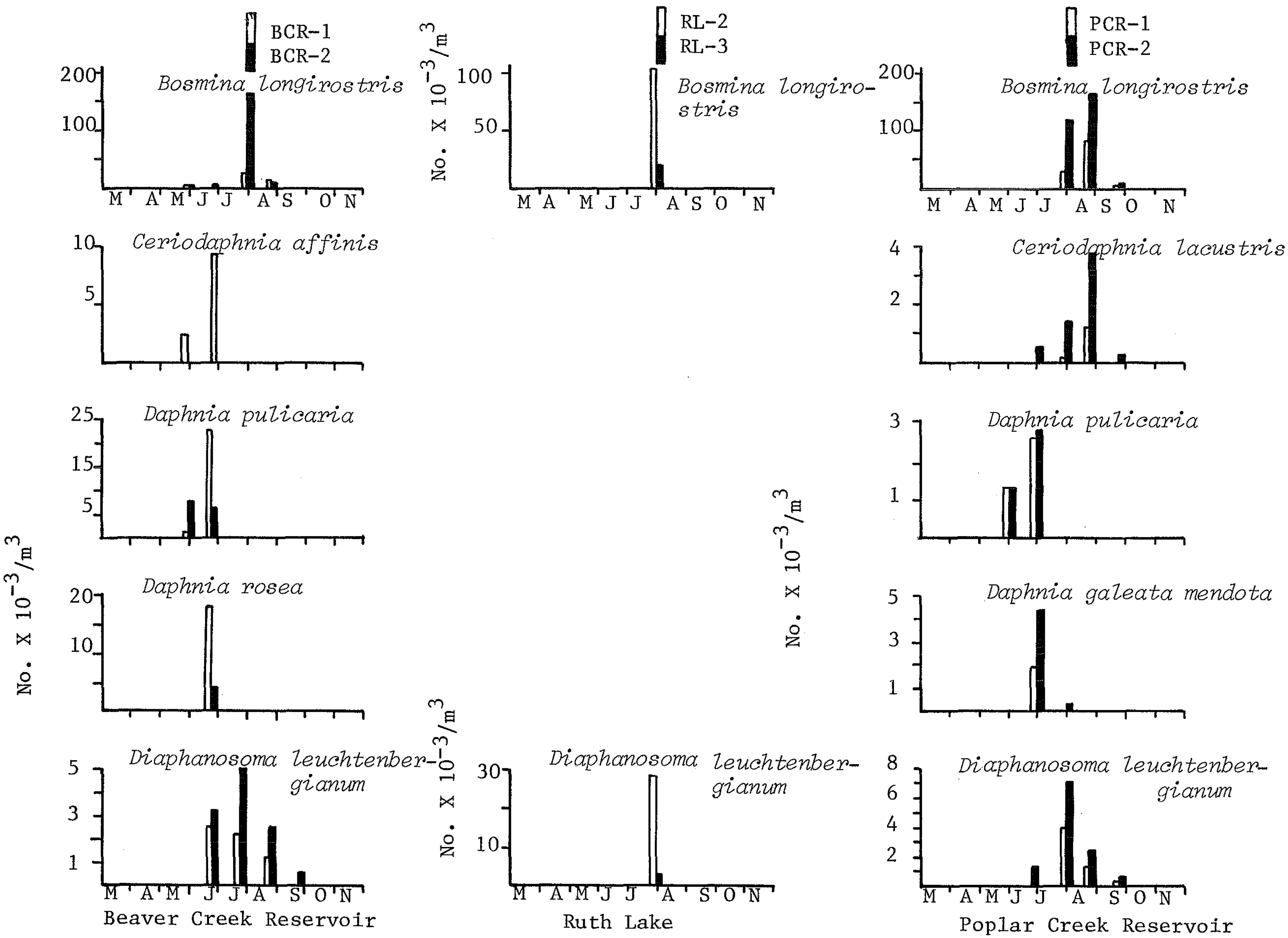

Figure 67. Abundance of the major species of Cladocera in the three water bodies in 1977.

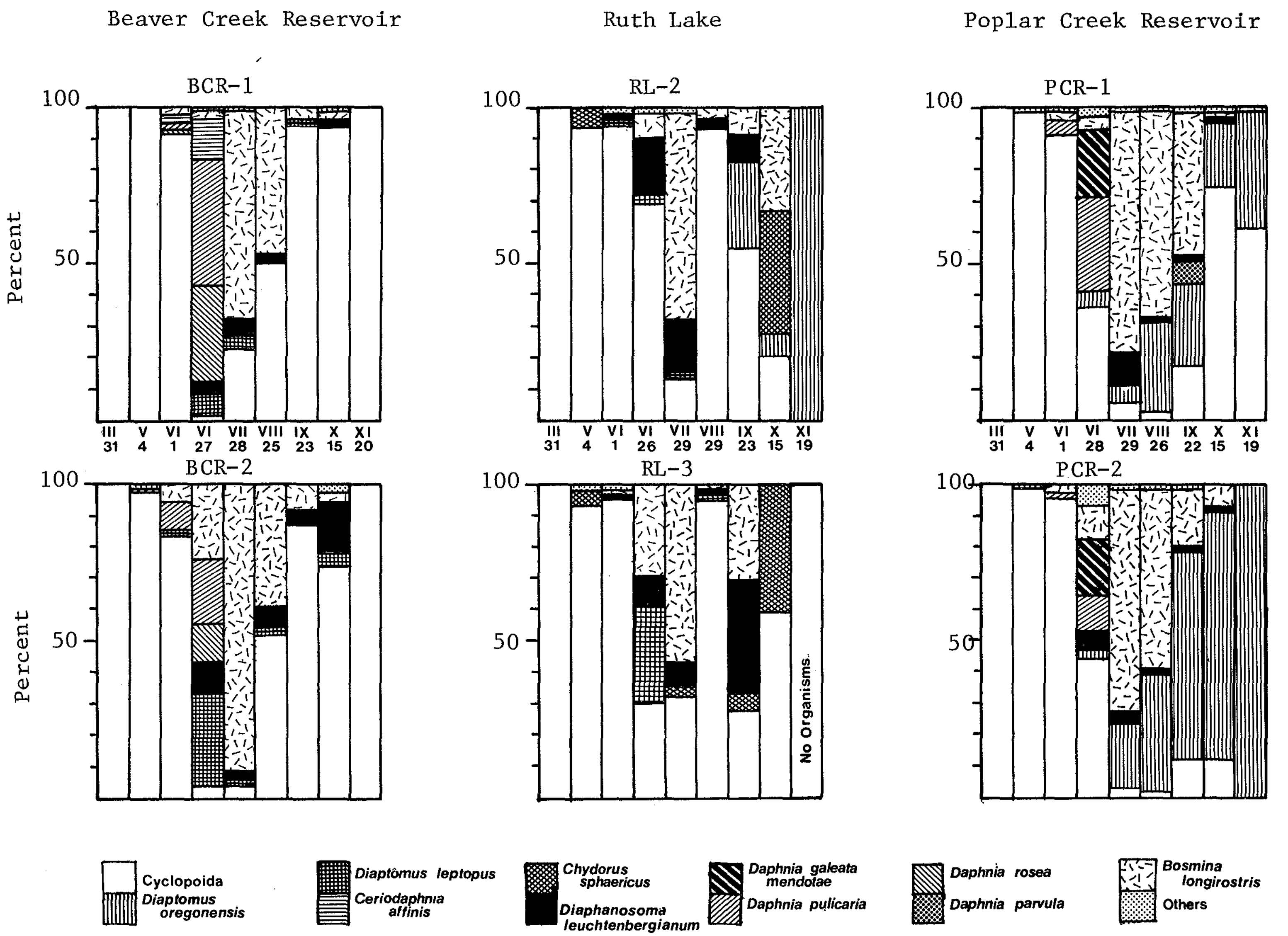

Figure 68. Numerical composition of the crustacean zooplankton in the three water bodies in 1977.

in the late summer and fall, cyclopoid copepods again became more important, except at PCR-2 where *Diaptomus oregonensis* became dominant. In Beaver Creek Reservoir and Ruth Lake, this late summer pulse of cyclopoids occurred around August and involved unidentified early stage copepodites. Abundance subsequently decreased, but cyclopoids still dominated, except at RL-2 where *Diaptomus oregonensis* was completely dominant. At PCR-1 in Poplar Creek Reservoir, cyclopoids were dominant in late fall, but *D. oregonensis* was relatively abundant. The cyclopoid pulse involved late stage copepodites and adults of *Cyclops bicuspidatus thomasi*. These probably arose from diapausing copepodite IV stages which resumed their development. At PCR-2 cyclopoid activity was not observed in late summer and fall and *D. oregonensis* completely dominated through this period.

Figures 69 and 70 show total abundance and biomass of crustacean zooplankton in the three lakes. There was an initial spring pulse in total abundance in all the water bodies in late May - early June due to cyclopoid copepods. Numbers were lower in late June but showed an increase at most stations in the late July - late August period. *Bosmina longirostris* was the major component of this late summer activity but cyclopoids and *Diaphanosoma leuchtenbergianum* were also abundant in Ruth Lake as was *Diaptomus oregonensis* in Poplar Creek Reservoir. After this late summer abundance, numbers decreased.

The spring cyclopoid pulse caused total biomass to increase in late May - early June. In Ruth Lake and Poplar Creek Reservoir biomass was lower in midsummer (as was abundance), but it increased in late summer, particularly in the reservoir. Subsequently biomass in these two waterbodies decreased. The late summer pulse in Poplar Creek Reservoir involved *Bosmina longirostris* and *Diaptomus oregonensis*. In Beaver Creek Reservoir, biomass did not decrease after the spring cyclopoid activity even though abundance declined. In late June, biomass was at maximum levels due to the presence of large zooplankton such as *Daphnia pulicaria*, *D. rosea* and *Diaptomus leptopus*. Biomass subsequently decreased through the remainder of the season.

The seasonal trends and total abundance appeared roughly similar among the water bodies. In the spring, biomass tended to be highest in Beaver Creek Reservoir, and in the late summer and fall, biomass was greatest in Poplar Creek Reservoir. Biomass values in Ruth Lake were generally lower than in the reservoir.

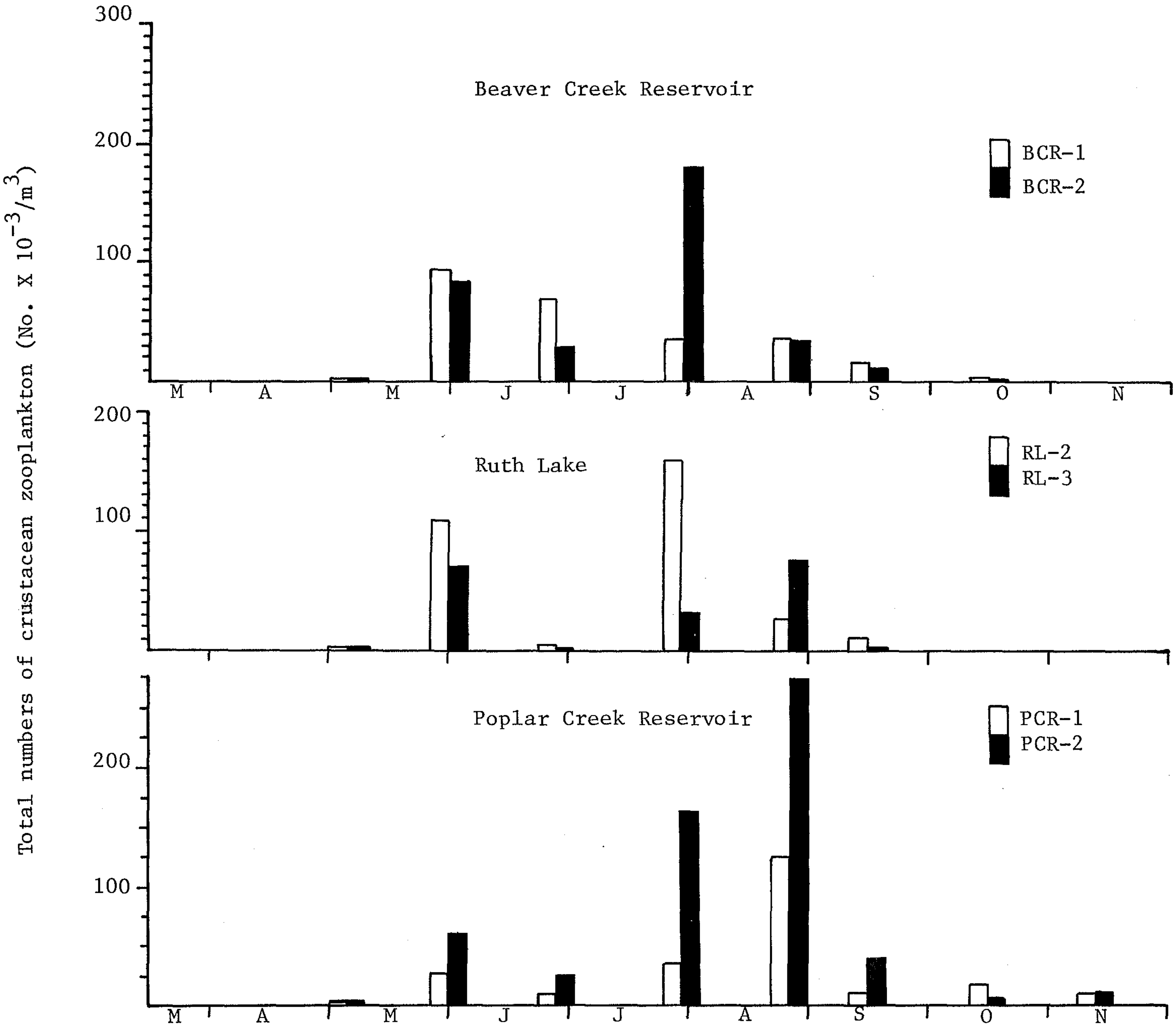

Figure 69. Total abundance of crustacean zooplankton in the three water bodies in 1977.

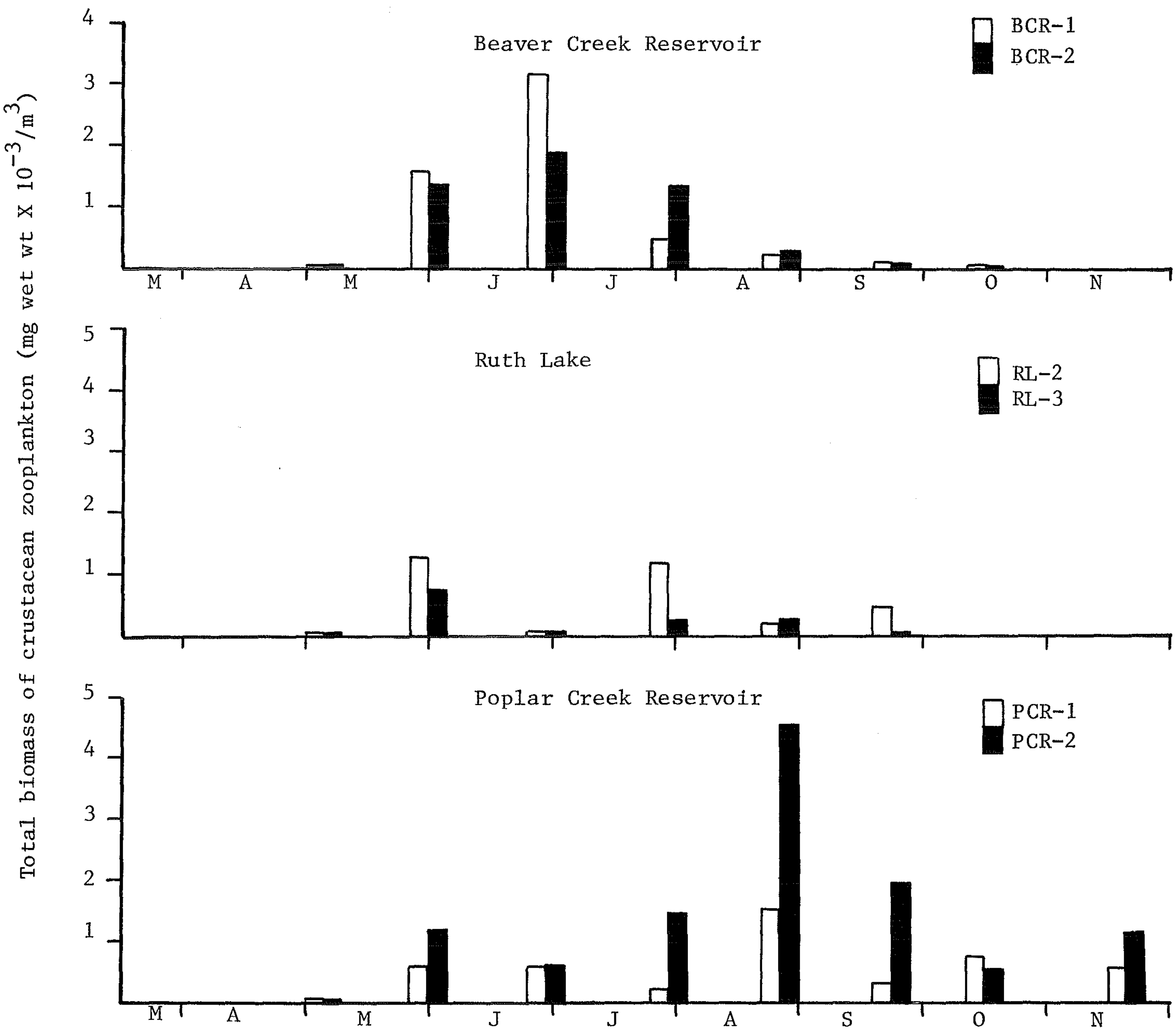

Figure 70. Total biomass of crustacean zooplankton in the three water bodies in 1977.

The species of littoral crustaceans collected in the three water bodies are presented in Table 95. Littoral sampling was not extensive since only two representative regions were examined in each water body in spring, summer and fall. Considering the semi-quantitative nature of sampling, and the fact that many littoral species were observed in very low numbers, definitive statements about this group are difficult to make. The Cladocera were the most important major group in terms of numbers of species; seventeen species were collected in the three water bodies. Fewer cladoceran species (five) were collected in Beaver Creek Reservoir than in the other two water bodies. Ruth Lake and Poplar Creek Reservoir had eleven species each, but only five were common to both. Since only a few individuals were collected of many of the species, further sampling would be required to confirm the distribution of species. *Chydorus sphaericus* was abundant at certain sites in the spring and summer. *Eucyclops agilis* was generally the most prevalent copepod.

Figure 71 presents the total numbers of benthic organisms collected at the sampling sites in the three water bodies in 1977, and Figure 72 shows the percentage composition of the benthos during the study. Dipteran larvae were important components of the benthos, but it should be reiterated that the 0.6 mm mesh size used to wash bottom samples would miss small, early instars, and therefore the numbers collected of this group reflect numbers of larger, late instars.

All the stations, except RL-3, showed an increase in numbers in the late summer-fall period at which time abundance reached a seasonal maximum. This pattern largely reflected increases in the larvae of the midge *Chironomus*, although at BCR-1 and PCR-1 it involved larvae of the phantom midge *Chaoborus flavicans*. Although RL-3 also displayed an increase in the fall, maximum abundance occurred in the spring and early summer due to larvae of the chironomid *Einfeldia*.

The stations in Poplar Creek Reservoir had the lowest abundances. This probably reflected the existence of an oxygen-deficient hypolimnion and also, at PCR-1, a generally inorganic substrate. Through spring and summer, RL-2 and BCR-1 had low numbers although numbers tended to be slightly greater than in Poplar Creek Reservoir. In fall, populations at these two sites were distinctly higher than in Poplar Creek Reservoir. There was no obvious explanation for the low numbers at these sites during spring and summer, but it could involve substrate conditions, food supply and other factors. BCR-2

Table 95. Littoral crustaceans in Beaver Creek Reservoir, Ruth Lake, and Poplar Creek Reservoir, 1977.

	Beaver Creek Reservoir	Ruth Lake	Poplar Creek Reservoir
AMPHIPODA			
Gammarus lacustris Sars		X	
Hyalella azteca (Saussure)	X	X	X
OSTRACODA	X	X	X
CONCHOSTRACA			
Lynceus brachyurus Muller	X	X	X
CLADOCERA			
Acroperus harpae Baird		X	X
Alona affinis (Leydis)		X	
Alona costata Sars		X	
Alona quadrangularis (Muller)			X
Alona rectangula Sars	X	X	X
Chydorus sphaericus (Muller)	X	X	X
Ilyocryptus spinifer Herrick		X	
Leydigia leydigii (Schoedler)		X	
Macrothrix laticornis (Jurine)			X
Pleuroxus denticulatus Birge	X	X	
Pleuroxus striatus	X	X	
Pleuroxus trigonellus (Muller)			X
Sida crystallina (Muller)	X	X	X
Simocephalus serrulatus Koch			X
Simocephalus vetulus (Muller)		X	X
Polyphemus pediculus (Linne)			X
COPEPODA			
HARPACTICOIDA		X	X
CYCLOPOIDA			
Eucyclops agilis (Koch)	X	X	X
Eucyclops speratus	X	X	X
Macrocyclops albidus (Jurine)	X	X	X
Microcyclops varicans rubellus Lilljeborg		X	X

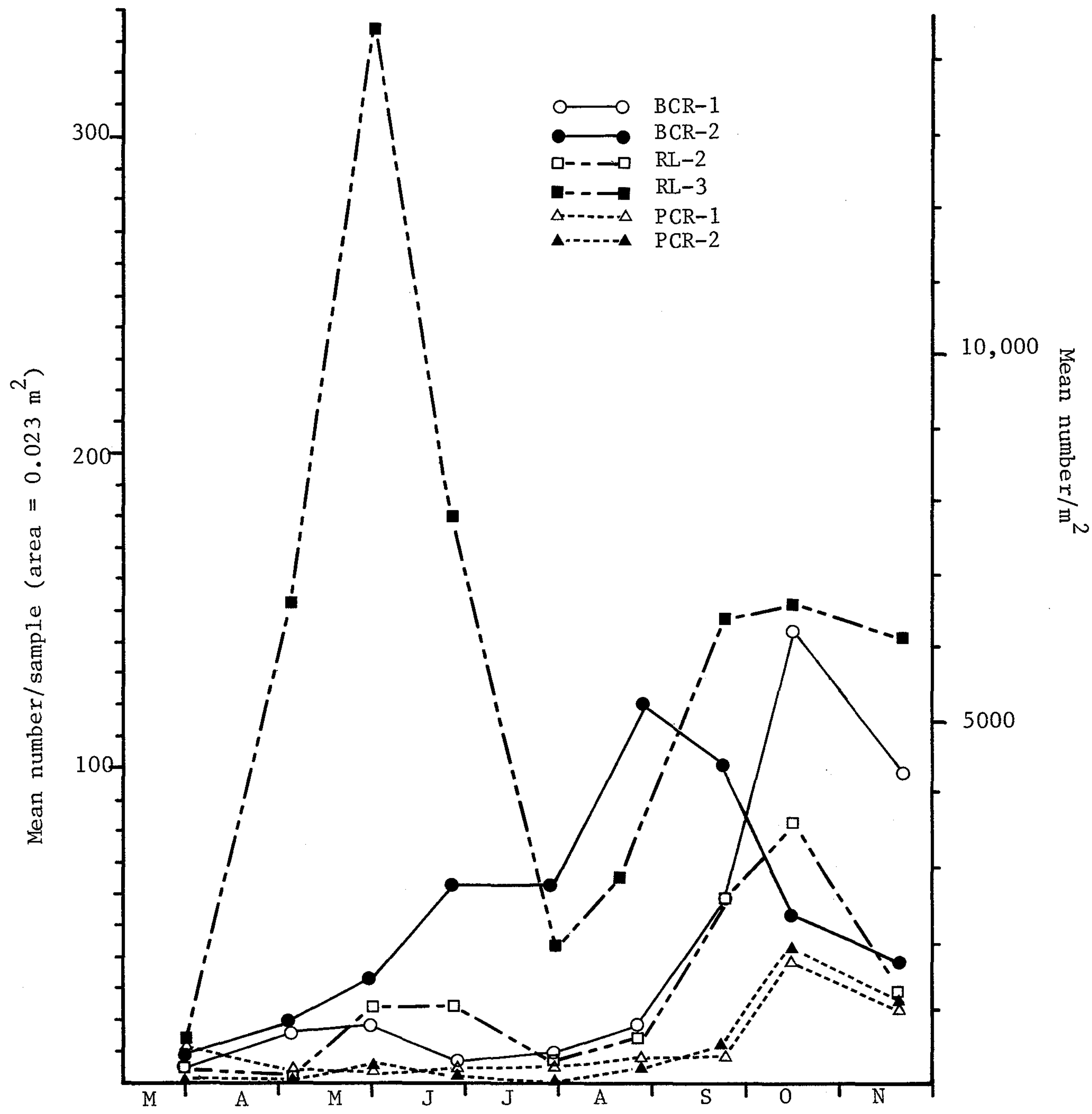

Figure 71. Total abundance of benthos in the three water bodies in 1977. Each value is the mean of three samples.

Numbers along the top of the graph indicate number of organisms collected.
Roman numerals and numbers along the bottom indicate month and date.

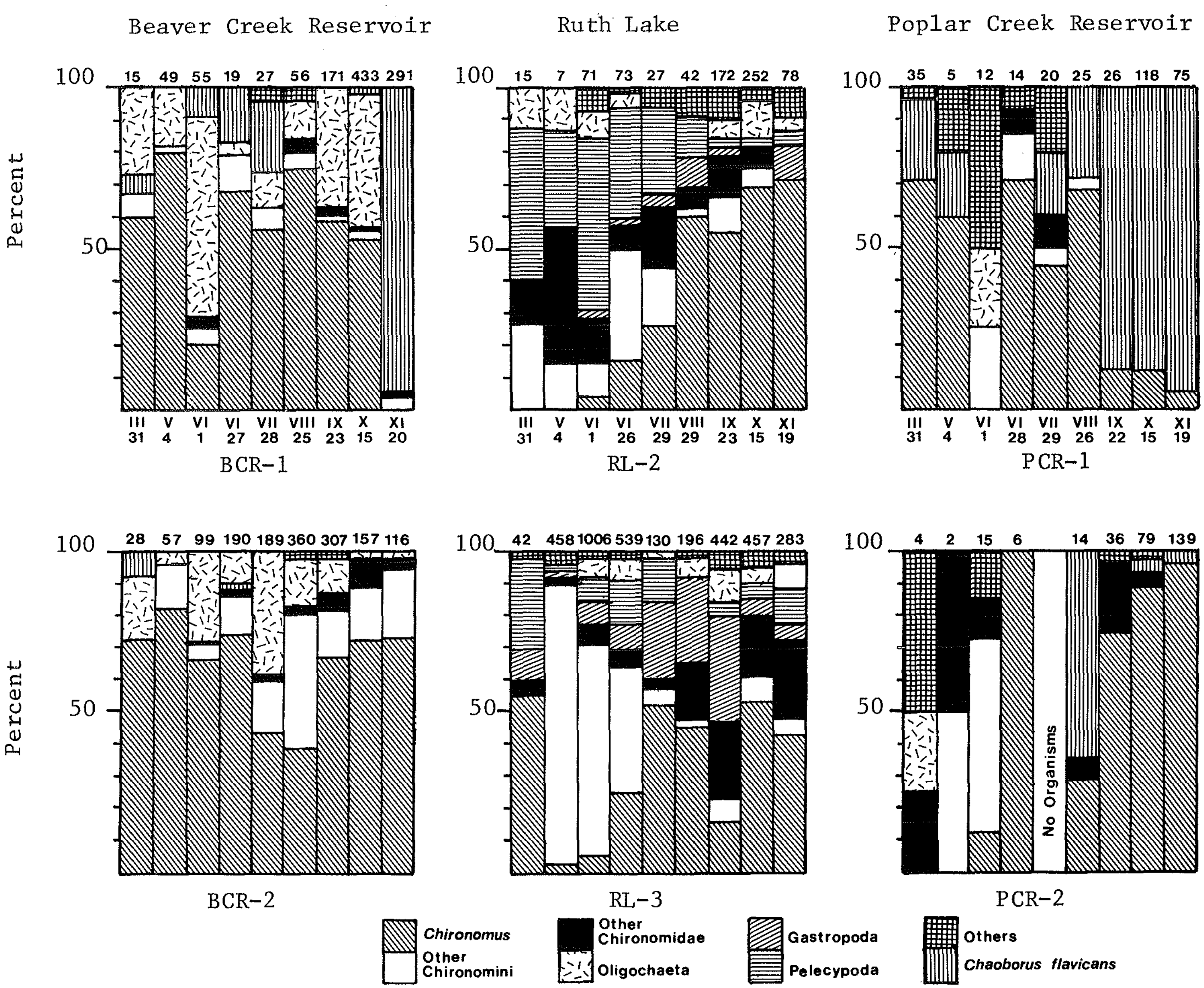

Figure 72 . Numerical composition of the zoobenthos in the three water bodies in 1977.

and RL-2 had higher numbers than the other sites through the spring and summer, but fall values were roughly comparable to RL-2 and BCR-1. These data indicated that abundance in Beaver Creek Reservoir, at least in the fall, was comparable to that of Ruth Lake and that Poplar Creek Reservoir had an impoverished benthos.

Chironomid larvae were the dominant component of the collected benthic fauna. Among the chironomid larvae, *Chironomus* was the predominant genus; however, *Einfeldia* was very abundant at RL-2 in the spring and early summer.

It appeared that at PCR-2 in Poplar Creek Reservoir, the period of growth of *Chironomus* larvae into late instars was restricted until after fall overturn when oxygen conditions were more favorable to growth. At other sites not subjected to severe oxygen depletion, fourth instar larvae were more abundant during the spring and summer and increases in their numbers during the fall period started earlier. Jonasson (1972) observed that in areas that underwent oxygen depletion in Lake Esrom, Denmark, *C. anthracinus* did not grow into late instar larvae until after fall overturn.

There are many factors that will influence the development of the bottom fauna on newly flooded areas. Among these are basin morphometry; physical-chemical nature of the substrate and overlying water (including the distribution and composition of flooded organic materials); productivity of the water body; erosion and sedimentation patterns; and development of macrophyte communities. In their early years reservoirs are not stable systems, and during their development the biota responds to the changing conditions within the reservoir. Fillion (1967) and McMillan (1972) demonstrated that in the early years of two western Canada reservoirs, the benthos showed major changes in the composition and abundance of the fauna, and it can be expected that the benthos in the two reservoirs in the diversion system will change noticeably over the years. Reservoirs often show higher productivity in the first few years after flooding because of the decomposition of flooded organic materials, and it remains to be seen if the abundance of 1977 will be maintained.

Chironomid larvae are among the most important initial colonizers of new water bodies (Paterson and Fernando, 1970; Fillion, 1967; McMillan, 1971), and these organisms were predominant in the reservoir benthos at all sites investigated. As would be expected, abundance of chironomids in littoral regions was greater than in other areas. In Beaver Creek Reservoir, samples taken along a transect showed that abundance was rather uniform in the profundal zone examined; however, at the time of sampling (August 6) there was a shift in dominance from *Glyptotendipes* in shallower regions to *Chironomus* in deeper regions. In Poplar Creek Reservoir it appeared that the firm, inorganic substrate in the south section of the reservoir severely limited benthos. Above the oxygen-deficient hypolimnion, numbers were higher in the north section, where the substrate had more organic material, than in the south; but below the hypolimnion, populations were very low in both sections.

Fifteen species of fish were collected in the diversion system in 1977 although only about seven were common. As a result of its proximity to the Athabasca River, Poplar Creek contained, by far, the most diverse fauna (fifteen species). Seven species of fish were collected from the rest of the system. Longnose and white suckers were the most abundant and ubiquitous of the large species encountered, and they are noted for their success in a wide range of aquatic habitats (Paetz and Nelson, 1970). Brook sticklebacks, fathead minnows and lake chub were, by far, the most abundant of all fish and the first two were widespread throughout the diversion system. Northern pike and arctic grayling were the most common sports species encountered and were mainly collected from Poplar Creek. Pike, however, were collected regularly in Beaver Creek Reservoir, and grayling were present in upper Beaver Creek. Other species, for example yellow walleye, lake and mountain whitefish, trout-perch and burbot, were occasionally collected in Poplar Creek but, with the possible exception of burbot, probably were not present in the diversion system upstream of the spillway.

The smaller, most abundant species of fish, fathead minnows, brook sticklebacks and lake chub, were reproducing in the system. Longnose and white suckers in Beaver Creek and Beaver Creek Reservoir were also reproducing somewhere within that portion of the system. The creek itself or the sand-gravel substrates on the dam and in the diversion canals may have provided spawning habitat for these species. Only adult pike were collected in Beaver Creek Reservoir, and the status of the pike population there is uncertain. They must have gained access to the reservoir from Beaver Creek although none were actually taken in the creek. It would seem that adequate food supplies, in the form of forage species, and adequate spawning habitat (aquatic vegetation) will exist in the reservoir for pike to establish there if they can survive winter oxygen depletion. Such deoxygenation occurs in both of the reservoirs and in Ruth Lake and may constitute a serious obstacle to fish colonization of those water bodies. Suckers were in all three lakes, but it is not known whether they were able to overwinter successfully in them, return to the vicinity of upper Beaver Creek where oxygenated water occurs in winter, or perished in the lakes from lack of oxygen. Suckers that had invaded Ruth Lake were consuming benthic invertebrates when investigated in June of 1977, and it is possible this species may affect the types and abundances of benthos in Ruth Lake.

In Poplar Creek it is likely that both species of suckers were spawning in the stream and utilizing it for feeding throughout the open-water season. Grayling spawned to a small extent in the stream but probably used the creek primarily as a feeding area. Pike were the only other species found there in spawning condition, but there was no evidence of their successful reproduction in the stream. The other less common species collected in the stream were probably using it during the open-water season, on an occasional basis, for feeding. No sampling was done under ice cover in Poplar Creek below the spillway, but field observation indicated that winter conditions in that section of the stream may have been unfavourable for fish.

The fish in the diversion system have expanded into the new water bodies and into existing water bodies newly available to them. Fish were available for this expansion in three areas: upper Beaver Creek (white and longnose suckers, pike, lake chub), Ruth Lake (fathead minnows and brook sticklebacks) and the Athabasca River - Poplar Creek system (all 15 species). The probable expansion and sources of these fish are portrayed in Figure 73. The abundant fathead minnows and brook sticklebacks probably originated mainly from Ruth Lake since they were less than common in both Poplar Creek and Beaver Creek in the past.

Amphibians

Three species of amphibians are known to occur in the region of the Syncrude Canada Ltd. operation (W. Roberts, pers. comm.): the wood frog (*Rana sylvatica*), boreal chorus frog (*Pseudacris triseriata*), and the Canadian toad (*Bufo hemiophrys* - Hodge, 1976). Adults and tadpoles of all three species were observed in the Beaver Creek diversion system and were most evident in standing water where emergent plant growth was well developed. This kind of habitat was most abundant at the northwest and southeast ends

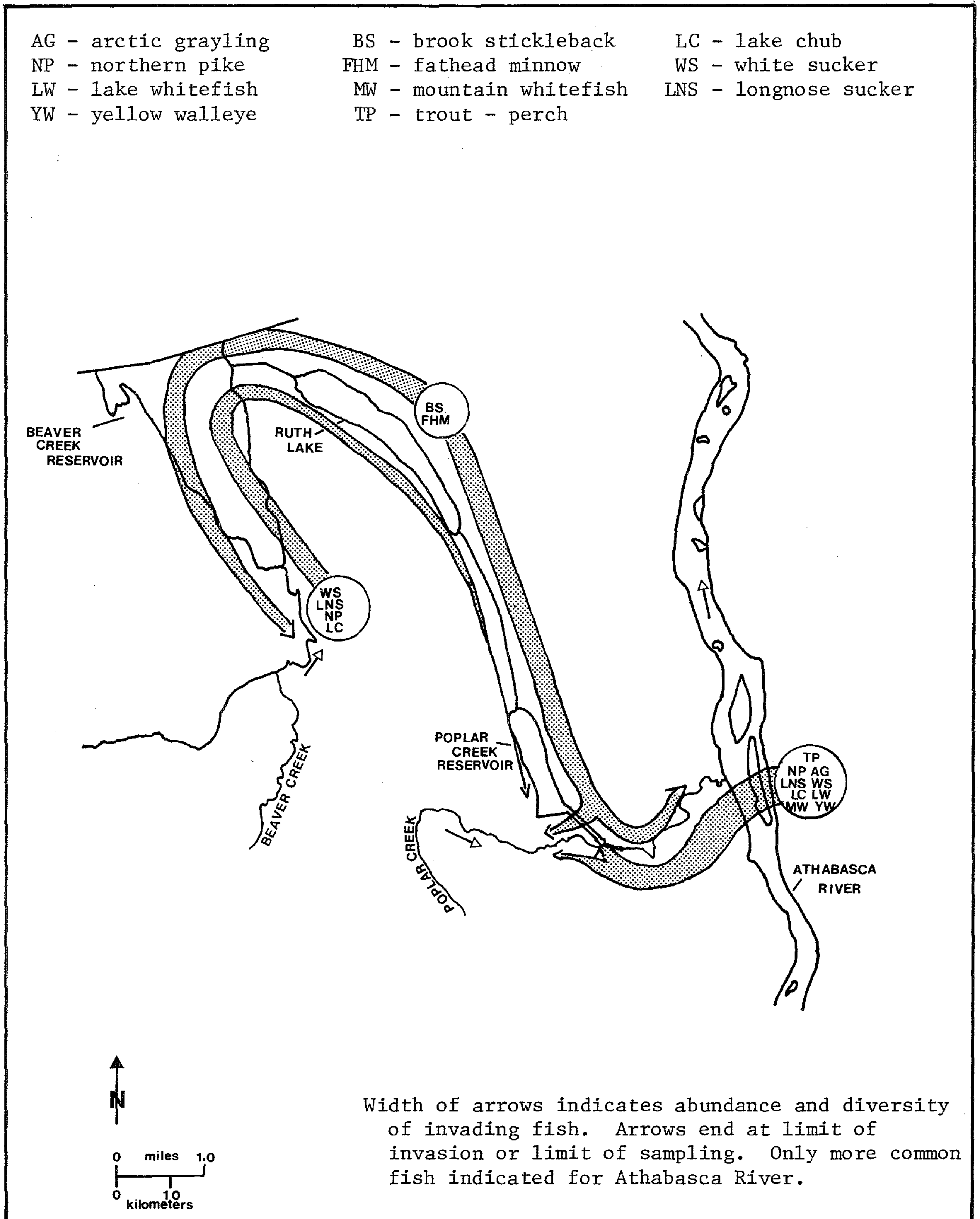

Figure 73. Sources and expansion of fish species in the Beaver Creek Diversion System.

of Ruth Lake and at the north end of Poplar Creek Reservoir. In these areas, the vocalizations (singing) of the species were very noticeable in early May during the breeding season. Beaver Creek Reservoir presently lacks a well-developed, emergent macrophyte community, and 'singing' was not commonly heard there in May, although small marshy ponds back from the reservoir shoreline contained large numbers of boreal chorus frogs and wood frogs at that time. In late June, tadpoles of all three species were collected in seine hauls taken in the two reservoirs and Ruth Lake. Poplar Creek was not examined intensively for amphibians, but they did not seem to be abundant at any time in the creek. No tadpoles were collected in the many seine hauls taken there for fish.

Changes in existing water bodies

The two pre-existing water bodies that have been involved in the Beaver Creek Diversion, Ruth Lake and Poplar Creek, have undergone some distinct changes since last surveyed in 1975. The two baseline surveys in 1974 and 1975 (RRCS, 1975; Noton and Chymko, 1977) provided information on these two water bodies to enable comparisons with conditions in 1977. The previous studies gave an indication of the year-to-year variations in aquatic conditions, and thereby allowed a comparison with the conditions observed in 1977. The changes, discussed previously for each individual water body, are summarized in Table 96.

The main determinant of the changes in these systems was the routing of Beaver Creek flows through Ruth Lake and the addition of these flows to Poplar Creek. The two creeks were similar in their basic water quality, and this is apparent in Table 96 where most of the water quality parameters in Poplar Creek have shown no major change since 1975. Ruth Lake water quality in the past was quite distinct from that of Beaver Creek, and as had been anticipated (Noton and Chymko, 1977), the addition of Beaver Creek flows to Ruth Lake produced noticeable changes (Table 31). Essentially, Beaver Creek streamwater has supplanted the orginal lakewater present in the basin, and in 1977 there was a more turbid, brown-coloured, nutrient-rich body of water there. Accordingly, phytoplankton increased in abundance, and blue-green algae bloomed in response to the increased nutrients. Aquatic macrophytes showed differences in their distribution and composition but possibly more as a result of changes in turbidity, pH and water levels than because of nutrient alterations. This group, in particular, can be expected to continue to change over a number of years.

Table 96. Changes in aquatic conditions in Ruth Lake and lower Poplar Creek since 1975.

		Ruth Lake	lower Poplar Creek
Physical:			
Water levels		More variable	
Discharge/flushing		++	++
Temperature		±	+
Suspended solids		±	±
Turbidity		++	±
Colour		++	±
Chemical:			
Dissolved oxygen		--	±, ?
pH		-	±
Alkalinity		-	±
Filtrable residue		+	+
Total organic carbon		++	±
$NO_2 + NO_3 - N$		++	±
Orthophosphate - P		++	±
Reactive silicate		+	±
Chemical oxygen demand		+	±
Hardness		-	±
Chloride		++	±
Metals		±	±
Biotic:			
Phytoplankton	- abundance	+++	
	- composition	ΔΔΔ	
Macrophytes	- distribution	ΔΔ	
	- composition	Δ	
Zooplankton	- abundance	++	
	- composition	ΔΔΔ	
Zoobenthos	- abundance	±	+++
	- composition	±	ΔΔΔ
	- seasonal dynamics	ΔΔ	ΔΔΔ
Drift	- abundance		++
	- composition		ΔΔ
Fish	- abundance	++	++
	- no. of species	++	++

+ = increase, - = decrease, Δ = change in quality, ± = no change apparent
Three symbols - tremendous change
Two symbols - distinct change
One symbol - some change
? - winter conditions unknown

The main zooplankton species in previous years, *Diaptomus oregonensis* (Calanoida), was virtually absent in 1977 while *Bosmina longirostris* (Cladocera), which had been a minor species, showed a very large summer pulse. As in former years, chironomid larvae were the dominant benthic organisms, but their seasonal dynamics may have changed to some extent. In Poplar Creek the main factors accompanying the diversion that were significant to stream biota were increased flows in lower Poplar Creek, modification of much of the stream's physical habitat, and the seston content of water entering from Poplar Creek Reservoir. Densities of riffle zoobenthos below the spillway confluence were much higher in 1977 than in previous years. Filter feeding invertebrates were particulary enhanced due to the seston input via the spillway. Greater numbers and varieties of fish were using the lower creek than in the past, probably because of the increased flows in the stream. The conditions existing under ice in lower Poplar Creek have not been investigated, but evidence indicated that fish may not be able to overwinter successfully there or leave the stream because of the physical nature of the drop structures.

Conditions in these two water bodies may continue to change as the aquatic environment in them approaches an equilibrium state. The situation existing in 1977 should not be considered as permanent but rather as the immediate change that has occurred in the existing water bodies.

SUMMARY

Objectives and Methods

The Beaver Creek Diversion System was investigated from March to November, 1977, to describe post-diversion conditions in Ruth Lake, Poplar Creek and upper Beaver Creek and to describe conditions in two impoundments created in the system. Regular sampling was done at four week intervals at a total of 10 sites in the system on upper Beaver Creek, Beaver Creek Reservoir, Ruth Lake, Poplar Creek Reservoir and Poplar Creek. Physical and chemical parameters, phytoplankton, zooplankton and benthic macroinvertebrates were sampled regularly. Additional surveys were done for fish, aquatic macrophytes, stream drift and stream habitat.

Upper Beaver Creek

Upper Beaver Creek was sampled regularly for water quality at one site. In the vicinity of the reservoir, it is a meandering brown-water system with mud banks and substrate.

1. Physical and chemical parameters. During the open-water season, oxygen was greater than 80% saturation and the maximum temperature observed was 19^{o}C. Highest discharge occurred in April, May and June, but overall flow in 1977 was lower than average. Chemical parameters (pH, alkalinity, filtrable residue, TKN, NO_3 - N, ortho PO_4 - P, Total P) were generally most extreme under March ice. In the open season, mean values for the following were: pH - 7.8, alkalinity 158 mg/l, filtrable residue 224 mg/l, TOC 31 mg/l, orthophosphate - P 0.047 mg/l, total - P 0.08 mg/l. TKN ranged from 0.1 to 6 mg/l; NO_3 - N, from less than 0.016 to 0.27 mg/l; and reactive silicate from 2.6 to 10.1 mg/l. Sodium and calcium were the principal cations and bicarbonate the dominant anion in the creek water. Substrate samples collected in July contained 4% organics by air-dried weight.

2. Benthic invertebrates. Benthic samples contained low numbers of invertebrates in spring and summer (about 600/m^2) but much higher numbers in fall (about 14,000/m^2). Chironomids were the most prevalent group, but high numbers of *Caenis* also occurred. The higher densities in fall may have reflected lower flows and increased organic accumulations and imply that the creek may have a considerable density of benthos at times.

3. Fish. A summer survey revealed that at least 7 fish species occur in upper Beaver Creek. Brook sticklebacks, fathead minnows, lake chub, white sucker and longnose sucker were the most prevalent species in the 1 km above the reservoir. Northern pike and arctic grayling also occurred there.

Beaver Creek Reservoir

The reservoir occupies the shallow Beaver Creek valley and has gently sloping shorelines. Substrates were variable over the reservoir, and plant debris was common on the bottom. The water was brown and somewhat turbid, and floating mats of muskeg were common. Regular sampling was carried out at two sites in the reservoir.

1. Physical and chemical factors. Water levels fluctuated with inflows from Beaver Creek. The maximum flushing rate in 1977 was about once in two months. The maximum observed temperature was 22.5^{o}C, and although vertical thermal gradients developed, persistent stratification did not occur. The reservoir was largely anaerobic in March. During the open-water season it was poorly oxygenated, rarely reaching saturation even in surface waters. Water quality at the two sites was similar and generally resembled that of Beaver Creek. Solutes were most extreme in level under March ice. In the open season, pH generally ranged from 7.6-7.9 but was as high as 8.5 during a bloom of blue-green algae. Total alkalinity ranged from 120-200 mg/l in the open season, filtrable residue from about 200 to 390 mg/l and TOC from 20 to 40 mg/l over the same period. Nutrients were highest under the ice in March but generally declined through the open season. Ca and HCO_3 were the main ions in spring, but Na was equally important in summer and fall. Chloride increased then also.

2. Phytoplankton. Phytoplankton abundance was about 2000 to 10,000 cells/ml in spring and fall and up to 70,000 cells/ml during a midsummer bloom of blue-green algae. At the water surface blue-greens occurred at times in excess of 100,000 cells/ml, and *Aphanizomenon flos-aquae* and *Anabaena flos-aquae* were the dominant species. Ultraplankton, flagellates, and green algae were important groups of phytoplankton while diatoms were of minor importance. Euglenoid algae (*Trachelomonas*, *Euglena* and *Phacus*) were not uncommon. Nutrient concentrations were typical of eutrophy but only the blue-green algae reflected this.

3. Aquatic macrophytes. Seventeen species of aquatic plants were collected from the reservoir. *Potamogeton berchtoldii* was the most abundant submergent, and *Ceratophyllum demersum, Myriophyllum exalbescens* and *Utricularia vulgaris* were also common. *Sparganium* was the most abundant floating-leafed plant. Based on composition and abundance, five regions of submergent and floating-leafed plant assemblages were delineated in the reservoir. Emergent aquatic plants were not abundant in the reservoir although *Carex* sp. was common in certain locations. Emergent plants may be influenced by fluctuating reservoir water levels. The macrophyte community reflected colonization of a new habitat wherein a small number of species are fairly abundant.

4. Zooplankton. In the regular samples, 10 species of Rotifera, 4 species of Cyclopoida, one Calanoida and 5 species of Cladocera were common. Rotifers (mainly *Keratella cochlearis, K. quadrata* and *Polyarthra*) were in the range 5×10^4 to $1 \times 10^6/m^3$ and were most abundant in the last half of summer. Cyclopoida (*Cyclops vernalis* and *C. navus* were probably most common) reached densities as high as 7×10^4 to $9 \times 10^4/m^3$ and were most abundant in the spring and late summer-early fall. *Diaptomus leptopus* was the only calanoid copepod found and was most abundant in June-July. *Ceriodaphnia affinis, Daphnia pulicaria, D. rosea, Bosmina longirostris* and *Diaphanosoma leuchtenbergianum* were the most common Cladocera. Total crustacean zooplankton numbers were highest in midsummer (about 3×10^4 to $18 \times 10^4/m^3$). Cyclopoida were predominant in spring and fall, and Cladocera were most abundant in summer. Eleven crustaceans were collected that could be considered littoral types, and their abundance and diversity were higher in samples collected in July than in May or October. In vertical samples taken in early August, crustacean zooplankton were somewhat more abundant near the water surface, but lower depths were not strongly avoided by these organisms.

5. Benthic macroinvertebrates. At the regular sites larval Chironomidae (mostly *Chironomus* sp.) dominated the collected benthos, with Oligochaeta the only other significant group. Total numbers were low in spring (1000/m^2 or less), higher in late summer and fall (about 4000-6000/m^2) and then somewhat lower by November. Samples taken on a transect in August contained about 43,000 organisms per m^2 at a shallow littoral site (with a high diversity of organisms) but contained fewer organisms (800-2500/m^2) at 9 deeper sites in the profundal zone. There was high variability

between samples at each site although chironomids (notably *Chironomus* and *Glyptotendipes*) predominated.

6. Fish. Brook sticklebacks, fathead minnows, white suckers and lake chub were abundant in the reservoir, and northern pike and longnose suckers were common. Habitat suitable for spawning for all species is present but it is not known if they will be able to adjust to problems of overwintering.

Ruth Lake

The lake is shallow and littoral with mud and organic substrates and slightly alkaline waters. Previously it had clear waters, stable levels and low to moderate phytoplankton densities. In 1977, the water level fluctuated markedly; the water was brown and more turbid; and phytoplankton abundance had increased to bloom densities.

1. Physical and chemical parameters. In 1977, Ruth Lake water levels fluctuated up to 1 m whereas very little fluctuation had been observed in 1974-75. The calculated 1977 maximum flushing rate was about once in 20 days. Maximum recorded temperature was 20^{o}C, and the lake was isothermal. In the open-water season, oxygen was usually 60-90% of saturation (compared to nearly 100% saturation in 1974-75) with a maximum of 139% during a blue-green algal bloom. Water quality was more variable this year, and the lake was higher in dissolved organic compounds and nutrients. Many water quality parameters had their most extreme levels under ice in March. In the open-water season, pH averaged 8.0 (up to 9.3 during a blue-green algal bloom), total alkalinity ranged from about 130 mg/l to 190 mg/l, filtrable residue was about 260-350 mg/l, turbidity was 1-4 NTU and TOC ranged from 16-51 mg/l and averaged 34 mg/l. Of the nutrient levels in the open-water season (which had also been highest under March ice) nitrate - N ranged from less than 0.016 mg/l to about 0.1 mg/l; TKN from 0.2 to 0.6 mg/l; orthophosphate - P declined through the summer from 0.06 mg/l to less than 0.016 mg/l; and total phosphorus paralleled this decline. Reactive silicate was about 3-5 mg/l during the open season. True colour was much higher this year; oil and grease concentrations ranged from 12 to 156 mg/l; and hardness, which ranged from 61-113 mg/l, was slightly lower than in 1975. Ca and HCO_3 were the dominant ions in spring, but Na was the main cation in summer and fall at which time Cl became an important anion. Metals changed little from 1975, and substrate samples contained 40-64% organics.

2. Phytoplankton. Phytoplankton density was about 7500-35,000 cells/ml in spring, much higher in summer (30,000-228,000 cells/ml) and then quite low (2500 cells/ml) from September through November. Blue-green algae were abundant in June and July when *Aphanizomenon flos-aquae* and *Anabaena flos-aquae* formed a bloom. Ultraplankton, flagellates and green algae were the most abundant types of algae at other times, and diatoms were somewhat less important. Phytoplankton populations reflected eutrophic conditions. Cell densities were much higher than in 1974-75, and the composition changed from one of ultraplankton dominance to a mixed dominance with blue-green algae predominant in midsummer.

3. Aquatic macrophytes. These plants, stable in composition and distribution between 1974 and 1975, differed this year with the disappearance of large beds of *Chara*. Extensive recolonization of the beds by other plants has not occurred. Emergent plants have largely been stranded by lowered water levels in 1977 and will probably show changes in response to water level fluctuations. *Nuphar* continued to occupy much of the deeper areas in high densities.

4. Zooplankton. In the regular samples, 10 species of Rotifera, 3 Cyclopoida, 2 Calanoida and 6 Cladocera species were common. Rotifers were most abundant in early May and late July, and *Keratella cochlearis, K. quadrata* and *Polyarthra* were the dominant types. Cyclopoida were highest in early June and July-August (7×10^4 to $10 \times 10^4/m^3$), and the major species were *Cyclops vernalis* and *C. navus*. The latter was not collected in 1974 and 1975. Previously, *C. bicuspidatus thomasi* had been the most abundant cyclopoid in the spring. *Bosmina longirostris* and *Diaphanosoma leuchtenbergianum* were the major Cladocera and were most abundant in July-August. *B. longirostris* had not been abundant in past years. The conchostracan *Lynceus brachyurus* was less abundant than in 1974 and 1975. The seasonal trends in total abundance have changed since 1974-75, but spring peaks, with lower numbers in summer-fall, still occurred. Cyclopoids were prevalent in spring and in August, and Cladocera dominated in summer. Low numbers occurred in September through November. The Calanoida, which comprised *Diaptomus leptopus* and *D. oregonensis*, were low in numbers. In 1974 and 1975 the latter species was much more abundant and dominated the crustacean zooplankton. Twenty littoral types of crustaceans were collected, of which *Chydorus sphaericus* and *Eucyclops agilis* were important in spring.

5. Benthic macroinvertebrates. As in previous years, RL-3 had higher benthos abundance (generally 2000-7000/m^2) than RL-2 (generally 200-2500/m^2). The former site had densities similar to those of 1974 and 1975, but at RL-2, densities during the spring and summer were slightly lower than in previous years. As in previous years, chironomids composed most of the benthos collected, and *Chironomus* was the dominant genus involved. Oligochaeta were present in low numbers, as they were in 1974 and 1975, but amphipods had declined in 1977. Conchostraca (*Lynceus brachyurus*) were not collected in the benthos this year. Odonata were slightly less abundant this year, but molluscs did not show major differences from 1974 and 1975. In 1977, *Chaoborus* was collected in the benthos for the first time.

6. Fish. Brook sticklebacks and fathead minnows are abundant in the lake and have not been noticeably affected by the diversion. White and longnose suckers have appeared in the lake, the former in high numbers. No pike or lake chub were collected but these species may eventually arrive from Beaver Creek Reservoir. The status of suckers in the lake through winter is uncertain.

Poplar Creek Reservoir

The reservoir is fairly deep (up to 20 m) with steeply sloping shorelines common. Reservoir water was brown and turbid, and floating mats of muskeg occurred. Its substrate included peat, sand, gravel, clay and boulders along the dam face. Two sites in the reservoir were sampled regularly.

1. Physical and chemical parameters. The maximum flushing rate calculated for the reservoir in 1977 was about once in 2 months. The maximum water temperature recorded was 20^{o}C and the reservoir was stratified with a thermocline in the 4-8 m stratum. Hypolimnetic temperature was about 6^{o}C, and turnover occurred in October. The hypolimnion was anaerobic, maximum recorded dissolved oxygen in the epilimnion was 101%, and epilimnetic oxygen saturation was usually about 50-60%. As in other areas of the diversion system, most of the extreme levels of water quality parameters occurred under March ice. During the open-water season, pH averaged 7.7 (up to 8.0 during a blue-green algae bloom) in the epilimnion but averaged about 7.2 in the hypolimnion. Total alkalinity was lowest in May (about 190 mg/l) and climbed to high values late in the study as did filtrable residue (up to about 330 mg/l). Turbidity and suspended solids were higher

hypolimnion than the epilimnion. TOC was generally in the range of 30-40 mg/l. Nitrogen did not differ greatly in top and bottom waters; nitrates declined through the season (from 0.2 to 0.02 mg/l); and TKN was fairly stable in the open season at about 0.3 mg/l. Phosphorus concentrations were higher and more variable in hypolimnetic than epilimnetic samples. Orthophosphate - P declined through the summer from 0.05 to less than 0.016 mg/l in September. Reactive silicate declined through the study from around 7-11 mg/l to about 2-5 mg/l. Water colour was 55-140 units and somewhat more intense in the hypolimnion. Oil and grease ranged from 5-141 mg/l, and hardness was usually 100-130 mg/l. Ca was the dominant cation in spring, but Na was equally important in summer and fall. Bicarbonate was the principal anion although chloride increased in summer and fall. Iron was up to 6 mg/l in the hypolimnion, and Cu, Zn and B were quite high at PCR-2 in fall. The organic fraction of the substrate at PCR-1 was lower and substrate metals were somewhat higher than at PCR-2.

2. Phytoplankton. Phytoplankton densities were about 2500 cells/ml in spring, 4000-8000 cells/ml in June, then up to 30,000 cells/ml during a blue-green algae bloom in July-August. Total numbers declined by September and were about 2500 cells/ml by November. Cell numbers were much lower in the hypolimnion. Diatoms were unimportant, but ultraplankton, flagellates and green algae were all major components of the phytoplankton. *Aphanizomenon flos-aquae* and *Anabaena flos-aquae* formed the blue-green algal bloom; only blue-green numbers reflected the rich nutrient supply.

3. Aquatic macrophytes. Submergent aquatic plants were moderately abundant and widespread in the reservoir. Emergent plants were only locally abundant although *Menyanthes trifoliata* (buck bean) formed an extensive stand at the north end of the reservoir. *Potamogeton berchtoldii*, *Utricularia vulgaris* and *Myriophyllum exalbescens* were the main submergent species, and *Sparganium* was the only common floating-leafed plant. Five regions of submergent plants were distinguished. The reservoir contained a moderately abundant assemblage of a few species of aquatic macrophytes.

4. Zooplankton. Rotifers were most abundant in August and ranged up to 1×10^6 individuals/m^3. *Conochilus unicornis*, *Polyarthra* and *Keratella*

cochlearis were the prevalent species of this group. *Cyclops vernalis* and *C. bicuspidatus thomasi* were the predominant Cyclopoida. *Diaptomus oregonensis* was the most abundant calanoid copepod. The major species of Cladocera were *Daphnia pulicaria, D. galeata mendotae, D. parvula, Bosmina longirostris, Ceriodaphnia lacustris* and *Diaphanosoma leuchtenbergianum*. The conchostracan *Lynceus brachyurus* occurred in low numbers. Total abundance was low in late winter-early spring but increased to a maximum in August and then declined during the fall. Cyclopoids dominated in spring and into early summer when cladocerans became prevalent. The latter prevailed until fall when calanoid copepods dominated. Seventeen types of littoral crustaceans were collected in seasonal samples. They were least abundant in fall. The vertical stratification study in August indicated that zooplankton were concentrated above the thermocline.

5. Benthic macroinvertebrates. Total numbers of benthos were generally low (about 50-500/m^2) but increased somewhat in late fall (1000-2000/m^2). *Chironomus* and *Chaoborus flavicans* were the predominant benthic organisms. Low abundances may be related to low oxygen saturation at the bottom and to substrate conditions. Samples collected on transects in August contained low numbers (less than 500/m^2) at sites on inorganic substrates or having low bottom oxygen saturation. Shallower sites had higher numbers, dominated by chironomids. Fall overturn apparently enabled *Chironomus* to grow rapidly at organic substrate sites previously exposed to long periods of deoxygenation.

6. Fish. Brook sticklebacks and fathead minnows were abundant and reproducing in the reservoir. White suckers were collected in small numbers. No other species of fish was observed. Overwintering of suckers is uncertain because of the anaerobic conditions that occur in winter.

Poplar Creek

Poplar Creek, a small brown-water stream, has been partly channelized and now receives increased flows from the diversion system. The creek was sampled at two sites below and one upstream of the spillway.

1. Physical and chemical factors. Flow in lower Poplar Creek has been increased about 2-3 times by the diversion. The highest temperature recorded was 23^{o}C, and the lower creek may be somewhat warmer than previously. The spillway oxygenates water that passes over it, and the creek was 90-100% saturated in the open-water season. Water quality at site

PC-B4 and PC-1 was fairly similar. Many parameters had their extreme values in March. Alkalinity and filtrable residue were more variable upstream of the spillway, but turbidity and suspended solids were similar in the upper and lower creek, as was TOC (mean concentration 32 mg/l). Nitrogen concentrations in the lower creek were more similar to those of Poplar Creek Reservoir than the upper creek, but phosphorus and silica differed little between upstream and downstream stations. Water colour was of the same intensity as the rest of the system, but oil and grease levels (6-57 mg/l) were lower than elsewhere. Hardness ranged from 66 to 138 mg/l. Ca was the dominant cation in spring, but both Na and Ca were important in summer and fall. HCO_3 was the major anion, and Cl, which ranged from 12-37 mg/l, was similar to 1975 levels. Metal concentrations were similar at the two stations and not dissimilar to 1975 values. Substrate organics were low (3-4%); some substrate metals were higher in concentration in the lower section of the creek than in the upper section.

2. Habitat. The physical dimensions of the stream below the stilling basin have changed. The stream was channelized for 1.85 km below the spillway and contains eleven low boulder drop structures with riffles and pools in between. Much of this channel was lined with boulder and rubble, and the stream was wider and more exposed than before. Erosion was occurring in the first 200 m below the channelized section, but downstream from that creek morphometry appeared similar to pre-diversion conditions.

3. Benthic macroinvertebrates. Total abundance and composition of the zoobenthos was very similar at sites below the spillway (PC-1 and PC-2). Numbers were about $2500/m^3$ in spring and early summer, 35,000 to $50,000/m^2$ in late August, lower in October (5000 to $10,000/m^2$) but very high in November (up to $65,000/m^2$). At PC-B4, spring densities were $1000\text{-}2000/m^2$; levels climbed to $5000\text{-}10,000/m^2$ in midsummer and then were as high as $14,000/m^2$ in fall. Higher densities and more abundant filter feeders and chironomids at lower sites were probably a result of increased organic material introduced through spillway flows. The increase in abundance below the spillway was mainly composed of Chironomidae, Simuliidae, and to a lesser extent, Trichoptera. Benthos at PC-B4 was similar to that found there in 1974 and 1975, but conditions at the lower sites can not

easily be compared between years because of alterations to stream habitat. During the study, orthoclad chironomids were one of the most abundant groups and were more common down stream. Simuliidae were as dense as $20,000/m^2$ downstream but only about $1000/m^2$ at PC-B4. *Cheumatopsyche* and *Hydropsyche* were the predominant trichopterans downstream while *Glossosoma* was prevalent at PC-B4. *Baetis* dominated the mayflies, and *Nemoura* was the dominant stonefly. These groups were important components of the benthos only at PC-B4.

4. Drift. Nonzooplankton invertebrate drift was similar in composition and abundance at PC-B4 and PC-1. Mayflies (primarily *Baetis*) and Diptera (primarily chironomids and simuliids) dominated. *Baetis* was night active. Mean drift density (excluding fish and crustacean zooplankton) was about $10/m^3$. It had been about $7/m^3$ in June, 1975. Zooplankton was abundant at PC-1 and was dominated by Cladocera. The composition of zooplankton entering the creek from the stilling basin during the study resembled that of Poplar Creek Reservoir.

5. Fish. Fish were more abundant and diverse in 1977 than previously in Poplar Creek below the spillway, and have also increased somewhat in the upper creek as well. Fifteen species were collected. Brook sticklebacks, fathead minnows and lake chub were most abundant, and white and longnose suckers were next in abundance. Grayling and pike were common and the most abundant game fish. White suckers successfully spawned in the creek, and longnose suckers did so to a lesser extent. Pike entered the creek in spawning condition but were not successful in reproducing. Grayling spawned to a small extent in the stream, and all used the creek for feeding. Species occasionally collected (yellow walleye, lake and mountain whitefish, burbot, trout-perch, and finescale dace) probably used the creek for feeding.

Amphibians

Adults and young of three species were collected; the wood frog (*Rana sylvatica*), boreal chorus frog (*Pseudacris triseriata*) and the Canadian toad (*Bufo hemiophrys*). They were most abundant in areas of emergent vegetation in the diversion system.

Diversion Canals

The two canals entering and leaving Ruth Lake varied in width from 10-30 m, contained a variety of substrates (sand, gravel, silt and peat), and were generally less than 1 m in depth. Some submergent plants occurred in them, and clumps of peat were lodged in sections adjacent to Ruth Lake.

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Appendix 1 . Fish collection data for Upper Beaver Creek, July 27-28, 1977.

Sample No.	Gear	Fork Length (mm)	Weight (g)	Age
Arctic grayling - *Thymallus arcticus*				
9	EF	275	85	2
White sucker - *Catostomus commersoni*				
2	GN	320	425	
3	GN	280	340	
4	GN	315	397	
5	GN	285	284	
6	GN	300	369	
7	GN	290	340	
8	GN	370	539	
Longnose sucker - *Catostomus catostomus*				
1	S	290	340	

Gear: EF - electrofishing, GN - gill net, S - seine

Appendix 2. Phytoplankton cell counts from Beaver Creek Reservoir, 1977.

	STATION BCR-1 - cells/ml.												
	March 31		May 4		June 1		June 27		July 28	Aug. 25	Sept. 23	Oct. 15	Nov. 20
	T	B	T	B	T	B	T	B					
Cyanophyta													
Anabaena flos-aquae							1590	42	13073				
Anabaena			146		678								
Aphanizomenon flos-aquae							2303	801	41258	+			
Coccoid forms (unid. further)													
Dactylococcopsis	56												
Filamentous forms (unid. further)	+												
Lyngbya			130	151									
Group % of total	1		4	6	7		87	84	93	1			
Bacillariophyceae													
Asterionella												+	132
Centric diatoms (unid. further)			195		15								
Cyclotella			65	301		30			70	70	+	32	237
Fragilaria													79
Melosira										1195	+	+	
Pennate diatoms (unid. further)				+	45						+		
Synedra			+	75	45	30			351	+	18		26
Tabellaria			114	60		90			+	+			
Group % of total			6	18	1	5			1	17	1	2	43
Flagellates													
Cryptomonas	1138	42	2790	120	1868	211	+	14	492	1230	527	308	105
Dinobryon sertularia					196	120							
Dinobryon									+	457	+		
Dinophyceae (unid. further)								+					
Euglena	42	+	16	+	15	+			+				26
Peridinium			49							141	+		+
Phacus									+				
Rhodomonas					1927	90	373	+		1581	53	65	53
Trachelomonas						30			281	176	53	49	+
Unidentified flagellates	28		81	210	572	392	16		632	211		97	
Group % of total	10	3	43	13	50	26	9	1	2	50	28	29	17
Chlorophyta													
Actinastrum													
Ankistrodesmus convolutus		+	324	90	256	45			70	70	176	211	184
Ankistrodesmus falcatus							81	28					
Ankistrodesmus			195	166	15	15			+	35	53	+	
Chlamydomonas											+		
Coccoid forms (unid. further)	14	28	973	392	1657	45							
Coelastrum							+						
Crucigenia					120	120			+	141	+		
Dictyosphaerium					181				281	105			
Gloeocystis							+	+					
Kirchneriella											18		
Oocystis							16						
Scenedesmus quadricauda			65						281		18		
Scenedesmus				+	60	+			+	141	18	+	
Selenastrum			65		151								
Staurastrum									+				
Unidentified forms							32	42	1617	879	615	32	26
Group % of total	1	2	24	26	26	7	3	7	4	18	39	13	19
Ultraplankton	10781	1364	1573	904	1506	2018	65	84	281	1125	738	1022	237
Group % of total	89	95	23	37	16	62	1	8	1	15	32	56	21
Grand Total	12059	1434	6781	2469	9307	3236	4476	1011	58687	7557	2287	1816	1105

\+ Occurred in quantities too low for enumeration   T-Samples from epilimnion   B-Samples from hypolimnion

Continued ...

Appendix 2 .Concluded

	STATION BCR-2 - cells/ml.								
	March 31	May 4	June 1	June 27	July 28	Aug. 25	Sept. 23	Oct. 15	Nov. 20
Cyanophyta									
Anabaena flos-aquae				334	8434	656			
Anabaena									
Aphanizomenon flos-aquae				14725	55244	375			
Coccoid forms (unid. further)					+				
Dactylococcopsis									
Filamentous forms (unid. further)	633		253						
Lyngbya									
Group % of total	43		4	94	89	23			
Bacillariophyceae									
Asterionella									
Centric diatoms (unid. further)		56	84						
Cyclotella		198			422	+		+	105
Fragilaria								75	
Melosira						23	81	176	
Pennate diatoms (unid. further)		28	28	+	+	+		50	
Synedra		14	+		181	23			+
Tabellaria			+		+	47			
Group % of total		9	2	1	3	2	4	8	15
Flagellates									
Cryptomonas	42	450	956	141	723	656	345	402	53
Dinobryon sertularia			155	+					
Dinobryon						258	20		
Dinophyceae (unid. further)									
Euglena		42			+	23			18
Peridinium						23		25	18
Phacus									
Rhodomonas		+	1054	474	843	1007		226	+
Trachelomonas			42		1024	258	81	100	35
Unidentified flagellates	28	254	351	35	181	70		50	18
Group % of total	5	22	44	4	4	51	21	21	20
Chlorophyta									
Actinastrum		56				187			
Ankistrodesmus convolutus	14	183	127		241	23	182	427	158
Ankistrodesmus falcatus				141					
Ankistrodesmus	+		14		60	+	+	25	18
Chlamydomonas					120		20		18
Coccoid forms (unid. further)	14	534	689						
Coelastrum									
Crucigenia			56			+	243		
Dictyosphaerium			219		1446	187			
Gloeocystis		+	+	+					
Kirchneriella							20		
Oocystis									
Scenedesmus quadricauda		56			241		+		
Scenedesmus		+	+		241	+	162	251	
Selenastrum									
Staurastrum									
Unidentified forms				53	1506	539	142	126	70
Group % of total	2	24	20	1	3	21	36	22	37
Ultraplankton	731	1560	1729	53	783	117	831	1908	211
Group % of total	50	45	30	1	1	3	39	49	28
Grand Total	1462	3431	5757	15956	71690	4472	2127	3841	722

Appendix 3. Summary of BCR-1 zooplankton data in 1977. Unbracketed values are number/m^3. Bracketed values are biomass expressed as mg wet weight/m^3.

	Mar. 31	May 4	June 1	June 27	July 28	Aug. 25	Sept. 23	Oct. 15	Nov. 20
ROTIFERA	12,350	208,000	238,000	18,700	245,000	1,130,000	1,280,000	268,000	161,000
CONCHOSTRACA									
Lynceus brachyurus									
nauplii		7							
CLADOCERA									
Bosmina longirostris			3230	360	23,800	17,200	680	55	
			(51.4)	(3.7)	(143.5)	(132.8)	(5.7)	(0.6)	
Ceriodaphnia affinis			2330	8610					
			(38.0)	(272.5)					
Ceriodaphnia reticulata				360					
				(12.0)					
Chydorus sphaericus			180		220				
			(1.0)		(1.0)				
Daphnia magna								18	
								(7.5)	
Daphnia pulicaria			720	23,000					
			(15.1)	(1752.2)					
Daphnia rosea		9		18,000					
		(0.1)		(1019.6)					
Diaphanosoma leuchtenbergianum				2510	2180	1260		37	
				(46.6)	(26.9)	(18.2)		(0.7)	
COPEPODA									
CALANOIDA									
Diaptomus leptopus									
nauplii				6460	3490				
copepodites			720	4300	1310		110		
			(31.4)	(73.0)	(21.3)		(4.2)		
adults			200	100	700				
			(90.0)	(39.0)	(255.0)				
CYCLOPOIDA									
nauplii		9350	76,800	12,200	15,700	32,600	21,100	1110	
copepodites I-III (unidentified)		650	57,000	360	7400	18,200	13,000	1500	44
		(12.5)	(472.5)	(1.4)	(31.1)	(93.7)	(71.4)	(9.3)	(0.3)
Cyclops vernalis - *Cyclops navus*									
copepodites IV-V		650	26,000		540		2100	98	27
		(28.5)	(725.7)		(7.4)		(38.7)	(1.7)	(0.5)
Cyclops vernalis									
adults		3	5200						1
		(0.3)	(255.8)						(0.1)
Cyclops bicuspidatus thomasi									
copepodites IV-V	15								2
	(0.4)								(0.1)
adults		3							7
		(0.3)							(0.6)
Cyclops navus									
adults									
Macrocyclops albidus									
adults			2						
			(0.1)						
TOTAL[1]	15	1315	95,584	57,500	36,150	36,660	15,890	1,708	81
	(0.4)	(41.7)	(1681.9)	(3220.0)	(486.2)	(244.7)	(120.0)	(19.8)	(1.6)

[1] excluding Rotifera, Conchostraca and nauplii of Copepoda.

Appendix 4. Summary of BCR-2 zooplankton data, 1977. Unbracketed values are number/m³. Bracketed values are biomass expressed as mg wet weight/m³.

	Mar. 31	May 4	June 1	June 27	July 28	Aug. 25	Sept. 23	Oct. 15	Nov. 20
ROTIFERA	108,000	213,000	177,000	64,800	900,000	1,000,000	1,486,000	193,000	152,000
CONCHOSTRACA									
Lynceus brachyurus		7							
nauplii									
CLADOCERA									
Bosmina longirostris			5010	7450	165,000	13,600	930	9	
			(48.3)	(93.6)	(995.0)	(122.1)	(8.3)	(0.1)	
Ceriodaphnia affinis									
Ceriodaphnia reticulata			500						
			(29.8)						
Chydorus sphaericus		8						9	
		(0.1)						(0.1)	
Daphnia pulicaria		23	8020	6480					
		(4.1)	(68.9)	(527.0)					
Daphnia rosea				3890					
				(324.5)					
Diaphanosoma leuchtenbergianum				3240	5180	2510	620	45	
				(75.2)	(75.1)	(46.5)	(16.9)	(1.0)	
COPEPODA									
CALANOIDA									
Diatomus leptopus									
nauplii			100	7800	6910				
copepodites			1000	8100	1730	560		13	
			(103.6)	(445.6)	(18.6)	(24.4)		(0.7)	
adults			500	970	500				
			(225.6)	(389.6)	(208.0)				
CYCLOPOIDA									
nauplii		7710	60,100	2600	13,800	66,700	22,300	3580	
copepodites I-III (unidentified)			52,000	650	7780	16,000	10,200	160	
			(385.6)	(1.9)	(54.5)	(82.4)	(75.6)	(0.8)	
Cyclops vernalis - Cyclops navus									
copepodites IV-V		1000	16,000	650		2000		40	
		(23.2)	(260.2)	(9.7)		(32.5)		(1.0)	
Cyclops vernalis									
adults		100	4010						
		(11.7)	(213.3)						
Cyclops bicuspidatus thomasi									
copepodites IV-V	12							5	5
	(0.3)							(0.2)	(0.1)
adults	2								5
	(0.2)								(0.2)
Cyclops navus									
adults		23	500						
		(1.0)	(63.7)						
TOTAL[1]	14	1,154	87,540	31,430	180,190	34,670	11,750	281	10
	(0.5)	(40.1)	(1399.0)	(1867.1)	(1351.2)	(307.9)	(100.8)	(3.9)	(0.3)

[1] excluding Rotifera, Conchostraca and nauplii of Copepoda.

Appendix 5 . Fish collection data from gill net catches in Beaver Creek Reservoir, 1977.

Sample No.	Date	Site	FL (mm)	Wt. (g)	Sex	Other
Northern pike (*Esox lucius* (Linnaeus))						
10	26/6	G2	395	482	-	S
11	26/6	G2	415	624	-	S
12	26/6	G2	480	908	-	S
13	26/6	G2	465	794	-	S
101	23/8	G1	515	1135	F	-
102	23/8	G1	570	1419	F	-
103	23/8	G1	555	1419	F	-
104	23/8	G1	425	1192	M	-
131	23/8	G2	489	965	M	-
132	23/8	G2	497	1021	M	-
133	23/8	G2	515	1192	M	-
134	23/8	G2	525	1220	M	-
135	23/8	G2	505	1078	M	-
White Sucker (*Catostomus commersoni* (Lacepede))						
1	26/6	G2	345	596	-	S
2	26/6	G2	275	284	-	S
3	26/6	G2	280	340	-	S
4	26/6	G2	305	397	-	S
5	26/6	G2	310	397	-	S
6	26/6	G2	310	397	-	-
7	26/6	G2	320	454	-	-
14	26/6	G1	285	255	-	S
15	26/6	G1	290	284	-	S
16	26/6	G1	310	397	-	S
17	26/6	G1	265	284	-	S
18	26/6	G1	285	312	-	S
19	26/6	G1	280	284	-	S
20	26/6	G1	305	397	-	S
21	26/6	G1	280	284	-	S
22	26/6	G1	270	284	-	S
23	26/6	G1	300	340	-	S
24	26/6	G1	280	340	-	-
25	26/6	G1	305	397	-	-
26	26/6	G1	285	340	-	-
27	26/6	G1	280	312	-	-
28	26/6	G1	305	397	-	-
29	26/6	G1	315	397	-	-
30	26/6	G1	300	369	-	-
31	26/6	G1	270	284	-	-
32	26/6	G1	265	255	-	-
33	26/6	G1	285	340	-	-
34	26/6	G1	270	312	-	-
35	26/6	G1	295	369	-	-
36	26/6	G1	260	255	-	-
37	26/6	G1	270	255	-	-
38	26/6	G1	330	425	-	-
39	26/6	G1	295	340	-	-
40	26/6	G1	280	284	-	-
41	26/6	G1	140	<57	-	-
42	26/6	G1	195	85	-	-
115	23/8	G1	194	113	-	-
116	23/8	G1	274	284	-	-
117	23/8	G1	306	397	-	-
118	23/8	G1	284	340	-	-
119	23/8	G1	312	425	-	-
120	23/8	G1	359	596	-	-
121	23/8	G1	305	340	-	-
122	23/8	G1	336	511	-	-
123	23/8	G1	291	312	-	-
124	23/8	G1	175	57	-	-
125	23/8	G1	182	57	-	-
126	23/8	G1	172	57	-	-
127	23/8	G1	303	397	-	-
128	23/8	G1	282	284	-	-
129	23/8	G1	358	624	-	-
130	23/8	G1	332	567	-	-
146	23/8	G2	400	851	-	-
147	23/8	G2	351	624	-	-
148	23/8	G2	316	425	-	-
149	23/8	G2	334	511	-	-
150	23/8	G2	279	284	-	-
151	23/8	G2	292	340	-	-
152	23/8	G2	170	57	-	-
153	23/8	G2	168	57	-	-
154	23/8	G2	179	57	-	-
155	23/8	G2	302	397	-	-
156	23/8	G2	334	567	-	-
157	23/8	G2	271	284	-	-
158	23/8	G2	361	681	-	-

Site: refer to map of sampling sites. Other: S - stomach examined.

Continued . . .

Appendix 5. Concluded.

Sample No.	Date	Site	FL (mm)	Wt. (g)	Sex	Other
159	23/8	G2	319	425	-	-
160	23/8	G2	328	454	-	-
Longnose sucker (*Catostomus catostomus* (Forster))						
8	26/6	G2	305	397	-	S
9	26/6	G2	290	369	-	S
43	26/6	G1	275	284	-	S
44	26/6	G1	290	340	-	S
45	26/6	G1	255	227	-	S
46	26/6	G1	265	255	-	S
105	23/8	G1	287	312	-	-
106	23/8	G1	332	482	-	-
107	23/8	G1	305	397	-	-
108	23/8	G1	328	511	-	-
109	23/8	G1	327	454	-	-
110	23/8	G1	311	397	-	-
111	23/8	G1	317	425	-	-
112	23/8	G1	316	397	-	-
113	23/8	G1	313	425	-	-
114	23/8	G1	313	369	-	-
136	23/8	G2	310	397	-	-
137	23/8	G2	296	312	-	-
138	23/8	G2	279	255	-	-
139	23/8	G2	308	425	-	-
140	23/8	G2	310	454	-	-
141	23/8	G2	296	312	-	-
142	23/8	G2	309	397	-	-
143	23/8	G2	292	369	-	-
144	23/8	G2	307	397	-	-
145	23/8	G2	321	454	-	-

Appendix 6.Phytoplankton cell counts from Ruth Lake, 1977

	STATIONS RL-2 and RL-3 - cells/ml																	
	March 31		May 4		June 1		June 26		July 29		August 24		September 23		October 15		November 19	
	RL-2	RL-3	RL-2	RL-3	RL-2	RL-3	RL-2	RL-3	RL-2	RL-3	RL-2	RL-3	RL-2	RL-3	RL-2	RL-3	RL-2	RL-3
Cyanophyta																		
Anabaena flos-aquae							4744	15340	68697	42593	176	1318						
Anabaena			+	+	+	383												
Aphanizomenon flos-aquae							15340	49788	75697	162219	6209	4645						
Aphanocapsa			900															
Chroococcus						58			+									
Dactylococcopsis	14	63																
Lyngbya limnetica											+							
Lyngbya			392															
Merismopedia							+		+	562								
Oscillatoria	+																	
Group % of total	1	1	4			5	67	93	97	90	42	20						
Bacillariophyceae																		
Asterionella											+				+		+	+
Centric diatoms (unid. further)			331	141		96												
Cocconeis											29	33						
Cyclotella				3795	326		949	+	1012	4077	498	1878	288	105	+	18	158	232
Diatoma			30															
Fragilaria crotonensis								+										
Melosira											59	1120	+	70	32	18		
Pennate diatoms (unid. further)			120	351	19		26	290	84	70	29	33		18	49	18		+
Stephanodiscus			151		19			817										
Synedra			219	35	96	19	+	+	422	1125	+	66	19		+	18		
Tabellaria			249			+		158			1816	1713			+			
Group % of total			3	16	5	1	3	2	1	2	17	16	13	11	19	5	15	17
Flagellates																		
Cryptomonas	759	674	1536	1792	671	1054	659	448	127	492	1201	297	249	439	162	211	211	63
Dinobryon sertularia					441	173	105	+										
Dinobryon				35					+		146	988	77	18	49	18		
Euglena	28	+	753	+		19	+					+		+		18		42
Peridinium			60	+							+					18	53	+
Phacus	+				38							66		18				
Rhodomonas			30	35	767	2817	1212	422	127	1617	1699	1548	77	140		53	88	84
Trachelomonas	+	+							127	2390	88	99	+	18		35	+	+
Unidentified flagellates	14	147	219	35	709	613	395	53		141	234	560		18	49	53	18	42
Group % of total	11	3	7	7	27	50	8	1	1	2	22	12	17	36	6	27	34	17
Chlorophyta																		
Actinastrum										562								
Ankistrodesmus convolutus		21	392	668	421	134	264	79	42	633	88	165	134	404	16	53	176	232
Ankistrodesmus falcatus							580	+			+	132				+		
Ankistrodesmus	14		271	281	19	19				+	29	33	19		32	+		232
Chlamydomonas									42		+					+		
Coccoid forms (unid. further)	28	63	783	1793	1801	1380												
Coelastrum					+		+	264				527						
Cosmarium	+																	
Crucigenia			120		230	77	105			281		659	+					
Dictyosphaerium					383	153			+	1125	234	5140						
Gloeocystis			120	105				474			+							
Kirchneriella lunaris													+					
Kirchneriella			120															
Lagerheimia					19	19					29							
Oocystis			120									132						
Pediastrum boryanum							+	+										
Pediastrum tetras					153													
Pediastrum									167		234	+	+					
Scenedesmus quadricauda			120	141			+		167	2671		132	191	+	32	70		
Scenedesmus			181	+	268	230	+	105	253	1125	+	527	268	+	211			42
Selenastrum			+															
Staurastrum										141								
Tetraedron caudatum			30	+														
Tetraedron minimum							26					+						
Tetraedron			+		38				42				19					
Unidentified Desmidiaceae											+							
Unidentified forms							1581	1212	1392	5974	1581	4514	421	141	114	141	18	21
Group % of total	1	1	6	11	35	21	9	3	1	5	14	40	44	30	30	18	17	38
Ultraplankton	6368	23658	29068	17571	3144	2166	3769	712	886	703	820	3690	613	422	616	738	369	401
Group % of total	88	96	80	66	33	23	13	1	1	1	5	12	26	23	45	50	34	28
Grand Total	7225	24626	36315	26778	9562	9410	29755	70162	149284	228501	15199	30015	2375	1811	1362	1480	1091	1391

\+ Occurred in quantities too low for enumeration

Appendix 7. Composition and relative abundance of submerged macrophytes, and relative abundance of *Nuphar variegatum* at transect points in Ruth Lake, August 4, 1977.

Point	Submergents	*Nuphar*
A-S	Pps-O, Mx-R	R
1	Ppc-A, Pps-C, Nf-C	O
2	Ppc-A, Pps-A	C
E	F-A	O
B-S	Mx-O, Pz-O, Ch-O, F-O	O
1	Ch-A, Pz-A; Pfol-O, Pr-O, F-O	C
2	Pz-O, Pr-O, Pps-O, F-O	C
3		A
4	F-O	C
E	Ch-C; Pps-O, F-O	O
C-S	Mx-C; Ch-O, Pfo-O	O
1		C
2		C
3	Pps-O, Uv-O, F-O	A
4	Uv-R	A
E	Mx-O, Pz-O, Ch-O, Uv-O, Pr-O	C
D-S	Mx-A; Ch-O, Nf-O, Pz-O, Pr-O, Pfo-O	O
1		O
2		C
3		A
4		A
5	Pz-O, F-O	C
6	Pz-O, Pr-R	O
E	Ch-A; Pr-O, Mx-R	O
E-S	Ch-C; Mx-R	C
1	Nf-C; Mx-O, Pr-O, Pfo-R	C
2	Nf-C; Ppr-O, Mx-O	C
3	Ppr-O	A
4		O
5	Pps-R, Ppc-R	O
E	Mx-O, Pz-O, Ch-O	O
F-S	Pz-O, Mx-O, F-O	O
1		C
2	Pz-O	A
3	Nf-A; Ppc-O, Pz-O	O
4	Ppc-C, Pz-C, Nf-C; Pr-O, Pps-O	O
5	Ppc-C; Pr-O, Pps-O	O
6	Ppc-C; Pz-O, Mx-O	O
7	Nf-O, Pz-O, Pfo-O, Pr-O	O
E	Pz-O, Nf-O, Mx-O	O
G-S	Ppc-O	O
1	Pr-O, Nf-O, F-R, Mx-R	R
2	Pr-O, Ppc-R, Pz-R, Uv-O, Mx-O	R
3	Mx-O, Uv-O, Pz-R	R
4	Mx-A; Ppc-O, F-O	R
5	Nf-A, Ppc-C; Mx-O	R
6	Pz-R, Mx-R	R
E	Mx-O, Pz-O	O
H-S	Pz-O, Mx-O, Pr-O	C
1	Pz-O, Pr-O, Mx-O, Uv-O	O
2	Pr-C, Pz-C; Ppr-R, Mx-R	O
3	F-O, Pz-O, Nf-O	O
4	Pz-C; F-O, Ppr-R	C
5	Pr-O, Uv-O, Nf-R	C
6	Nf-O, Ppc-O	O
E	Mx-O, Pr-O, Pz-O	O
I-S	Uv-O, Mx-O, Pz-O, Nf-O	R
1	Uv-O, Pfo-O, Ppc-O, Nf-O	O
2	Pps-O, Pz-O, Ppr-O, Ppc-O, Uv-R, F-R	C
3	Nf-O, Ppc-R	A
4	Uv-O	C
5	Pz-O, Uv-O, Nf-O	C
6	Uv-O	C
E	Pz-O, Mx-O, Uv-O, Pr-O	O
J-S	Pz-C, Pr-C, Mx-C	C
1	F-C, Pz-C; Mx-O	A
2	Pz-C	O
3	Nf-A; Pps-C	C
4	Ppr-A; Mx-O. Pps-O	O
5	Ppc-C; Mx-O, Pz-R	R
6	Ppc-A; Nf-O, Mx-O	O
7	Pfo-R, Mx-R	R
E	Nf-O, Mx-O, Pps-O, Pr-O, Pz-O	R
K-S	Pz-C, Ppc-C, Mx-C; Pr-O, Nf-R	O
1	Ppc-C, Nf-C, Pps-C, Mx-C; Pz-O, F-O	R
2	Ppc-C, Pr-C, Pz-C; Mx-O	R
3	Ppc-C, Nf-C; Pr-O, Mx-O, Pps-O	O
4	Ppc-A; Nf-O, Pfo-O,Mx-O, Pz-O	R
5	Ppc-O, Nf-O, Pfo-O, Pz-O	O
6	Ppr-O, F-O, Mx-O, Ppc-O, Pz-O	C
E	Pz-C, Mx-C, Pfo-C	C

Macrophyte symbols are from Table 35.
A - abundant; C - common, O - occasional; R - rare
Sampling points are sequential in direction of travel along transects (A to K - see map of Ruth Lake macrophytes).

Appendix 8. Summary of RL-2 zooplankton data in 1977. Unbracketed values are number/m^3. Bracketed values are biomass expressed as mg wet weight/m^3.

	Mar. 31	May 4	June 1	June 26	July 29	Aug. 24	Sept. 23	Oct. 15	Nov. 19
ROTIFERA	113,000	742,000	350,000	337,000	1,810,000	697,000	820,000	264,000	428,000
CONCHOSTRACA									
nauplii		240	280						
juveniles & adults		40	5						
CLADOCERA									
Bosmina longirostris			280 (4.7)	360 (2.2)	110,000 (501.9)	1520 (13.5)	930 (8.3)	95 (1.1)	
Ceriodaphnia affinis			1730 (41.2)	180 (0.6)					
Chydorus sphaericus		120 (0.9)	840 (8.7)		1000 (5.5)		72 (0.3)	110 (1.2)	
Daphnia pulicaria		20 (0.8)	560 (3.4)						
Daphnia rosea			280 (5.0						
Diaphanosoma leuchtenbergianum			1090 (26.6)	920 (11.1)	28,400 (350.0)	1190 (24.4)	930 (24.5)		
COPEPODA									
CALANOIDA									
nauplii				1800	2720	4670			
Diaptomus leptopus									
copepodites			1090 (129.1)	180 (2.5)					
adults					980 (194.5)				
Diaptomus oregonensis									
copepodites							930 (27.8)		
adults							1860 (168.3)	14 (1.6)	410 (37.9)
CYCLOPOIDA									
nauplii		25,000	188,000	2670	9920	89,100	20,800	260	
copepodites I-III (unidentified)		360 (2.5)	76,400 (504.4)	3580 (17.3)	18,200 (106.4)	34,900 (168.3)	3920 (148.6)	27 (0.2)	
Cyclops vernalis- *Cyclops navus*									
copepodites IV-V		1400 (31.4)	20,700 (430.0)		2020 (31.5)				
Cyclops vernalis									
adults			5650 (146.9)		2020 (30.1)	290 (5.6)	1860 (108.0)	23 (1.3)	
Cyclops bicuspidatus thomasi									
copepodites IV-V	110 (2.6)								
adults	200 (12.9)								
Cyclops navus									
adults		160 (7.6)	560 (63.0)						
TOTAL[1]	310 (15.5)	2,060 (43.2)	109,190 (1363.0)	5,220 (33.7)	162,620 (1219.9)	37,900 (211.8)	10,502 (485.8)	269 (5.4)	410 (37.9)

[1] excluding Conchostraca and nauplii of Copepoda.

Appendix 9 . Summary of RL-3 zooplankton data in 1977. Values not enclosed in brackets are numbers/m^3. Values enclosed in brackets are biomass expressed as mg wet weight/m^3.

	Mar. 31	May 4	June 1	June 26	July 29	Aug. 24	Sept. 23	Oct. 15	Nov. 19
ROTIFERA	118,000	430,000	208,000	267,000	658,000	511,000	164,000	133,000	207,000
CONCHOSTRACA									
nauplii		100							
CLADOCERA									
Bosmina longirostris			840 (7.0)	550 (7.3)	18,800 (114.6)	1570 (10.5)	120 (1.2)		
Ceriodaphnia affinis		20 (0.1)	840 (20.0)						
Chydorus sphaericus		100 (0.6)	420 (2.3)		1,050 (6.0)		25 (0.1)	190 (2.2)	
Daphnia pulicaria									
Diaphanosoma leuchtenbergianum			420 (13.0)	180 (4.0)	2,820 (57.0)	940 (18.3)	250 (7.7)		
COPEPODA									
CALANOIDA									
nauplii					4,700				
Diaptomus leptopus									
copepodites				550 (17.6)		310 (9.3)			
adults									
CYCLOPOIDA									
nauplii		90,200	113,000	12,000	29,000	150,000	11,300	2,090	
copepodites I-III		160 (0.7)	54,300 (380.2)	550 (2.5)	10,130 (55.6)	73,000 (286.1)	120 (0.5)		
Cyclops vernalis - *Cyclops navus* copepodites IV-V		1,190 (21.9)	11,210 (198.3)		530 (10.2)		23 (0.5)	40 (1.2)	
Cyclops vernalis adults		20 (2.1)	3,800 (109.8)					40 (1.0)	
Cyclops bicuspidatus thomasi copepodites IV-V	160 (6.6)	40 (1.9)						190 (4.6)	
adults									
Cyclops navus adults		200 (9.0)	840 (36.8)						
TOTAL[1]	160 (6.6)	1,770 (38.1)	72,670 (767.4)	1,830 (31.4)	33,330 (243.4)	75,820 (324.2)	538 (10.0)	460 (9.0)	

[1] excluding Rotifera, Conchostraca and nauplii of Copepoda.

Appendix 10. Fish collection data from gill net catches in Ruth Lake, 1977.

White Sucker (*Catostomus commersoni* (Lacepede)

Sample No.	Date	Site	FL (mm)	Wt. (g)	Sex	Other
1	26/6	G1	285	312	-	S
2	27/6	G1	285	340	-	S
3	27/6	G1	295	340	-	S
4	27/6	G1	260	255	-	S
5	27/6	G1	280	284	-	S
6	27/6	G1	265	227	-	S
7	27/6	G1	275	312	-	-
8	27/6	G1	265	255	-	-
9	27/6	G1	180	57	-	-
10	27/6	G1	165	57	-	-
11	27/6	G1	200	113	-	-
12	27/6	G1	177	57	-	-
13	27/6	G1	156	57	-	-
14	27/6	G1	145	<57	-	-
15	27/6	G1	176	<57	-	-
16	27/6	G1	154	<57	-	-
17	27/6	G1	152	57	-	-
19	27/6	G1	165	57	-	-
22	27/6	G2	273	255	-	S
23	27/6	G2	302	369	F	S
24	27/6	G2	275	340	-	S
25	27/6	G2	278	284	-	S
26	27/6	G2	267	284	-	S
34	27/6	G2	274	312	-	-
35	27/6	G2	271	284	-	-
36	27/6	G2	271	284	-	-
37	27/6	G2	293	397	-	-
38	27/6	G2	273	284	-	-
39	27/6	G2	265	284	-	-
40	27/6	G2	264	255	-	-
41	27/7	G2	258	227	-	-
42	27/6	G2	271	255	-	-
43	27/6	G2	252	227	-	-
44	27/6	G2	161	57	-	-
45	27/6	G2	149	57	-	-
46	27/6	G2	203	113	-	-
47	27/6	G2	183	57	-	-
48	27/6	G2	182	85	-	-
49	27/6	G2	179	85	-	-
50	27/6	G2	163	57	-	-
51	27/6	G2	149	57	-	-
52	27/6	G2	162	57	-	-
101	24/8	G2	180	85	-	-
102	24/8	G2	198	113	-	-
103	24/8	G2	204	113	-	-
104	24/8	G2	174	57	-	-
105	24/8	G2	152	57	-	-
106	24/8	G2	199	113	-	-
107	24/8	G2	184	85	-	-
108	24/8	G2	273	284	-	-
109	24/8	G2	271	255	-	-
110	24/8	G2	242	227	-	-
111	24/8	G2	270	255	-	-
112	24/8	G2	252	227	-	-
113	24/8	G2	282	312	-	-
114	24/8	G2	258	227	-	-
115	24/8	G2	272	284	-	-
116	24/8	G1	267	284	-	-
117	24/8	G1	306	397	-	-
118	24/8	G1	312	454	-	-
119	24/8	G1	260	255	-	-
120	24/8	G1	275	284	-	-
121	24/8	G1	251	227	-	-
122	24/8	G1	263	255	-	-
123	24/8	G1	189	85	-	-
124	24/8	G1	182	85	-	-
125	24/8	G1	177	85	-	-
126	24/8	G1	171	57	-	-
127	24/8	G1	206	113	-	-
128	24/8	G1	202	113	-	-
129	24/8	G1	205	113	-	-
130	24/8	G1	192	113	-	-

Longnose sucker (*Catostomus catostomus* (Forster))

Sample No.	Date	Site	FL (mm)	Wt. (g)	Sex	Other
20	27/6	G1	290	284	-	S
21	27/6	G1	284	312	-	S
27	27/6	G2	289	340	-	S
28	27/6	G2	254	227	-	S

Site: refer to map of sampling sites. Other: S - stomach examined.

Continued . . .

Appendix 10. Concluded.

Sample No.	Date	Site	FL (mm)	Wt. (g)	Sex	Other
29	27/6	G2	243	198	-	S
30	27/6	G2	255	255	-	S
31	27/6	G2	275	312	-	S
32	27/6	G2	272	255	-	S
33	27/6	G2	245	198	-	S
131	24/8	G1	318	425	-	-
132	24/8	G1	322	454	-	-
133	24/8	G1	283	284	-	-

Appendix 11. Phytoplankton cell counts from Poplar Creek Reservoir, 1977

	STATION PCR-1 - cells/ml																
	March 30	May 5		May 31		June 28		July 29		August 26		September 22		October 15		November 19	
	T	T	B	T	B	T	B	T	B	T	B	T	B	T	B	T	B
Cyanophyta																	
Anabaena flos-aquae						1291	114	20942	798	3479	274	+					
Anabaena				+													
Aphanizomenon flos-aquae						935		8267		14461	991	479		182			
Coccoid forms (unid. further)																	
Dactylococcopsis	211			+													
Filamentous forms (unid. further)	346																
Lyngbya			+														
Merismopedia																	
Group % of total	45					52	14	93	44	93	48	14		5			
Bacillariophyceae																	
Asterionella				+						35		153				+	+
Centric diatoms (unid. further)		58		130		+											
Cyclotella				+					60	+		19					
Melosira								+		264	358	+			+		+
Pennate diatoms (unid. further)		+	14	16	+	13		48	+		+						
Stephanodiscus								72	+								
Synedra		19	+	65	96		+		+		63					246	
Tabellaria											+			+			
Group % of total		2	1	4	1	1		1	3	2	16	5		1		17	
Flagellates																	
Ceratium hirundinella				16				+									
Cryptomonas	30	786	70	535	38	92	+	72	45	+	+	+			18	18	
Dinobryon sertularia				357	58	79	16										
Dinobryon								72	30								
Dinophyceae (unid. further)																	
Euglena	+	19	14				+		+		21						
Peridinium	15	38													18		
Phacus								+	+								
Rhodomonas		38		827		132				18		153	81	1663	339	176	18
Trachelomonas				+					90			38			+		
Unidentified flagellates	30	767	28	454	19	67	+	72	60	18	21	77		182	70	35	35
Group % of total	6	53	11	38	1	9	2	1	12	1	2	8	4	54	46	16	3
Chlorophyta																	
Ankistrodesmus convolutus		58	42	162	77		16	+	60		84	403	292	41	53	141	264
Ankistrodesmus falcatus						830	+										
Ankistrodesmus		19	+	49	+		49	96	60	18		+	16	41		18	70
Chlamydomonas			28							88	21						
Characium						13											
Coccoid forms (unid. further)	30	268		779	19	40	+	72									
Coelastrum																	
Crucigenia tetrapedia				65													
Crucigenia								96		+							
Dictyosphaerium				195	77												
Gloeocystis						+						+					
Kirchneriella lunaris												+	130				
Oocystis		77						+		+							
Pediastrum								192									
Scenedesmus quadricauda								383	+								
Scenedesmus				65	77			479	60	+	84	77		81	+		+
Tetraedron caudatum																	
Tetraedron				+													
Unidentified forms									75	228		115	697	162	70	70	53
Group % of total	2	13	6	23	2	21	9	4	14	2	7	18	60	10	13	16	23
Ultraplankton	587	1016	899	1979	10715	778	600	599	497	615	717	1840	697	1075	404	738	1212
Group % of total	47	32	82	35	96	18	75	2	27	3	27	55	36	31	41	51	73
Grand Total	1250	3163	1095	5693	11175	4270	795	31461	1835	19223	2636	3355	1913	3426	972	1441	1652

\+ Occurred in quantities too low for enumeration   T-Samples from epilimnion   B-Samples from hypolimnion

Continued ...

Appendix 11.Concluded

	STATION PCR-2 - cells/ml								
	March 30	May 5	May 31	June 28	July 29	August 26	Sept. 22	Oct. 15	Nov. 19
Cyanophyta									
Anabaena flos-aquae				772	2688	2066	1546		
Anabaena	+								
Aphanizomenon flos-aquae				2673	4138	10416	3655		
Coccoid forms (unid. further)	+								
Dactylococcopsis	183								
Filamentous forms (unid. further)	239								
Lyngbya									
Merismopedia				+					
Group % of total	23			43	65	74	51		
Bacillariophyceae									
Asterionella			+			+			
Centric diatoms (unid. further)			380	38					
Cyclotella					184	21			
Melosira					+	1075	176		
Pennate diatoms (unid. further)	+	15	21	75	369		53	+	+
Stephanodiscus		+	21						
Synedra		75	148	+					
Tabellaria		+					176		
Group % of total		6	7	1	5	6	4		
Flagellates									
Ceratium hirundinella					+				
Cryptomonas	93	105	1392	527	132	42	18	19	47
Dinobryon sertularia			696	941					
Dinobryon					53				
Dinophyceae (unid. further)				19					
Euglena	+	+	+			+			
Peridinium									
Phacus					+				
Rhodomonas		+	1054	358		253	1423	460	234
Trachelomonas			63		+	21	+		
Unidentified flagellates	127	226	422	433		+	18	38	94
Group % of total	12	23	43	29	2	2	14	45	19
Chlorophyta									
Ankistrodesmus convolutus	14	151	274		237	949	756	+	164
Ankistrodesmus falcatus				75					
Ankistrodesmus	28	105	+	38	53		18	+	94
Chlamydomonas				+	53	105			+
Characium									
Coccoid forms (unid. further)	127	241	633						
Coelastrum				+	+	337			
Crucigenia tetrapedia									
Crucigenia					211				
Dictyosphaerium			+	+		211			
Gloeocystis									
Kirchneriella lunaris									
Oocystis									
Pediastrum									
Scenedesmus quadricauda					316				
Scenedesmus			211		158	+	70		
Tetraedron caudatum		+							
Tetraedron									
Unidentified forms				320	712	42	141	38	187
Group % of total	9	34	13	5	17	10	10	3	22
Ultraplankton	1040	542	3163	1751	1186	1328	2144	613	1171
Group % of total	56	37	37	22	11	8	21	52	59
Grand Total	1851	1460	8478	8020	10490	16866	10194	1168	1991

Appendix 12. Summary of PCR-1 zooplankton data in 1977. Unbracketed values are number/m^3. Bracketed values are biomass expressed as mg wet weight/m^3.

	Mar. 30	May 5	May 31	June 28	July 29	Aug. 26	Sept. 22	Oct. 15	Nov. 19
ROTIFERA	5,740	63,400	91,100	17,100	128,000	416,000	41,300	36,500	2,600
CONCHOSTRACA									
Lynceus brachyurus		30							
nauplii									
juveniles & adults			5	2					
CLADOCERA									
Bosmina longirostris			800 (11.3)	360 (3.2)	27,900 (115.4)	84,300 (463.4)	5630 (50.3)	190 (2.0)	48 (0.6)
Ceriodaphnia affinis			70 (5.8)	180 (3.6)	230 (0.8)				
Ceriodaphnia lacustris				36 (1.2)	150 (3.4)	1340 (11.7)			
Chydorus sphaericus		12 (0.1)	70 (0.3)	36 (0.2)					
Daphnia galeata mendotae			35 (1.8)	1960 (146.3)	76 (2.0)		160 (2.6)		
Daphnia parvula							880 (22.5)	190 (2.1)	
Daphnia pulicaria			1400 (102.4)	2630 (319.2)					
Daphnia rosea				110 (1.4)					
Diaphanosoma leuchtenbergianum					4020 (77.7)	1340 (43.2)	160 (6.8)	380 (8.1)	
COPEPODA									
CALANOIDA									
nauplii				2780	10,000	18,300			
Diaptomus leptopus									
adults			5 (1.8)	3 (1.1)					
Diaptomus oregonensis				2780	10,000	18,300			
copepodites				360 (5.6)	1700 (32.6)	36,000 (807.6)	570 (9.7)	190 (13.6)	
adults				71 (11.8)	150 (20.7)	1880 (213.9)	2430 (248.1)	3600 (405.3)	3280 (285.2)
CYCLOPOIDA									
nauplii				10,000	5470	1070	3510	750	
copepodites I-III			9800 (53.8)	1100 (4.6)	1300 (5.1)	1070 (3.7)	1300 (6.3)	190 (1.9)	
Cyclops vernalis - *Cyclops navus* copepodites IV-V		120 (3.6)	5600 (135.4)		150 (3.1)		160 (3.3)		
Cyclops vernalis adults		12 (1.7)	2230 (76.1)					190 (7.3)	
Cyclops bicuspidatus thomasi copepodites IV-V	40 (1.0)	160 (6.6)	8080 (188.7)	430 (10.4)			460 (7.8)	13,200 (350.3)	3660 (182.0)
adults	50 (4.0)	600 (50.7)	140 (3.4)	930 (38.4)				190 (12.9)	1600 (100.5)
Cyclops navus adults				71 (6.4)	76 (3.1)				
Mesocyclops edax copedites		250 (8.0)		320 (11.3)					
adults		24 (3.7)	140 (6.5)	320 (40.7)				190 (7.8)	
TOTAL[1]	90 (5.0)	1,178 (74.4)	28,365 (587.3)	8,914 (605.4)	35,772 (263.9)	125,930 (1543.5)	11,750 (357.4)	18,510 (811.3)	8,588 (568.3)

[1] excluding Rotifera, Conchostraca and nauplii of Copepoda.

Appendix 13. Summary of PCR-2 zooplankton data in 1977. Unbracketed values are numbers/m^3. Bracketed values are biomass expressed as mg wet weight/m^3.

	Mar. 30	May 5	May 31	June 28	July 29	Aug. 26	Sept. 22	Oct. 15	Nov. 19
ROTIFERA	1,640	193,000	50,100	203,000	751,000	900,000	169,000	21,000	3,160
CONCHOSTRACA									
Lynceus brachyurus		27							
nauplii									
juveniles & adults		9	4	4	4				
CLADOCERA									
Bosmina longirostris			1700	2770	118,000	161,000	8200	560	
			(17.6)	(39.7)	(494.7)	(882.6)	(68.3)	(16.6)	
Ceriodaphnia affinis				1100	390				
				(34.8)	(1.3)				
Ceriodaphnia lacustris				620	1540	3760	290		
				(8.8)	(3.7)	(33.8)	(9.7)		
Daphnia galeata mendotae				4310	390				
				(76.4)	(6.9)				
Daphnia parvula							5	70	
							(0.5)	(3.8)	
Daphnia pulicaria		9	1390	2770					
		(0.3)	(81.9)	(252.1)					
Diaphanosoma leuchtenbergianum				1390	7330	2500	590	46	
				(23.6)	(105.7)	(145.7)	(21.1)	(2.1)	
COPEPODA									
CALANOIDA									
nauplii				1850	35,500	28,400	590		
Diaptomus leptopus									
copepodites			2						
adults			8	4	2				
			(3.3)	(1.5)	(0.7)				
Diaptomus oregonensis									
copepodites				770	32,000	96,500	7050	370	
				(35.8)	(664.7)	(2509.1)	(176.8)	(26.4)	
adults					770	8770	20,000	5070	12,300
					(106.1)	(1008.1)	(1688.6)	(490.7)	(1190.4)
CYCLOPOIDA									
nauplii		15,800	66,800	22,800	9,250	6,680	6,460	370	
copepodites I-III		44	10,900	7700	2000	3130	2640	560	
		(0.3)	(63.7)	(39.7)	(9.0)	(12.4)	(11.9)	(1.8)	
Cyclops vernalis -									
Cyclops navus		80	23,000	150			590		
copepodites IV-V		(1.8)	(500.0)	(3.1)			(10.1)		
Cyclops vernalis									
adults		9	6680						
		(0.8)	(237.2)						
Cyclops bicuspidatus thomasi									
copepodites IV-V	65	88	16,700	150				190	
	(2.0)	(3.6)	(328.8)	(2.9)				(9.1)	
adults	25	350		920					
	(1.8)	(16.8)		(41.6)					
Cyclops navus									
adults			442						
			(11.6)						
Mesocyclops edax									
copepodites		61		1230	3100		1470	62	
		(1.7)		(19.7)	(60.0)		(18.3)	(18.9)	
adults		100		620	390		290		
		(13.7)		(73.8)	(14.2)		(10.6)		
TOTAL[1]	90	741	60,812	24,500	165,910	275,660	41,120	6,928	12,300
	(3.8)	(39.0)	(1244.1)	(653.5)	(1467.0)	(4591.7)	(2015.9)	(559.4)	(1190.4)

[1] excluding Rotifera, Conchostraca and nauplii of Copepoda.

Appendix 14. Organisms in Hess samples from PC-B4 Poplar Creek, 1977. Three samples were taken per site. Area of each sample = 0.1 m^2.

	March 30			May 3			May 31			June 29			July 27		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
COELENTERATA-*Hydra*															
OLIGOCHAETA					1	3	1	1	2			1	4	2	2
HIRUDINEA															
NEMATA											2	1	1	1	8
CRUSTACEA-Ostracoda				21											
ARACHNOIDEA-Hydracarina				1	5										
INSECTA															
COLLEMBOLA															
EPHEMEROPTERA															
Ameletus															
Baetis							47	38	30	118	108	131	173	345	223
Caenis															
Cinygmula										3	19	6	1		1
Ephemerella										6	1	25	33	28	17
Heptagenia										4	13	8	15	21	15
Leptophlebia															
PLECOPTERA															
Alloperla															2
Arcynopteryx															
Isogenus												2		2	
Nemoura				3	9	2	1			4		5	17	13	16
HEMIPTERA-Corixidae															
ODONATA-Anisoptera								1							
TRICHOPTERA															
Arctopsyche															
Brachycentrus															
Ceraclea															
Cheumatopsyche												1	1	4	1
Glossosoma				23	89	4	2	23	17	19	2	3	5	80	20
Hesperophylax															
Hydropsyche							1						10		3
Lepidostoma															
Neureclipsis															
Ochrotrichia									1	4		1			
Oxyethira															
Psychomyia															
Rhyacophila							6	12	2	13	9	18	2	4	2
Wormaldia											1	5	2	2	4
pupae											1		4	1	2
unidentified															
COLEOPTERA															
Agabus															
Deronectes															
Donacia														1	
Galerucella															
Gyrinus															
Haliplus															
Heterlimnius					3		1			2	2		1	4	2
Narpus															
Optioservus															
Rhantus															
DIPTERA															
Ceratopoginidae				2				1	1					3	1
Chironomidae															
Chironominae															
Chironomini					2			5	2	2		4	6	57	8
Tanytarsini					25	3						9	10	8	3
Diamesinae									2		2		1	1	
Orthocladiinae					5	1	91	93	46	60	103	102	73	250	92
Tanypodinae						1								6	
Culicidae															
Chaoborus															
Dolicopodidae							1								
Empididae							1						7	10	6
Muscidae															
Rhagionidae															
Atherix variegata															
Simuliidae															
larvae							9	39	4	29	46	34	44	238	119
pupae															
Stratiomyidae															
Tabanidae															
Tipulidae-*Dicranota*							1				2	4		1	
MOLLUSCA															
Gastropoda															
Ferrissia rivularis															
Gyraulus															
Helisoma															
Physa															
Pelecypoda															
Pisidium															
Sphaerium															
TOTAL				50	139	14	162	214	107	264	314	360	409	1082	547
Mean per sample					68			161			313			679	
Mean per m^2					680			1610			3130			6790	

Continued . . .

Appendix 14. Concluded.

	Aug.	27		Sept.	22		Oct.	14		Nov.	18	
	1	2	3	1	2	3	1	2	3	1	2	3
COELENTERATA- *Hydra*												
OLIGOCHAETA	3	5	5	1	7	2	6	1	4	3	1	1
HIRUDINEA												
NEMATA										2	4	3
CRUSTACEA-Ostracoda										6	12	6
ARACHNOIDEA-Hydracarina			4			3	1		1	11	6	5
INSECTA												
COLLEMBOLA												
EPHEMEROPTERA												
Ameletus												
Baetis	6	16	13	29	31	60	12	24	5	32	32	54
Caenis	6	5	4									
Cinygmula		1										
Ephemerella	2	11	4	1	8	14		10	12	14	5	8
Heptagenia	15	25	17	14	19	16	3	5	7	23	21	11
Leptophlebia												
PLECOPTERA												
Alloperla				1	1	1	1	2	1	4	12	4
Arcynopteryx	1	1	2	3	2	4	1	2	5	13	6	7
Isogenus												
Nemoura	158	205	179	190	77	364	70	186	762	67	75	119
HEMIPTERA-Corixidae												
ODONATA-Anisoptera												
TRICHOPTERA												
Arctopsyche												
Brachycentrus						4						
Ceraclea												
Cheumatopsyche	2	42	28	21	50	79	4	24	4	53	12	22
Glossosoma	40	93	61	60	112	180	70	121	59	56	32	190
Hesperophylax						1						1
Hydropsyche	27	59	47	33	73	139	5	21	16	46	12	27
Lepidostoma												
Neureclipsis				2	1							
Ochrotrichia												
Oxyethira									1			
Psychomyia												
Rhyacophila												
Wormaldia		4										
pupae	2	9	3									
unidentified												
COLEOPTERA												
Agabus												
Deronectes												
Donacia												
Galerucella												
Gyrinus												
Haliplus												
Heterlimnius	1	2		2	5	7	3	3		7	7	2
Narpus												
Optioservus											3	
Rhantus												
DIPTERA												
Ceratopodinidae	3	8	2	1	8	3		6		5	3	1
Chironomidae												
Chironominae												
Chironomini	33	30	27	3	28	15	10	38	30	115	150	100
Tanytarsini	26	37	30	72	180	483	78	88	155	550	395	315
Diamesinae												
Orthocladiinae	106	123	106	31	51	149	38	87	233	447	450	465
Tanypodinae	18	8	19	13	37	55	35	33	65	85	40	40
Culicidae												
Chaoborus										2		
Dolicopodidae												
Empididae	7	19	7	4	27	12	1	6	8	5	4	5
Muscidae			1									
Rhagionidae												
Atherix variegata												
Simuliidae												
larvae	26	9	10	18	9	11	5	6	5	1		
pupae	1	1										
Stratiomyidae												
Tabanidae					1							
Tipulidae-*Dicranota*	1	1	1	1	3	1	2	2	1	6	8	6
MOLLUSCA												
Gastropoda												
Ferrissia rivularis												
Gyraulus												
Helisoma												
Physa												
Pelecypoda												
Pisidium												
Sphaerium												
TOTAL	484	714	561	500	730	1603	345	665	1374	1553	1290	1392
Mean per sample		586			944			795			1412	
Mean per m^2		5860			9440			7950			14120	

Appendix 15. Organisms in Hess samples from PC-2 Poplar Creek, 1977. Three samples were taken per site. Area of each sample = 0.1 m^2.

	March 30			May 3			May 31			June 29			July 27		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
COELENTERATA-*Hydra*										5	1	2	30	45	35
OLIGOCHAETA		98	2	26	11	5	13	3	2	7	2	27	30	128	7
HIRUDINEA												1	2	3	
NEMATA			2	1	3				1				1		
CRUSTACEA-Ostracoda															
ARACHNOIDEA-Hydracarina	1	4								1					1
INSECTA															
COLLEMBOLA															
EPHEMEROPTERA															
Ameletus															
Baetis	2						44	13	62	40	166	183	71	52	24
Caenis		1													
Cinygmula										4	1				
Ephemerella												3		1	
Heptagenia							1		4	14	6	31	4	19	20
Leptophlebia	1														
PLECOPTERA											1	1	2		
Alloperla														1	
Arcynopteryx															
Isogenus															
Nemoura	6	15	6	6	28	1									
HEMIPTERA-Corixidae															
ODONATA-Anisoptera															
TRICHOPTERA															
Arctopsyche															
Brachycentrus															
Ceraclea															
Cheumatopsyche												2	37	12	21
Glossosoma													2		
Hesperophylax															
Hydropsyche										4	7	4	13	13	24
Lepidostoma															
Neureclipsis												2			
Ochrotrichia											2				
Oxyethira															
Psychomyia														2	
Rhyacophila															
Wormaldia															
pupae											1	1	13	17	18
unidentified	1						1								
COLEOPTERA															
Agabus											1	1			
Deronectes															
Donacia															
Galerucella															
Gyrinus															
Haliplus															
Heterlimnius	1	4								1	2	1			3
Narpus															
Optioservus		2											2		
Rhantus															
DIPTERA															
Ceratopodinidae								1	1			1			
Chironomidae															
Chironominae															
Chironomini			2	3		2	32	16	28	14	46	59	140	92	54
Tanypodinae	2	2		3	4	3			3	43	43	62	95	50	76
Diamesinae		3								7	2				
Orthocladiinae	79	600	16	179	226	116	75	6	33	204	565	351	1215	796	1200
Tanypodinae	2	16			1	1					9	9	40	23	23
Culicidae															
Chaoborus															
Dolicopodidae													1		
Empididae	2	12			1		1					1	3		1
Muscidae															
Rhagionidae															
Atherix variegata															
Simuliidae															
larvae	11						271	7	100	251	920	835	3040	1710	1496
pupae															344
Stratiomyidae															
Tabanidae															
Tipulidae-*Dicranota*											2	7	1	1	1
MOLLUSCA															
Gastropoda															
Ferrissia rivularis															
Gyraulus													5	11	5
Helisoma															
Physa															
Pelecypoda															
Pisidium															
Sphaerium															
TOTAL	108	757	28	218	274	128	438	46	234	588	1782	1587	4747	2976	3353
Mean per sample		298			207			239			1319			3692	
Mean per m^2		2980			2070			2390			13190			36920	

Continued . . .

Appendix 15. Concluded.

		Aug. 27			Sept. 22			Oct. 14			Nov. 18	
	1	2	3	1	2	3	1	2	3	1	2	3
COELENTERATA-*Hydra*	20	38	58	1	3	4						
OLIGOCHAETA	21	23	28	20	55	13	82	33	18	28	37	14
HIRUDINEA		1			5	4	2	2				
NEMATA					1	1				3		2
CRUSTACEA-Ostracoda	1	1	1		3		1		1	30		2
ARACHNOIDEA-Hydracarina	1	1	2	1	6	4		2		8	2	
INSECTA												
COLLEMBOLA									1	1		
EPHEMEROPTERA												
Ameletus												
Baetis	63	20	54	192	64	45		6	14	185	53	20
Caenis	1	2	2					5	1			
Cinygmula												
Ephemerella				1	2					2		2
Heptagenia	3	10	2		24	9	3	5	7	1	6	7
Leptophlebia		1									1	1
PLECOPTERA												
Alloperla												
Arcynopteryx					2							2
Isogenus												
Nemoura	8	12	13	5	7	2	2	4	2	3	8	7
HEMIPTERA-Corixidae												
ODONATA-Anisoptera												
TRICHOPTERA												
Arctopsyche												
Brachycentrus												1
Ceraclea												
Cheumatopsyche	116	433	228	484	158	319	8	122	82	141	20	21
Glossosoma	1	1		6		5	1		1	2		1
Hesperophylax												
Hydropsyche	60	378	461	838	259	375	19	94	84	646	308	84
Lepidostoma												
Neureclipsis												
Ochrotrichia	10	59	33	16	8	35		4	3	5	4	5
Oxyethira												
Psychomyia		1	2	1		2						
Rhyacophila	1											
Wormaldia												
pupae	2	1	1		1	1						
unidentified												
COLEOPTERA												
Agabus												
Deronectes												
Donacia												
Galerucella												
Gyrinus												
Haliplus							1		1			
Heterlimnius	1	3		3		8	1		2	1		2
Narpus												
Optioservus					1							
Rhantus												
DIPTERA												
Certopoginidae	3		4			1		1	1	1		
Chironomidae												
Chironominae												
Chironomini	104	280	277	66	310	114	46	63	85	550	134	175
Tanytarsini	64	380	211	459	730	1018	80	243	81	335	64	112
Diamesinae												
Orthocladiinae	1850	3275	3734	469	395	432	15	64	50	1070	277	272
Tanypodinae	110	265	109	185	360	186	29	296	88	120	30	93
Culicidae												
Chaoborus												
Dolicopodidae												1
Empididae	5	12	10	25	28	29		19	6	8	7	12
Muscidae												
Rhagionidae												
Atherix variegata						1						
Simuliidae												
larvae	269	154	380	106	55	89	2	8	12	185	250	154
pupae	56	29	1388									
Stratiomyidae					1							
Tabanidae	1											
Tipulidae-*Dicranota*					2		2	3	5	12	5	14
MOLLUSCA												
Gastropoda												
Ferrissia rivularis												
Gyraulus	8	7	13	1	15	2	9	2	2	2	5	8
Helisoma			1		1							
Physa					1		1		2			
Pelecypoda												
Pisidium												
Sphaerium												1
TOTAL	2779	5387	7012	2879	2497	2699	304	976	549	3340	1211	1013
Mean per sample		5059			2692			610			1855	
Mean per m^2		50590			26920			6100			18550	

Appendix 16. Organisms in Hess samples from PC-1 Poplar Creek, 1977. Three samples were taken per site. Area of each sample = 0.1 m^2.

	March 30			May 3			May 31			June 29			July 27		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
COELENTERATA-*Hydra*										4		5	10	2	14
OLIGOCHAETA	5		6	1			1	1		6	1	2	1	19	7
HIRUDINEA															1
NEMATA	4	1	1		1			2					5	2	1
CRUSTACEA-Ostracoda															
ARACHNOIDEA-Hydracarina							1	1		1		2		2	
INSECTA															
COLLEMBOLA															
EPHEMEROPTERA															
Ameletus													1		2
Baetis							49	14	46	151	130	105	69	174	131
Caenis							1								
Cinygmula										8	13	13			
Ephemerella												1		9	
Heptagenia										1			24	15	20
Leptophlebia	2	14													
PLECOPTERA															
Alloperla														1	
Arcynopteryx															
Isogenus															
Nemoura	14	69	4	2	17	4					1	4	9	12	6
HEMIPTERA-Corixidae									1						
ODONATA-Anisoptera															
TRICHOPTERA															
Arctopsyche										1					
Brachycentrus												1			1
Ceraclea															
Cheumatopsyche													74	97	38
Glossosoma										2			1	2	8
Hesperophylax															
Hydropsyche										3	7	7	20	42	8
Lepidostoma															
Neureclipsis															
Ochrotrichia															1
Oxyethira															
Psychomyia													1		
Rhyacophila													3		
Wormaldia															
pupae															5
unidentified															
COLEOPTERA															
Agabus															
Deronectes															
Donacia															
Galerucella														1	
Gyrinus											1				
Haliplus															
Heterlimnius						2		1	1		1		2	1	1
Narpus	1														
Optioservus															
Rhantus									1						
DIPTERA															
Ceratopoginidae	1			1							1	1			1
Chironomidae															
Chironominae															
Chironomini			5	1			18	2	28	31	3	5	66	86	70
Tanytarsini	2			5	2	2	3	5	3	48	33	69	165	163	124
Diamesinae		2					1			1		4			
Orthocladiinae	28	67	28	339	325	431	102	98	108	258	255	273	470	922	373
Tanypodinae					1					7	7	10	43	18	34
Culicidae															
Chaoborus															
Dolicopodidae															
Empididae			1							2	2		7	5	3
Muscidae															
Rhagionidae															
Atherix variegata															
Simuliidae															
larvae		2		4		2	81	178	75	265	459	1004	162	2509	466
pupae													126	483	82
Stratiomyidae															
Tabanidae			1												
Tipulidae-*Dicranota*													3	2	1
MOLLUSCA															
Gastropoda															
Ferrissia rivularis															
Gyraulus															
Helisoma													3	1	8
Physa													1		
Pelecypoda															
Pisidium															
Sphaerium															
TOTAL	57	155	46	353	346	441	257	302	263	789	914	1506	1266	4568	1406
Mean per sample		86			380			274			1070			2413	
Mean per m^2		860			3800			2740			10700			24130	

Continued . . .

Appendix 16. Concluded.

	Aug. 27			Sept. 22			Oct. 14			Nov. 18		
	1	2	3	1	2	3	1	2	3	1	2	3
COELENTERATA-*Hydra*		1	1									
OLIGOCHAETA	19	21	55	50	21	13	8	10	3	4	2	2
HIRUDINEA	1	1	2		1				2			
NEMATA		2		5		2					4	1
CRUSTACEA-Ostracoda										700	30	200
ARACHNOIDEA-Hydracarina	3	6	6	3		3		4	1	5	9	3
INSECTA												
COLLEMBOLA								1				
EPHEMEROPTERA												
Ameletus												
Baetis	115	223	171	174	75	29	48	53	108	303	611	630
Caenis	1		8		1	1	1		4			1
Cinygmula												
Ephemerella	2	4	7	7	3	10	1		3	11	17	6
Heptagenia	1	6	7	3		1			4	2		2
Leptophlebia		1	1			1						
PLECOPTERA												
Alloperla			2								1	
Arcynopteryx						1					1	1
Isogenus												
Nemoura	18	38	26	16	11	14	5	10	16	20	30	14
HEMIPTERA-Corixidae												
ODONATA-Anisoptera					2	1						
TRICHOPTERA												
Arctopsyche												
Brachycentrus		1	1							1	1	5
Ceraclea												
Cheumatopsyche	163	309	321	203	185	93	61	55	235	172	243	307
Glossosoma	6	1		2	4	1	8	8	2	3		14
Hesperophylax								1				
Hydropsyche	163	594	612	464	261	140	81	47	249	192	379	520
Lepidostoma					1							
Neureclipsis	1	1	3	2	4	2	2	1	5	4	3	
Ochrotrichia												
Oxyethira												
Psychomyia	3		1									
Rhyacophila	1											
Wormaldia		1	1									
pupae	4	1										
unidentified			2									
COLEOPTERA												
Agabus												
Deronectes										1		
Donacia												
Galerucella												
Gyrinus												
Haliplus												
Heterlimnius	8	32	23	3	5	1	3	6		5	33	9
Narpus												
Optioservus												
Rhantus												
DIPTERA												
Ceratopoginidae	1	2	5	4		3		1	1	6	2	
Chironomidae												
Chironominae												
Chironomini	14	22	22	27	43	69	15	8	23	1300	310	730
Tanytarsini	45	97	127	338	365	452	111	67	347	1040	600	695
Diamesinae												
Orthocladiinae	998	1571	1600	379	319	361	318	97	597	3870	2040	1840
Tanypodinae	30	126	83	96	152	100	25	29	81	390	110	230
Culicidae												
Chaoborus										1	1	
Dolicopodidae												
Empididae	31	54	35	52	41	54	6	1	71	81	19	49
Muscidae												
Rhagionidae												
Atherix variegata												
Simuliidae												
larvae	586	1022	668	511	79	12	165	91	158	540	470	1005
pupae	18	119	111									
Stratiomyidae												
Tabanidae											1	
Tipulidae-*Dicranota*											2	
MOLLUSCA												
Gastropoda												
Ferrissia rivularis		1										
Gyraulus												
Helisoma	6	10	19	5	3	17	19	27	35	19	7	12
Physa									3	1	2	2
Pelecypoda												
Pisidium												
Sphaerium												
TOTAL	2238	4267	3920	2344	1576	1381	877	517	1948	8671	4928	6278
Mean per sample		3475			1767			1114			6626	
Mean per m^2		34750			17670			11140			66260	

Appendix 17. Fish collection information from Poplar Creek, 1977.

Sample No.	Date	Site	Gear	FL (mm)	Wt. (g)	Age
White sucker						
1	15/4	DS-1	EF	243	57	
3	26/4	DS-2	EF	205	57	
5	26/4	DS-1	EF	243	170	
6	26/4	DS-1	EF	250	170	
7	26/4	DS-1	EF	300	284	
9	26/4	DS-1	EF	274	284	
10	26/4	DS-3	EF	380	624	
11	26/4	DS-3	EF	340	425	
12	26/4	DS-3	EF	240	142	
13	26/4	DS-4	EF	400	738	
14	26/4	DS-4	EF	295	340	
18	27/4	DS-2	GN	295	340	
23	02/5	SB	EF	385	624	
24	02/5	SB	EF	350	511	
25	02/5	SB	EF	285	284	
26	02/5	SB	EF	290	284	
27	02/5	SB	EF	400	794	
28	02/5	DS-11	EF	145	57	
29	02/5	DS-11	EF	290	255	
30	02/5	DS-11	EF	420	965	
31	02/5	DS-3	EF	575	2951	
38	06/5	DS-3	EF	295	312	
40	06/5	DS-3	EF	168	57	
41	06/5	DS-3	EF	280	255	
66	11/5	SB	EF	315	425	
67	11/5	SB	EF	255	198	
68	11/5	SB	EF	250	170	
69	11/5	SB	EF	280	255	
70	11/5	SB	EF	235	170	
71	11/5	SB	EF	270	255	
73	11/5	S7	EF	345	482	
74	11/5	S7	EF	265	255	
75	11/5	S7	EF	255	227	
76	11/5	S7	EF	320	425	
77	11/5	S7	EF	280	255	
78	11/5	S7	EF	240	170	
79	11/5	S7	EF	265	255	
80	11/5	S7	EF	230	170	
86	12/5	SB	GN	390	794	
87	12/5	SB	GN	355	539	
88	12/5	SB	GN	355	681	
89	12/5	DS-10	EF	380	681	
91	18/5	SB	EF	325	397	
92	18/5	SB	EF	275	227	
93	18/5	DS-11	EF	300	397	
94	18/5	DS-11	EF	275	284	
99	18/5	DS-3	EF	310	340	
107	25/7	DS-1	EF	300	340	
112	26/7	DS-2	GN	332	567	
113	26/7	DS-2	GN	320	511	
114	26/7	DS-2	GN	285	397	
115	26/7	DS-2	GN	290	340	
116	26/7	DS-2	GN	290	340	
117	26/7	DS-2	GN	290	340	
122	26/7	SB	GN	330	596	
123	26/7	SB	GN	345	681	
124	26/7	SB	GN	345	624	
125	26/7	SB	GN	320	482	
135	25/7	S8	EF	275	227	
136	25/7	S9	EF	250	198	
144	19/9	SB	EF	286	369	
145	19/9	SB	EF	251	227	
146	19/9	SB	EF	312	425	
147	19/9	SB	EF	203	113	
148	19/9	SB	EF	262	227	
149	20/9	DS-2	GN	268	255	
150	20/9	DS-2	GN	296	369	
151	20/9	DS-2	GN	311	397	
152	20/9	DS-2	GN	310	397	
159	20/9	SB	GN	342	567	
Longnose sucker						
32	02/5	DS-3	EF	255	227	
35	06/5	DS-10	EF	295	340	
39	06/5	DS-3	EF	390	567	
42	06/5	DS-3	EF	210	113	
43	06/5	DS-3	EF	250	227	
56	11/5	DS-3	EF	300	284	

Site: refer to map of sampling locations. Gear: EF - electrofisher, GN - gill net, S - seine, A - angling.

Continued . . .

Appendix 17. Continued.

Sample No.	Date	Site	Gear	FL (mm)	Wt. (g)	Age
57	11/5	DS-3	EF	260	255	
58	11/5	DS-3	EF	300	284	
59	11/5	DS-3	EF	190	57	
60	11/5	DS-3	EF	240	170	
61	11/5	DS-3	EF	210	113	
62	11/5	DS-4	EF	390	539	
63	11/5	DS-4	EF	410	539	
64	11/5	DS-7	EF	320	369	
65	11/5	DS-7	EF	275	227	
97	18/5	DS-10	EF	240	198	
98	18/5	DS-10	EF	185	113	
100	18/5	DS-3	EF	250	284	
102	18/5	DS-7	EF	315	284	
131	26/7	S7	EF	250	198	
134	26/7	S7	EF	250	170	
138	26/7	DS-11	EF	235	170	
139	26/7	DS-11	EF	258	198	
140	26/7	DS-3	EF	300	340	
141	26/7	DS-3	EF	305	284	
142	26/7	DS-3	EF	310	340	
		Arctic Grayling				
2	20/4	DS-3	EF	193	57	2
15	26/4	DS-6	EF	140	30	1
16	26/4	DS-7	EF	170	113	2
72	11/5	S7	EF	228	142	3
95	18/5		EF	235	170	3
126	26/7	S7	EF	370	681	6
127	26/7	S7	EF	275	340	4
128	26/7	S7	EF	300	284	3
129	26/7	S7	EF	320	454	4
130	26/7	S7	EF	305	340	3
132	26/7	S7	EF	320	397	5
133	26/7	S7	EF	270	255	3
153	20/9	DS-2	GN	368	624	6
154	20/9	DS-2	GN	359	596	6
166	20/9	DS-10	EF	140	85	1
167	20/9	DS-10	EF	125	57	1
168	20/9	DS-3	S	220	113	2
169	29/9	DS-3	EF	151	30	1
171	20/9	DS-7	EF	243	227	3
172	20/9	DS-7	EF	280	397	3
174	20/9	DS-7	EF	228	170	3

Sample No.	Date	Site	Gear	FL (mm)	Wt. (g)	Age
		Northern pike				
4	26/4	DS-2	EF	310	227	4
17	27/4	DS-2	GN	600	1475	8
34	06/5	DS-10	EF	355	425	6
36	06/5	DS-10	EF	440	681	6
37	06/5	DS-10	EF	475	823	7
44	06/5	DS-7	EF	470	738	7
50	11/5	DS-1	EF	530	1235	9
53	11/5	DS-2	A	595	1248	10
54	11/5	DS-2	A	535	993	8
55	11/5	DS-2	A	593	1504	8
80-A	12/5	DS-2	GN	470	851	7
81	12/5	SB	GN	485	823	8
82	12/5	SB	GN	500	908	7
83	12/5	SB	GN	540	965	8
84	12/5	SB	GN	510	1106	7
85	12/5	SB	GN	640	1731	9
105	29/6	SB	A	490	851	5
106	29/6	SB	A	496	851	5
111	26/7	DS-2	GN	515	1192	5
118	26/7	SB	GN	490	1248	7
119	26/7	SB	GN	475	965	5
120	26/7	SB	GN	485	1078	5
121	26/7	SB	GN	455	851	6
137	26/7	DS-11	EF	510	681	6
157	20/9	DS-2	GN	678	1759	9
158	20/9	DS-2	GN	490	596	6
160	20/9	SB	GN	590	1646	9
161	20/9	SB	GN	555	1475	7
162	20/9	SB	GN	565	1248	8
163	20/9	SB	GN	510	1021	9
164	20/9	SB	GN	485	851	10
165	20/9	SB	GN	520	993	11
		Yellow walleye				
19	27/4	PC-AR	EF	510	1589	
20	27/4	PC-AR	EF	445	965	
21	27/4	PC-AR	EF	380	567	
22	27/4	PC-AR	EF	355	454	
33	02/5	DS-1	EF	390	652	
51	11/5	DS-1	EF	410	738	
52	11/5	DS-1	EF	370	454	
108	25/7	PC-AR	A	440	965	
109	25/7	PC-AR	A	440	0	
110	25/7	PC-AR	A	290	255	
175	21/9	PC-AR	A	415	567	

Continued . . .

Appendix 17. Concluded.

Sample No.	Date	Site	Gear	FL (mm)	Wt. (g)	Age
			Lake whitefish			
8	26/4	DS-1	EF	375	738	
103	18/5	DS-2	EF	380	1067	
104	18/5	DS-2	EF	320	425	
143	19/9	SB	EF	400	1333	
155	20/9	DS-2	GN	383	936	
156	20/9	DS-2	GN	387	965	
			Mountain whitefish			
45	06/5	DS-7	EF	175	57	
46	06/5	DS-7	EF	190	85	
96	18/5	DS-10	EF	170	71	
101	18/5	DS-7	EF	100	-	
			Burbot			
-	27/4	PC-AR	GN	457	567	
170	20/9	DS-3	EF	474	936	
173	20/9	DS-7	EF	420	567	