

**YOHO
NATIONAL
PARK**

AQUATIC RESOURCES INVENTORY

BY

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ABSTRACT

During 1973-74 extensive limnological investigations were conducted on 22 lakes and 30 stream sites in Yoho National Park. Field and laboratory investigations included: benthic samples, shoreline survey, shore trawl, phytoplankton, zooplankton, macrophytes, fish, fish parasites, sounding, primary production, water chemistry, water temperature, pH, conductivity, and light penetration. In addition to the sites visited during the present study, data available on 20 other lakes were analysed.

The physical and chemical limnology of Park waters is described and discussed. Lakes, ponds, and streams in the Park were found to exhibit a wide diversity of morphological types.

The taxonomy, species composition, numbers, and distribution of benthic, shoreline, phytoplankton, and zooplankton communities are described and discussed. Lakes and ponds in the Park are classified on the basis of thermal properties, trophic levels, phytoplankton communities, zooplankton communities, and potential fish production.

The biotic communities of the Park were generally found to be relatively sparse and the lakes oligotrophic, although a fairly wide range of habitat types was observed. General levels of productivity were comparable to those characteristic of many arctic lakes. Slow growth rates and long generation times characterize such oligotrophic waters.

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INTRODUCTION

This report is a summary of information obtained from examination of limnological collections and field data gathered during 1973 and 1974 in Yoho National Park. This study was conducted in the Park for the National and Historic Parks Branch by the Canadian Wildlife Service as part of a general inventory including geology, soils, vegetation, and wildlife, as well as aquatic resources. Aside from the accumulation of basic inventory information the study also provides information for planning, interpretation, and resource management.

The two year project was organized in three general sections: (1) field collections; (2) examination and identification of material from field collections; (3) comparative study and interpretation of results.

The aquatic resources inventory included an examination of 30 stream and 42 lake sites. At most sites several aspects of limnology were investigated, including benthic invertebrates, zooplankton, phytoplankton, fish, fish parasites, temperatures, bacteriology, water chemistry, morphometry, stream flow, and primary production. As a result of these investigations, a large quantity of data has been gathered. In order to simplify the process of review and interpretation, these data were compiled as a separate data section which forms Volume III of the present report. Because of its importance to public health, a separate report on the coliform bacteria in the natural waters of Yoho National Park was prepared earlier (Mudry and

Anderson 1973) for the National and Historic Parks Branch. The results of all other investigations concerning the aquatic resources of Yoho National Park are included in the present report.

Yoho National Park is located on the western slope of the Canadian Rockies in British Columbia and comprises the drainage basin of the upper Kicking Horse River and its tributaries. The principal tributaries include Yoho River, Amiskwi River, Otterhead River, and Procupine Creek from the north and west, and Ottertail River, Beaverfoot River, and Cataract Brook from the east and south. These waters flow westward out of the Park into the Columbia River and eventually into the Pacific Ocean.

Several medium sized lakes are located in the east-central portion of the Park and smaller lakes and ponds occur throughout the Park, mainly near the headwaters of Amiskwi River, Yoho River, and Cataract Brook.

The earliest reported limnological studies in Yoho National Park were the surveys by V. E. F. Solman (1947) at Emerald Lake in connection with fisheries management problems. The first detailed limnological survey in the Park was that of F.H. Schultz (1953) where certain limnological parameters were examined in 17 lake and 6 stream sites. No further basic limnological studies were conducted until Anderson (1968b, 1970a, 1974a) collected morphometric, chemical, and zooplankton data from a number of lakes and ponds, many of which were examined for the first time. During 1971 a number of collections were made in 5 lakes and 5 streams as part of an Opportunity for Youth Program project. Samples and data were not completely analyzed at that time and

are included in the present report.

Some additional reports treated aspects of limnology in Yoho National Park in connection with other studies. Anderson (1970b) reported on the effects of an oil spill in the Kicking Horse River. Chuang (1972) prepared a check list of flora of the Park which included a number of aquatic species. Ward (1967, 1972, 1974) reported the introduction of Mysis relicta to Emerald Lake and related fisheries management problems. Several studies were concerned mainly with possible fecal coliform contamination and nutrification in Park waters (Wishart 1970; Robinson 1972; Anderson and Krochak 1972; Mudry and Anderson 1973).

METHODS

Methods used in the collection of limnological data must be selected with a view to the objectives of the study. The present study was organized to provide information on both qualitative and quantitative aspects of aquatic communities. Information on community structure, production, and water quality was also considered a necessary part of an aquatic resource inventory. For these reasons the field and laboratory methods outlined below were used to obtain the data presented in this report.

Stream kick samples

Stream invertebrates were sampled by a kick-sample technique using a "D" shaped net with a 30 cm. wide by 27 cm high opening. The net was placed on the stream bottom and the substrate immediately upstream was then disturbed by kicking it with one foot for 30 seconds. The area sampled, as well as its depth, was approximate, but was estimated to be about 0.18 to 0.2 square metres and 4 to 8 cm deep. Kick-samples were taken at three different spots (usually about 5 metres apart) which appeared to be representative for the stream site. The dislodged invertebrates, substrates and debris collected in the net were then sorted in a white enamel tray. The invertebrates collected were preserved in 70% ethanol for later identification.

Benthic dredge samples

Benthic samples were taken with a 6 inch Ekman dredge. Two

dredge samples were taken at one or more representative sites or depths at each lake. The two combined dredge samples from each site were washed through a mesh-bottomed pail (aperture size 0.36 x 0.52 mm) and sorted in a white enamel tray. The invertebrates were preserved in 70% ethanol for later identification.

Phytoplankton.

Phytoplankton was collected by immersing a 100 ml "cabinet oval" bottle to a depth of 0.5 m and allowing it to fill. Samples were preserved for later identification by adding 3 drops of Lugol's iodine to the bottle. In some cases phytoplankton was collected from depths greater than 0.5 m with a Van Dorn sampler.

Zooplankton.

Zooplankton was collected using a 25 cm diameter Wisconsin style plankton net with a mean aperture dimension of approximately 70 microns. Two vertical tows were made from each of one or more depths near the centre of each lake. In lakes of approximately 8m or more in depth two tows were made from half depth (or 10m whichever is less) and two from the bottom. A weighted net was used to assist in determining when the bottom was reached in order to draw the vertical sample from within a few centimetres of the bottom. For some lakes studies, supplementary horizontal tows were collected from inshore areas. Samples were preserved in 3% formalin for later microscopic examination.

Shoreline survey.

Shoreline collections of invertebrates were made at each

lake site for a 30 minute timed interval. Shoreline samples were taken from the water's edge to a depth of approximately 50 cm. The shoreline invertebrates were sought by lifting rocks, moving logs, or agitating the bottom or rooted aquatic macrophytes. Very active invertebrates were caught with a small hand net, while more sluggish species were removed from the rocks or debris with the aid of forceps. A minimum of 100 metres of shoreline were covered at each site. Invertebrates collected were preserved in 70% ethanol for examination.

Shore trawl.

Trawl samples were collected in the littoral zone by pulling a small trawl through representative areas of rooted aquatic macrophytes and over the substrate for a distance of 20 metres. The samples collected were not considered quantitative and only a representative sample of the invertebrates were kept for further study. Often species not collected during the shoreline survey were present in trawl samples. Invertebrates collected were preserved in 70% ethanol.

Fish collections.

All stream collections of fish were made using a Smith-Root Type V Electrofisher. Usually a stream section of at least 100 metres was sampled.

Lake sampling was accomplished using gill nets in gangs of several mesh sizes. Gangs composed of 25 metre sections of $3/4$, $1\frac{1}{2}$, 2, and $3\frac{1}{2}$ inch mesh were set for 24 hours in each of the

lakes sampled.

Whenever possible a sample size of at least 10 fish of each species at each locality was collected and frozen for later study.

Water chemistry.

Water samples for chemical analysis were collected in 2.0 litre bottles supplied by the Calgary laboratory of the Inland Waters Branch. For filling the bottles were first rinse and then immersed to 0.5 m and allowed to fill. Samples were kept on ice in styrofoam coolers, except in the case of very cool weather (40F) when no ice was used. Analysis of the samples was done by the Inland Waters Branch, Calgary.

Water temperature, pH, conductivity, and light penetration.

Field analysis of water temperature, pH, specific conductivity and light penetration were performed at the time of collection using the following instrumentation:

Yellow Springs Instrument Co. Model 425C

thermistor telethermometer (calibrated at
each use against a mercury thermometer)

Hellige Pocket Comparator optical pH meter

Dionic Series 3 conductivity meter

20-cm diameter black and white Secchi disk

Sounding.

Extensive sounding for the establishment of contour lines

was done on three lakes using a Fish-Lo-K-Tor electronic sounder. The sounder was used to check the reliability of existing contour maps. McArthur Lake was sounded using an electronic recording sounder.

Primary production.

Water samples from the appropriate depths were collected with non-metallic samplers near the deepest part of each of the lakes and ponds. Each sample was filtered through a bolting-silk filter directly into polyethylene bottles for chemical analysis, Jena-glass bottles for production experiments, and bottles containing Lugol's acetic-acid preservative for phytoplankton examination. Number-12 bolting silk (aperture 120 μ) was used because it retained virtually no phytoplankton, most rotifers, and all of the crustacean plankton present in the samples at the time of the experiments.

Chemical and physical methods have been described elsewhere (Anderson, 1970a). Field analysis were begun within 20 min of sampling. Total inorganic carbon was calculated according to methods outlined in Standard Methods (American Public Health Association, 1971).

Phytoplankton primary production was measured by the ^{14}C -isotope technique (Steemann Nielsen, 1952). Two light bottles and one darkened bottle containing natural phytoplankton samples from each depth sampled were inoculated with approximately 4 μ -Curies of ^{14}C as NaHCO_3 and resuspended at the depth from which the samples came. After incubation (usually about 3h),

bottles were put into a light-free box and taken to a semi-darkened work area for immediate filtration through a membrane filter (porosity $\approx 0.50 \mu$) at a pressure differential of less than 0.3 atmospheres. Mean filtration time was about 3 min for each bottle. Filters were air dried for approximately 24 h and returned to The International Agency for counting.

Macrophytes.

Representative macrophytes from several lakes were collected by hand and pressed for later identification.

Stream flow.

Measurement of stream water velocity was made with a G.M. current meter. Whenever possible the measurements were made by immersing the meter for one minute while slowly moving across the stream in order to get an average velocity. Calibration of the meter was done by Hydraulics Division, Canada Centre for Inland Waters, Burlington, Ontario.

Laboratory methods.

Laboratory analysis of plankton, benthic, and fish samples consisted of counting the number of individuals in each sample and identifying each individual to the lowest taxonomic level possible with available taxonomic keys. The level of identification achieved thus varies with the particular group examined.

For larger invertebrates and macrophytes a Wild M5 dissecting microscope was used for examination.

Phytoplankton identification as well as counts were made from 10 or 25 ml of sample depending on the density of the phytoplankton. Phytoplankton were sedimented in a settling chamber, then examined on a Wild M40 inverted microscope. Most of the identifications and counts were made using magnifications of 100X, 400X and 1000X with phase contrast illumination. The number of cells per ml was calculated after microscopic examination of a known area of the settling chamber base.

During fish examination weight, fork length, sex and age were recorded. For parastiological examination the following tissues, organs and cavities, were examined and dissected when necessary: external body surface, fins, body musculature, eyes, nasal cavities, buccal cavity, gills heart, esophagus, stomach, pyloric caeca, intestine, coelom, mesenteries, gall bladder, liver, swim bladder, kidneys, urinary duct and gonads. Examination of each fish required from 1-3 hours depending on size. Parasites obtained were fixed in alcohol-formalin-acetic acid (AFA). Nematodes were transferred to glycerine-alcohol for clearing and all other parasites were transferred to 70% ethanol for preservation. For identification, nematodes were examined in temporary glycerine whole mounts. Representative specimens of other helminths were stained in Grenacher's borax carmine and mounted in Canada balsam.

PHYSICAL LIMNOLOGY

The Study Area

Lakes. Sixty-one lakes and ponds were identified and numbered by Ward (1974) in Yoho National Park (Figure 1). In addition to these, three other small ponds have been identified: one near Celeste Lake (Anderson 1974a), one near Hidden Lake (Schultz 1953, Anderson 1974a), and one near Lower Opabin Pond (present report). Limnological investigations have been conducted on 42 of the 64 lakes and ponds (Table 1) in the Park (Schultz 1953; Anderson 1968b 1970a 1974a; present report).

Of the 42 lakes and ponds investigated (Figure 2) the lowest, Ottertail Flats Lake, lies at 1118 m and the highest, Kiwetinok Lake, lies at 2455 m. All of the lakes and ponds in the Park lie within the alpine, treeline, subalpine, and montane altitudinal belts described by Anderson (1971a). Because altitudinal belts are based on terrestrial plant communities which may have considerable effect on the limnology of water bodies the following list is presented. Lakes and ponds are classified according to the criteria of Anderson (1971a).

Alpine zone

Lakes

Fairy
Kiwetinok
Indigo
Oesa
Upper Opabin (14)
McArthur

Ponds

Waves



Table 1. Summary of morphometric data for lakes examined in Yoho National Park.

Lake No.	Lake name	Grid reference	Altitude m/ft	Depth max.	m mean*	Surface area (ha)	Volume* $\times 10^6 \text{ m}^3$
6	Ottertail	11U/NG289827	1118/3665	1.5	(1.0)	4.0	(0.04)
7	Schaffer	11U/NG454885	2170/7114	2.5	(1.2)	0.4	(0.005)
8	McArthur	11U/NG460870	2240/7344	84.4	25.6	77.0	21.2
9	O'Hara	11U/NG466895	2014/6603	38.1	19.1	34.4	6.59
10	Mary	11U/NG465888	2034/6668	3.5	(2.0)	6.5	(0.13)
11	Opabin	11U/NG473883	2234/7324	1.4	(1.0)	0.3	(0.003)
12	Victoria	11U/NG480895	2225/7295	4.5	3.5	0.4	0.014
13	Opabin	11U/NG474881	2234/7324	1.5	(1.0)	0.3	(0.003)
14	Opabin	11U/NG475880	2245/7360	2.7	(1.0)	1.7	(0.017)
15	Opabin	11U/NG480877	2270/7442	12.3	3.96	3.1	0.123
15A	Opabin	11U/NG472884	2204/7275	1.2	(0.7)	0.1	(0.001)
16	Oesa	11U/NG485893	2285/7491	39.0	13.6	16.1	2.19
17	Ross	11U/NG486984	1729/5670	21.5	7.3	6.0	0.442
18	South Narao	11U/NG455967	1715/5625	6.3	(3.0)	0.7	(0.021)
19	North Narao	11U/NG455971	1715/5625	2.0	(0.7)	3.0	(0.021)
20	Wapta	11U/NG454987	1590/5203	8.2	4.2	24.1	1.02
21	Lwr Morn. Glory	11U/NG444905	1995/6540	3.5	(2.0)	0.6	(0.012)
22	Mid Morn. Glory	11U/NG444903	1997/6550	2.5	(1.5)	1.0	(0.015)
23	Up. Morn. Glory	11U/NG440902	2006/6580	7.0	(2.0)	1.7	(0.034)
24	Linda	11U/NG437909	2098/6880	12.0	(4.0)	4.0	(0.16)
25	Vera	11U/NG428915	2097/6900	5.5	(3.0)	2.2	(0.066)
26	Emerald	11U/NG327990	1300/4272	28.0	17.0	116.0	19.8
28	Ptarmigan	11U/NG207990	2014/6600	2.0	(1.0)	0.8	(0.008)
29	Crystal	11U/NG206974	2206/7230	2.0	(1.0)	1.2	(0.012)
31	Little Gem	11U/NG190947	1908/6250	20.7	(8.0)	9.0	(0.72)
35	Otto	11U/NH198023	2060/6750	6.4	(3.0)	0.7	(0.021)

Table 1. Lake morphometric data - cont'd.

Lake No.	Lake name	Grid reference	Altitude m/ft	Depth max.	m mean*	Surface area (ha)	Volume* X10 ⁶ m ³
37	Kiwetino	11U/NH278073	2455/8050	15.0	(7.0)	6.0	(0.42)
38	Hamilton	11U/NH294004	2140/7020	12.2	(6.0)	5.0	(0.3)
41	Celeste	11U/NH337074	1997/6550	5.7	(3.0)	2.0	(0.06)
41A	Unnamed	11U/NH336078	1976/6480	2.0	(1.0)	0.2	(0.002)
42	Duchesnay	11U/NH347080	1595/5230	1.0	(0.7)	3.5	(0.02)
43	Yoho	11U/NH359024	1825/5985	12.0	(6.0)	3.3	(0.19)
44	Hidden	11U/NH360035	1845/6050	8.0	(4.0)	1.0	(0.04)
44B	Unnamed	11U/NH360035	1845/6050	1.0	(0.7)	0.1	(0.007)
47	Sherbrooke	11U/NH428005	1800/5918	12.0	3.85	35.0	1.34
48	Sink	11U/NG482998	1622/5320	2.0	(1.5)	5.0	(0.07)
49	Summit	11U/NG492999	1628/5340	1.2	(1.0)	2.0	(0.02)
50	Fairy	11U/NH363107	2232/7320	21.0	(10.0)	12.0	(1.2)
51	Waves	11U/NH349146	2226/7300	3.6	(2.0)	0.4	(0.08)
52	Marpole	11U/NH328102	2070/6800	5.0	(2.5)	1.7	(0.04)
55	Amiskwi	11U/NH247155	2088/6850	9.8	(4.0)	6.0	(0.24)
61	Indigo	11U/NH204109	2272/7450	43.0	(18.0)	4.0	(0.72)

*() indicate estimated values

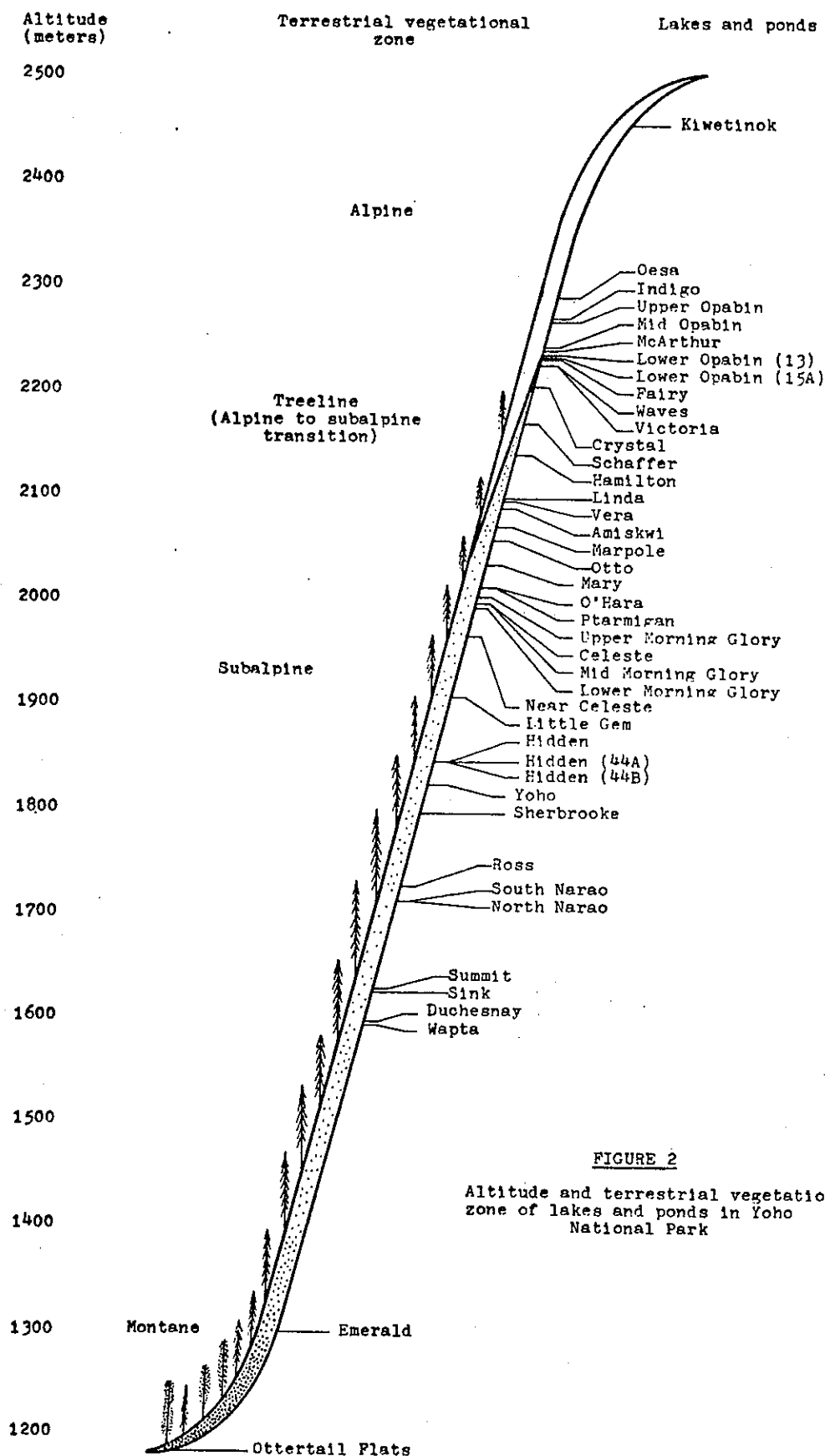


FIGURE 2

Altitude and terrestrial vegetation
zone of lakes and ponds in Yoho
National Park

TreelineHamilton
OttoPtarmigan
Crystal
Lower OpabinSubalpineAmiskwi
Little Gem
O'Hara
Wapta
Yoho
Ross
Mary
Sink
Linda
Sherbrooke
Marpole
South Narao
Celeste
VeraVictoria
Opabin (11)
Opabin (13)
Opabin (15A)
Hidden
Hidden (44B)
Celeste (41A)
Duchesnay
Summit
Schaffer
Mid Morning Glory
Lower Morning GloryMontaneEmerald
Ottertail Flats

Lake morphometry. The majority of water bodies investigated so far are small in size with 29 being less than 5 hectares (ha) in area, 10 between 5-35 ha in area, and only 2 (McArthur and Emerald) are more than 75 ha in area (Figure 3). Although Emerald and McArthur Lakes are the largest bodies of water in the Park they are small when compared with some lakes in other mountain National Parks.

The ponds and lakes range in depth from about 1 m to over 80 m in depth (Figure 4). There appears to be no general correlation between surface area and depth - for example Indigo, Oesa and O'Hara Lakes are all deeper than Emerald Lake although Emerald is many times larger in size.

Many of the lakes exhibit characteristics common with cirque lakes formed as a result of glacial action; they have

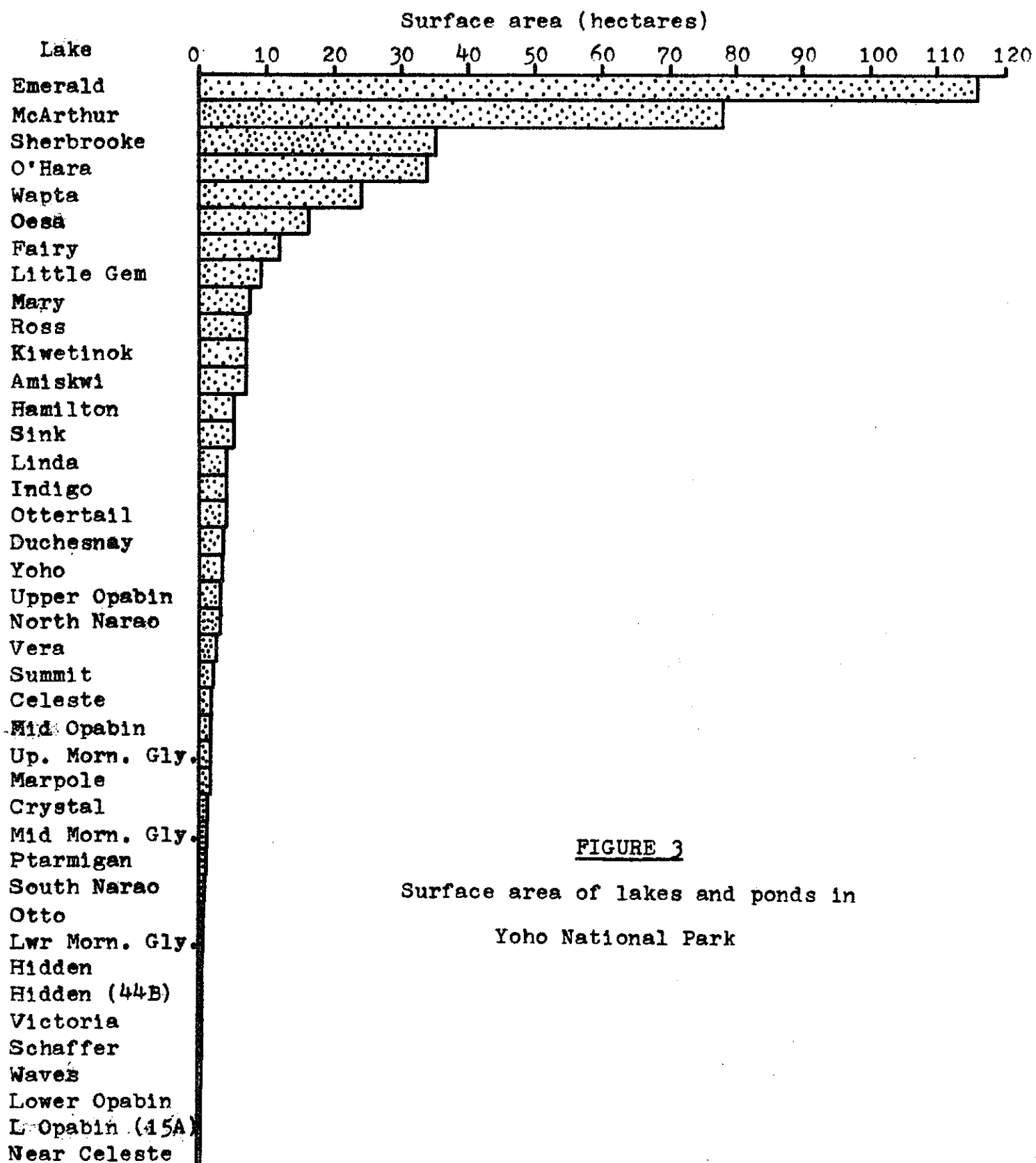
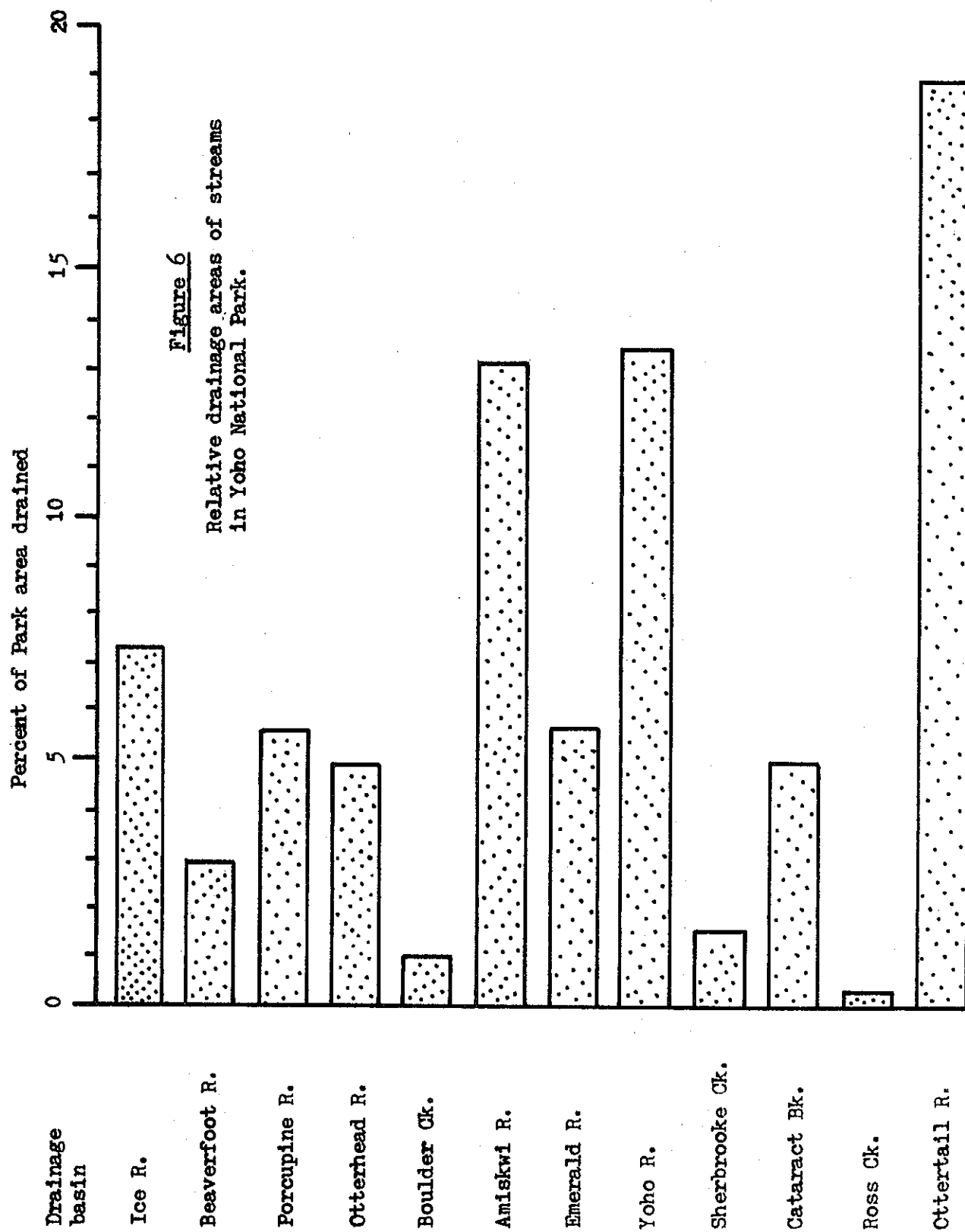


FIGURE 3

Surface area of lakes and ponds in
Yoho National Park

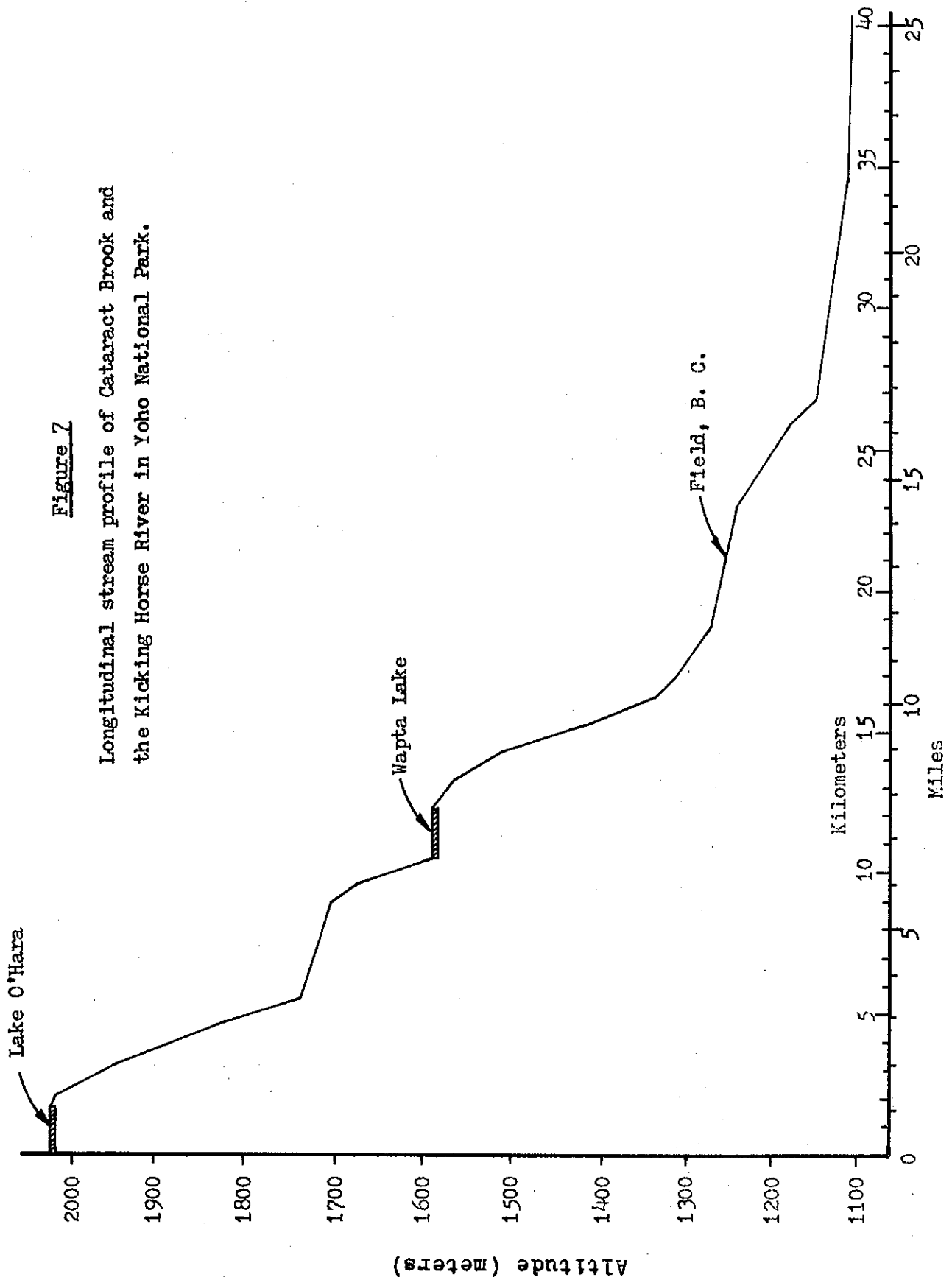
Table 2. Summary of morphometric data for streams in Yoho National Park.

Stream name	Length km	Drainage area ha x100	Percent of Park drained	Gradient m/km	Form factor
Amiskwi	29	173	13.2	32	5.9
Beaverfoot	27.9	304	2.7	11	5.3
Boulder	9	14	1.0	109	1.5
Cataract	9	64	4.9	47	7.1
Emerald	7	76	5.7	20	10.8
Hoodoo	5	10	0.7	206	2.0
Ice	19	96	7.3	34	5.0
Morning Glory	1.8	3	0.2	83	1.5
Oesa	1.1	4	0.3	246	3.8
Opabin	2	4	0.3	128	1.8
Otterhead	20	67	5.0	29	3.3
Ottertail	24	248	18.9	42	10.3
Porcupine	17	74	5.6	50	4.3
Ross	1.5	5	0.4	69	3.1
Sherbrooke	7	21	1.6	161	3.0
Yoho	19	176	13.4	46	9.2



of flow from the various basins, especially during the summer months. Long and narrow shaped basins (with low form factors) have a reduced chance of receiving heavy rainfall over the entire region, hence can be expected to have a more consistent flow.

Stream morphometry. A wide range of stream habitat types exist in the Part as a result of the varying gradient or slope (Table 2). This characteristic is expressed as vertical decent per unit of horizontal distance (metres/kilometres). Generally, the region of steeper slope is near the headwaters, while gradients are lower near the mouth of the stream. Through erosion and deposition, the longitudinal profile of the gradient attains the form of a shallow, irregular arc with an upward concavity flattening toward the mouth of the stream. Local equilibria are established at points along the stream through adjustments between channel form, velocity, gradient, and discharge. In time, irregularities along the stream slope are more or less leveled (Reid 1961). The Kicking Horse River is a good example of changing stream profile (Figure 7) where the upper reaches have a steep gradient causing high water velocities and scouring (degrading) while the lower reaches are an area of deposition (aggrading). The mean gradients given in Table 2 are an indication of the types of gradients to be found in Park streams. The very high values for Sherbrooke Creek and Boulder Creek and to a lesser extent those of Ross Creek, Cataract Brook, Yoho River,



Amiskwi River, Ottertail River, Otterhead River, Porcupine Creek, and Ice River probably indicate areas where active erosion of the stream bed is taking place with only minor locally important areas of deposition or aggrading. The Beaverfoot River, however, with a mean gradient of only 11.4 m km^{-1} , indicates a gradient profile of equilibrium has been achieved over much of its length. The several miles of oxbows near its mouth are evidence of the low gradient in this area. The accumulation of sediment and silt in the lower reaches of the Beaverfoot River can be compared, for example, with the rocky, silt free bottom of Porcupine Creek with its mean gradient of 50 m km^{-1} .

Discharge. The volume of water discharged by the various streams in the Park is almost directly related to the drainage area of the stream (Table 1). The large drainage areas of the Ottertail, Otterhead, Ice, Amiskwi, and Yoho Rivers, make substantial contributions of water to the Kicking Horse River. Smaller drainages such as Boulder Creek make only minor contributions to the total volume of the Kicking Horse River.

Historic records of flow in the Kicking Horse River are limited to measurements from 1912 to 1921 (Water Survey of Canada, 1970). The highest daily discharge recorded was 4380 cubic feet per second (cfs) on June 26, 1912. As with other glacial meltwater streams the Kicking Horse River

attains its maximum discharge during the warm summer months. The available records indicate a much reduced but continuous flow during the ice covered seasons, with discharges of less than 100 cfs (Smith 1972).

Smith (1972) established stage recorders at the Field bridge during August 3 to September 15, 1971 and July 9-27, 1972 (Figure 8). During August the local daytime temperatures ranged into the 90's causing maximum melting of the glaciers at the headwaters of the Yoho River. Discharges showed marked diurnal variations with daily extremes varying by factors of 1.5 to nearly 2.0 (Figure 9).

Flow measurements made during 1973 at all of the major tributaries of the Kicking Horse River are presented in Table 3. The relative discharges for July are shown in Figure 10 with the total Kicking Horse River discharge estimated to be 3300 cfs.

Melting glaciers not only contribute large amounts of surface runoff but also affect the quality of stream habitats by contributing large amounts of glacial silt. Approximately 30% of the Yoho River drainage area is occupied by glaciers which contribute large amounts of silt in meltwaters during late summer. The glacial silt produces a high turbidity in the Yoho River and greatly affects the biological potential of that stream. Sherbrooke Lake and Emerald Lake serve as primary catch basins for other glacial meltwater streams.

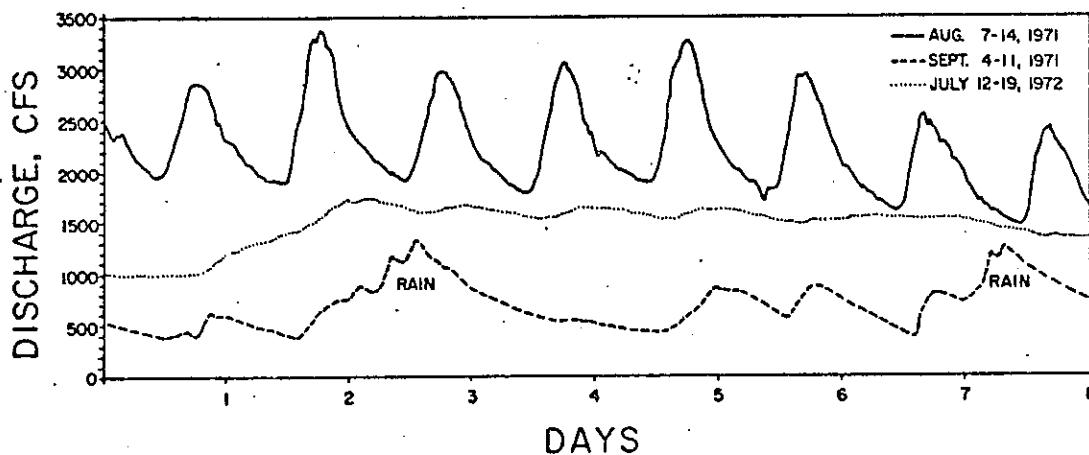


Figure 8. Discharge of the Kicking Horse River at Field, British Columbia (Smith 1972).

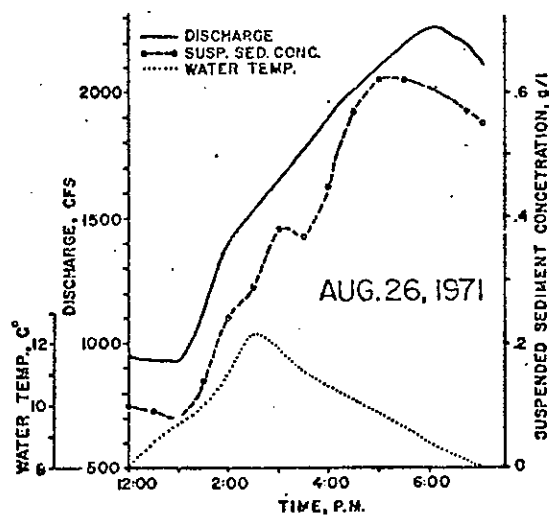


Figure 9. Diurnal fluctuation in discharge, suspended sediments, and temperature in the Kicking Horse River at Field, British Columbia (Smith 1972).

Table 3. Summary of stream discharge data in Yoho National Park during 1973.

SITE	NAME	DATE	TIME	CUBIC FEET PER SECOND
102	Ice R.	24 July	1100	210.3
107	Porcupine Ck.	24 July	1330	203.6
108	Ottertail R.	24 July	1500	603.9
		20 August	1240	253.9
111	Otterhead R.	11 July	2030	433.3
		20 August	1200	89.8
113	Boulder Ck.	24 July	1515	17.6
		20 August	1310	5.9
114	Amiskwi R.	11 July	2000	603.3
		24 July	1815	312.9
		20 August	1140	137.5
114A	Emerald R.	11 July	1900	392.9
		24 July	1800	189.5
		20 August	1120	525.8
115	Upper Amiskwi R.	24 July	1915	155.8
116	Otto Ck.	24 July	1900	90.1
120	Upper Yoho R.	24 July	1615	702.3
		20 August	1430	423.2
123	Sherbrooke Ck.	25 July	0815	112.9
		20 August	1510	37.2
125	Kicking Horse R.	25 July	0800	286.4
		20 August	1520	117.7
128	Cataract Bk.	25 July	0845	78.8

Summary of Streamflow Data (1973) - cont'd.

SITE	NAME	DATE	TIME	CUBIC FEET PER SECOND
128	Cataract Bk.	21 August	1820	30.1
129	Morning Glory Ck.	25 July	0900	48.2
131	Mary Ck.	25 July	0915	3.9
		22 August	1330	0.4
132	Opabin Ck.	25 July	0930	23.7
		22 August	1345	9.9
133	Oesa Ck.	25 July	0940	24.7
		22 August	1350	4.0
134	Ross Ck.	25 July	1100	9.9
		20 August	1530	4.0

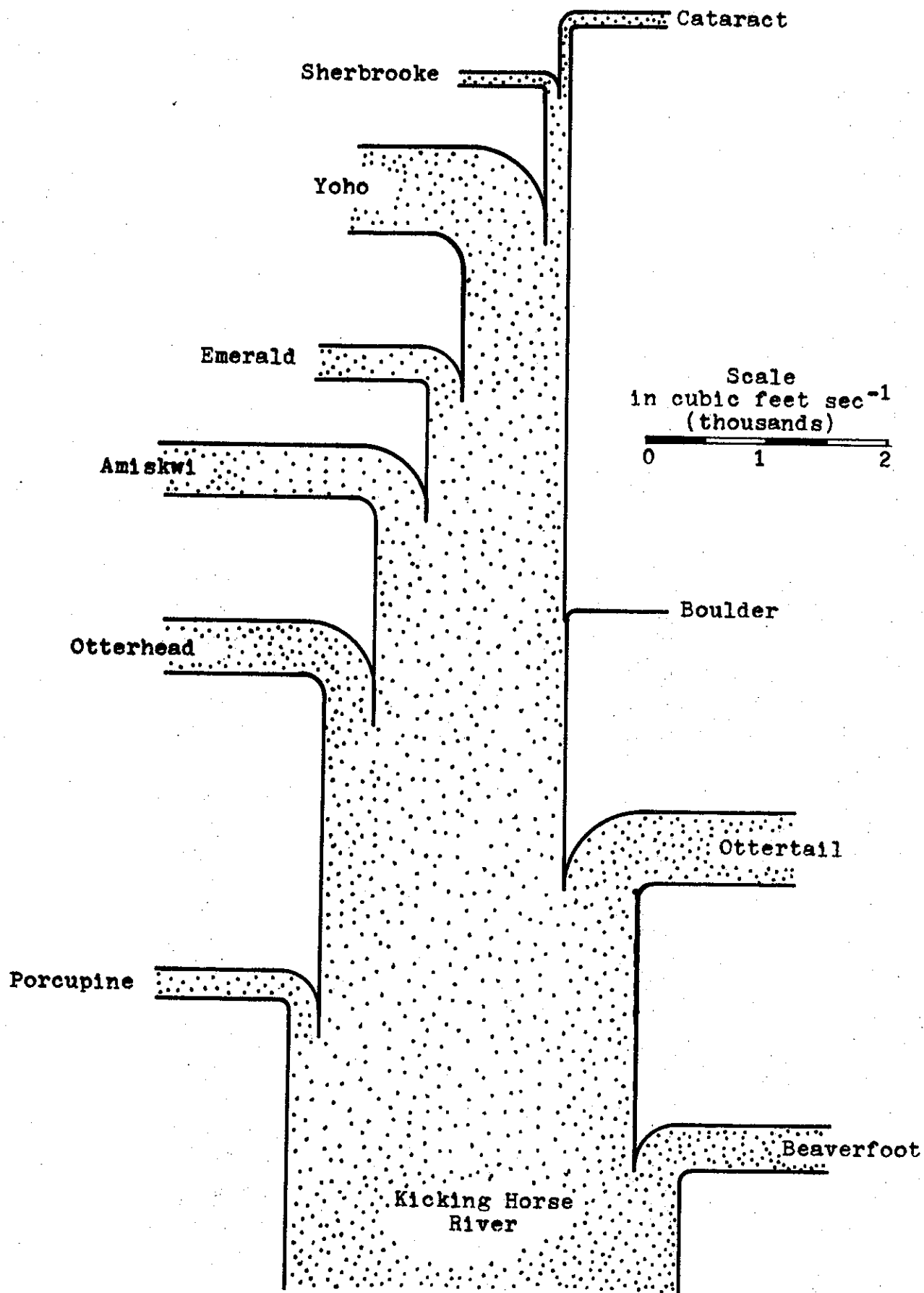


FIGURE 10

Mean summer contribution of water to the Kicking Horse River
by streams in Yoho National Park.

Smith (1972) found suspended sediments in the Field reach of the Kicking Horse River had concentrations of 1 g l^{-1} during high August flows, whereas low September discharges contained concentrations as low as 0.01 g l^{-1} . In a review of the effects of logging on fish, Gibbons and Salo (1973) found that prolonged exposure to suspended sediment concentrations of from 0.02 to 0.03 g l^{-1} were lethal to fish. Suspended sediments cause erosion of gill membranes, degradation of rearing habitat and lowered production of aquatic plants and invertebrates. The overall production of Park waters can thus be greatly affected by the presence of glaciers in the drainage basins of streams.

Thermal properties

Lakes. The alpine, treeline, subalpine, and montane lakes in the Park exhibit thermal characteristics which place them in first, second, or third order lakes described by Whipple (1898; see Hutchinson 1957).

First order lakes in which summer thermal stratification occurs but bottom temperatures remain close to 4°C are McArthur, O'Hara and Oesa. Available information indicates these lakes establish a metalimnion (thermocline) between 6-12 m in depth (Figure 11). Actual depth of the metalimnion layer appears to be determined in the early part of the open water season by a combination of temperature and wind velocity (Schindler 1971). The metalimnion will be found at a higher

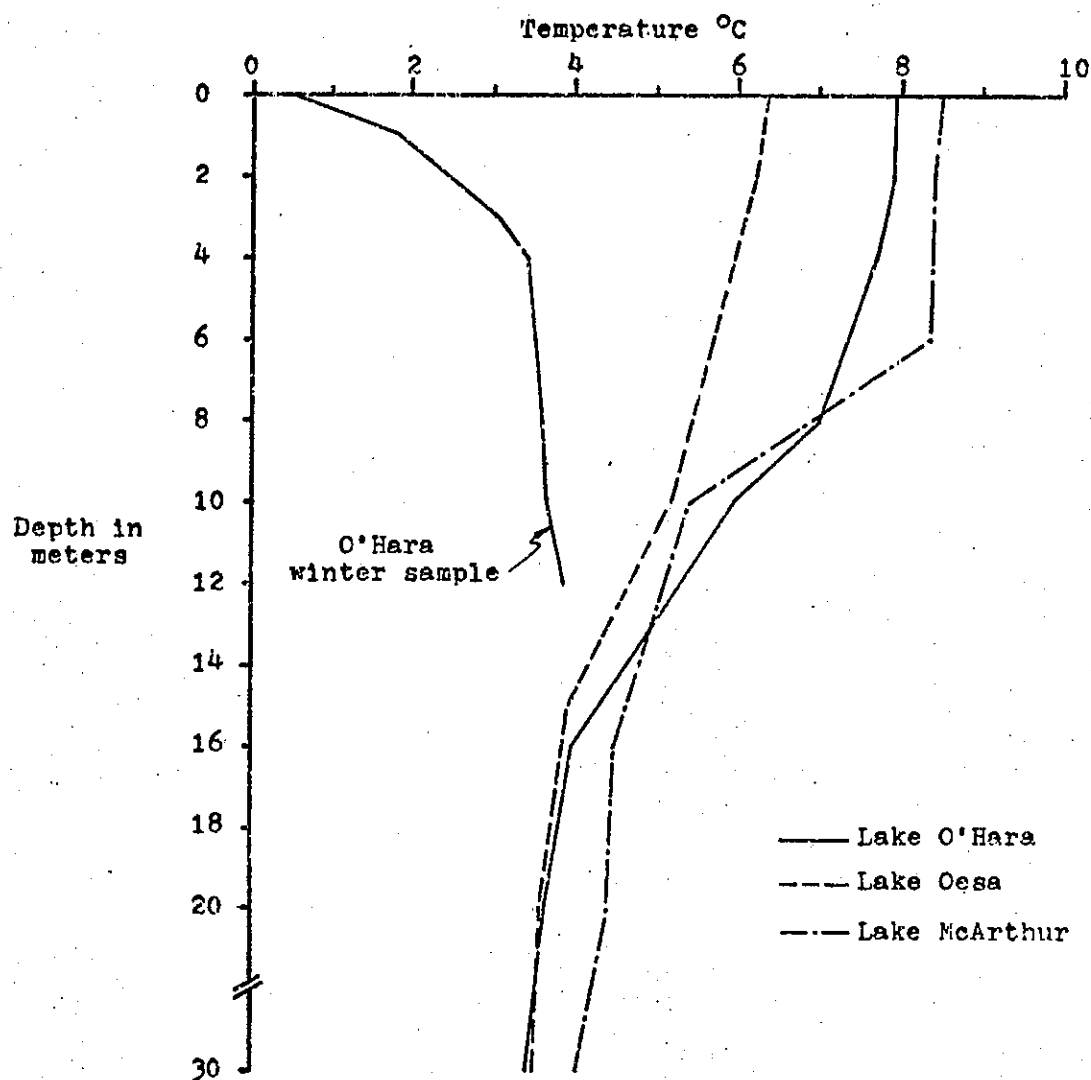


FIGURE 11

Temperature profiles of first order lakes
in Yoho National Park.

level if stratification occurs during a period of hot-still weather. After formation strong winds will have little effect on the level of the metalimnion. Maximum surface temperatures in the epilimnion layer were found to reach 8.5, 11.0, and 6.3°C in McArthur, O'Hara, and Oesa respectively during August. Hypolimnion temperatures remained between 3.5 and 4.2°C in all three lakes.

Only one of these first order lakes has been sampled under winter conditions. Lake O'Hara was found to have an inverted stratification when examined on January 25, 1974. Temperatures were 0.5°C at the surface and increased with depth to 3.8°C at 12m (Figure 11).

Synthesis of temperature data from several different sampling dates allowed establishment of seasonal isotherms for Lake O'Hara (Figure 12). As is the case with most thermally stratified lakes in the Park, Lake O'Hara is of the dimictic type in which two circulations take place each year in the spring and summer. Thermal stratification is inverse in winter and direct in summer. Reid (1961) notes that during the stratified summer period the metalimnion constitutes an effective barrier between the epilimnion and hypolimnion. Currents stimulated by wind, as well as convection currents derived from cooling at the surface, are limited in depth to the metalimnion. This means that heat and nutrients present in the region of maximum light are prevented from mixing throughout the body of the lake.

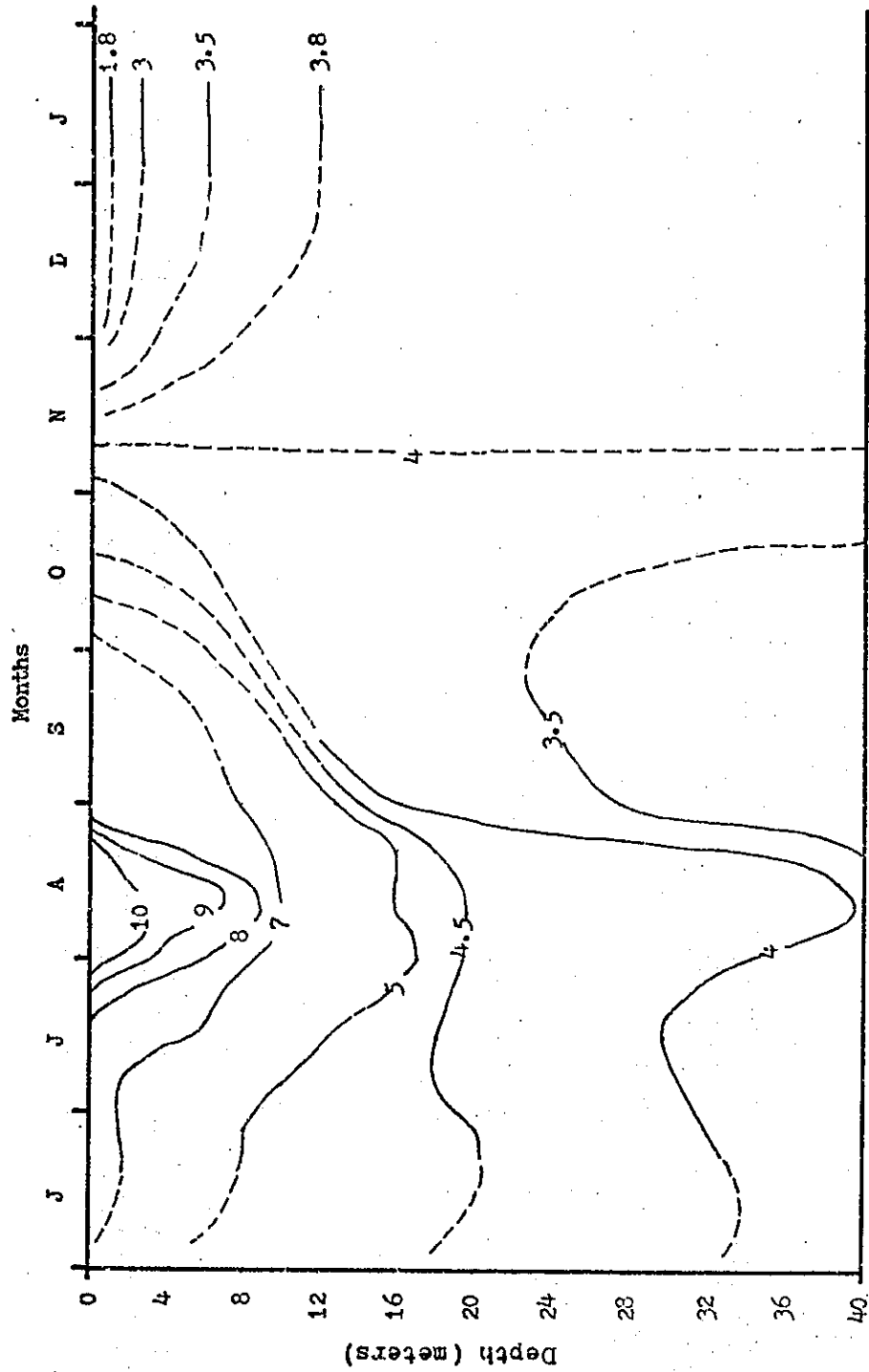


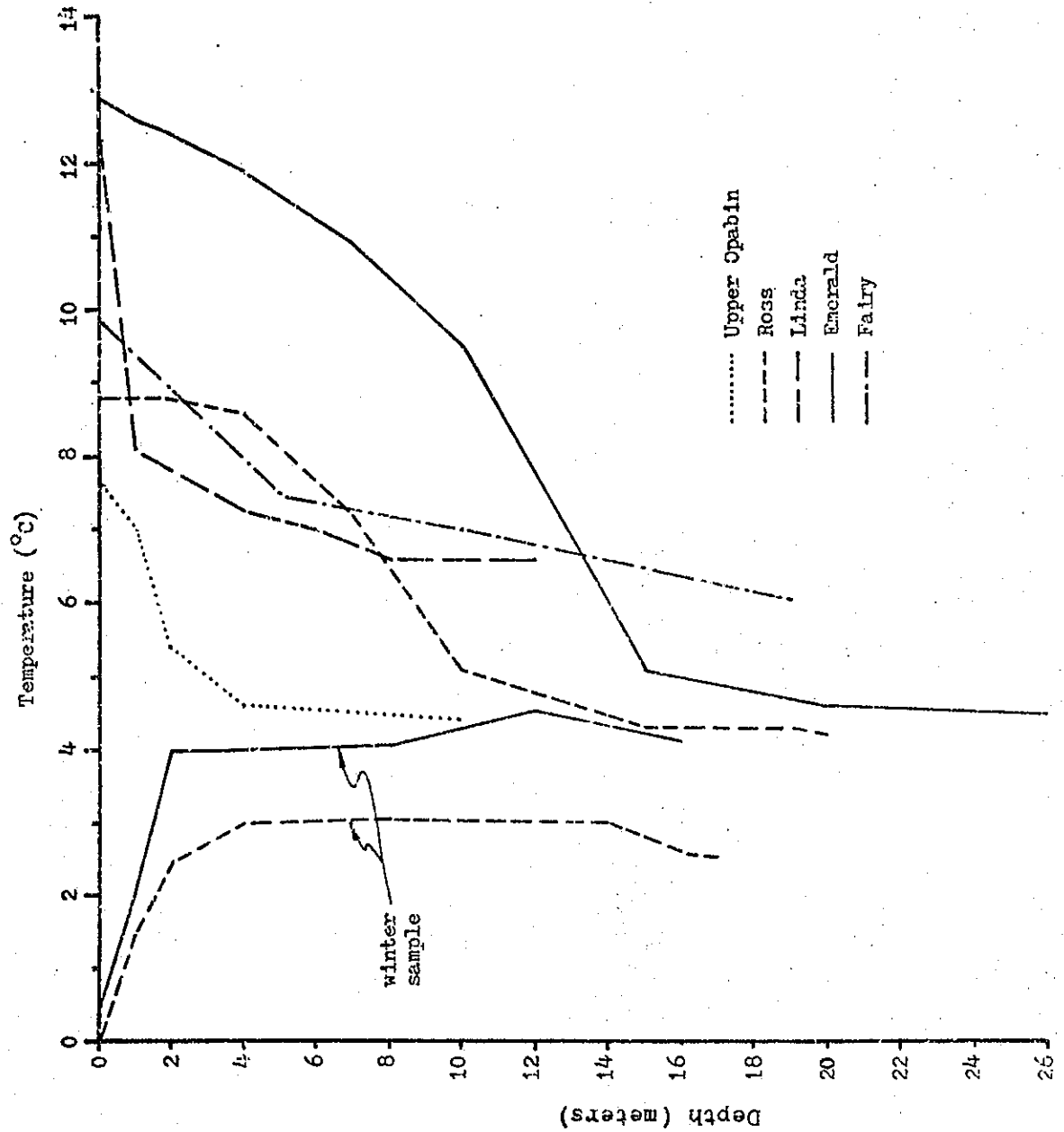
Figure 12
Temperature isopleths for Lake O'Hara during 1973-74 (°C).

Similarly, hypolimnetic water substances and many nonmotile organisms and those of limited mobility are restricted to the hypolimnion. For photosynthetic organisms this state of affairs is particularly critical. Depending on the depth of the lake, of course, photosynthesis may be inhibited in the hypolimnion. This means that oxygen available for animal respiration may be reduced, carbon dioxide increased, and microscopic algae (phytoplankton) as plant food for herbivorous animals is scarce. During autumn, a period of cooling begins and, as the lake loses heat, density differences between thermal strata become less. As thermal resistance to mixing is weakened, wind-generated currents reach ever more deeply into the lake until a period of total autumnal circulation occurs, usually when the lake waters reach 4°C in first order lakes. This circulation may not occur until midwinter in large deep lakes with high heat capacity. When cooled below 4°C the inverted stratification shown in Figure 11 may form below the ice cover and remain until spring.

Second order lakes in which summer thermal stratification occurs but hypolimnion temperatures are somewhat above 4°C are Ross, Emerald, Linda, Fairy, and Upper Opabin. All five lakes have a rather narrow summer epilimnion layer with high temperatures only in the uppermost 1-3 m and a rather constant temperature drop in the metalimnion down to a depth of 8-15 m (Figure 13). The maximum surface temperatures recorded for these lakes are:

Figure 13

Temperature profiles of second order lakes
in Yoho National Park.



Emerald	17.0
Ross	15.0
Linda	12.3
Upper Opabin	8.2
Fairy	9.8

Hypolimnion temperatures range from 4.5 for Emerald to 6.7 for Linda Lake.

Poorly defined metalimnia of the type shown in Figure 13 may be the result of late-developing stratification. Presumably this happens when a lake becomes thermally stratified just before a spell of cool weather and a deep circulating epilimnion is produced. A subsequent spell of warm and relatively calm weather may now set up a shallow thermocline in the epilimnion, which behaves as if it were a complete homeiothermal lake (Hutchinson 1957). An indication of the lateness thermal stratification may occur in the Park is found in the data from Upper Opabin Lake. This lake was found to be nearly homeiothermic on July 10, 1973 with temperatures ranging from 1.1 at the surface to 1.8°C at the bottom.

Two of these second order lakes (Emerald and Ross) have been sampled under winter conditions. Both had inverted thermal stratification when examined and Emerald appeared to maintain slightly higher temperatures in the hypolimnetic region than did Ross (Figure 13). The lower temperatures in Ross Lake may be caused by sustained autumn circulation or the relatively small volume of water actually in the hypolimnetic zone resulting in a reduced amount of heat

storage capacity for this lake. Emerald Lake, on the other hand, has a large volume of water in the hypolimnetic region resulting in the rather stable summer and winter hypolimnetic temperatures observed.

Seasonal circulation periods for these dimictic second order lakes are essentially as described for first order lakes except that autumnal circulation occurs not at 4°C but at the higher temperature of the hypolimnion characteristic of second order lakes (Figure 14).

Several of the lakes examined in the Park are of the third order type in that they are essentially unstratified during the summer. These lakes are generally homeiothermic (and thus holomictic) as a result of their shallow depth. However, this group may be subdivided on the basis of the probable cause of the homeiothermic condition.

Two third order lakes, Sherbrooke and Wapta, are fairly deep (12.0 and 8.2 m respectively) yet remain unstratified probably as a result of continuous windy conditions or high water renewal rates. Sherbrooke Lake was found to be unstratified when examined during four different summers (Schultz 1953; Anderson 1968b; present report 1971, 1973) and often had less than 2.0°C difference between bottom and surface temperatures (Figure 15).

Examination of seasonal isotherms for Wapta Lake reveals the almost vertical orientation of the isotherms (Figure 16).

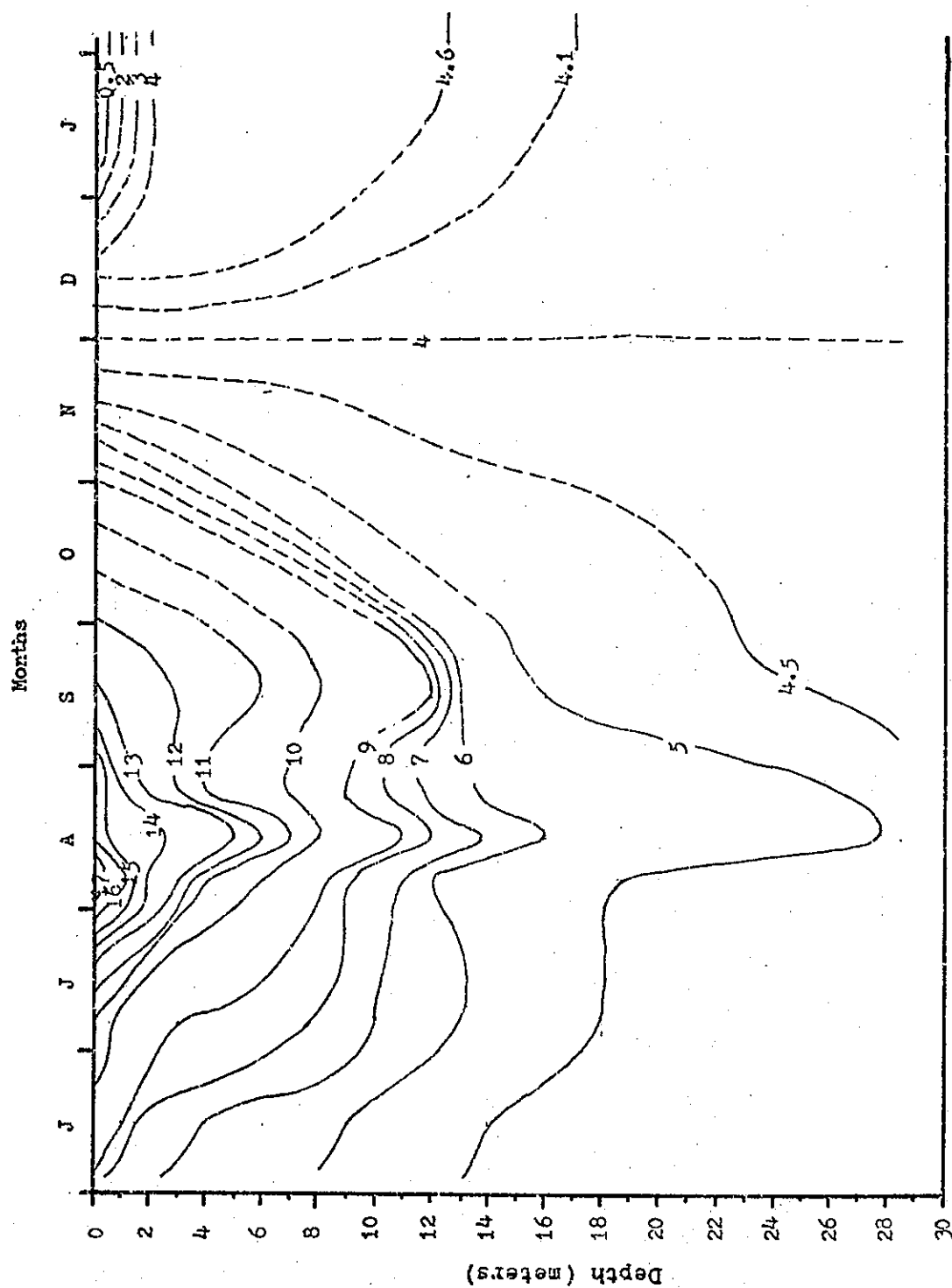


Figure 14

Temperature (°C) isopleths for Emerald Lake during 1973-74.

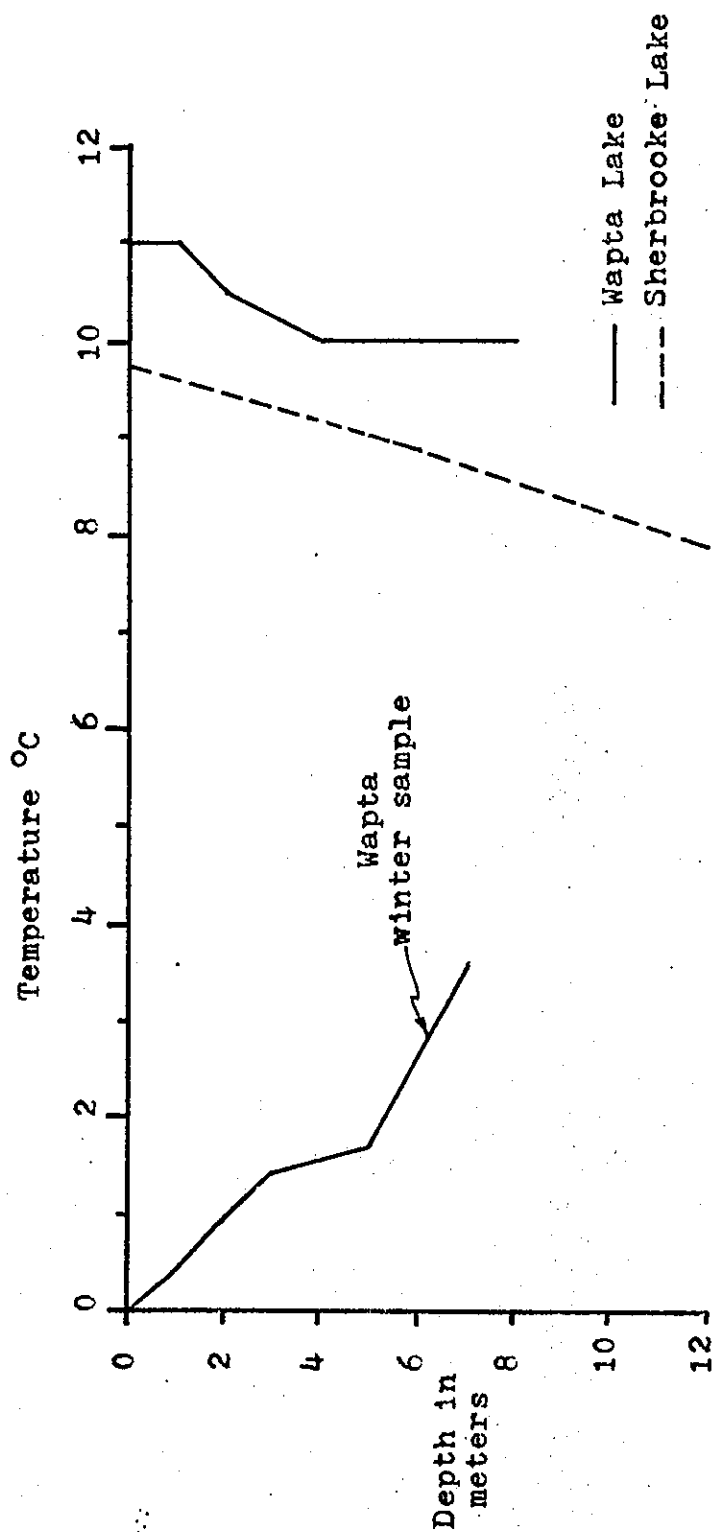


FIGURE 15

Temperature profiles of deep third order lakes in Yoho National Park.

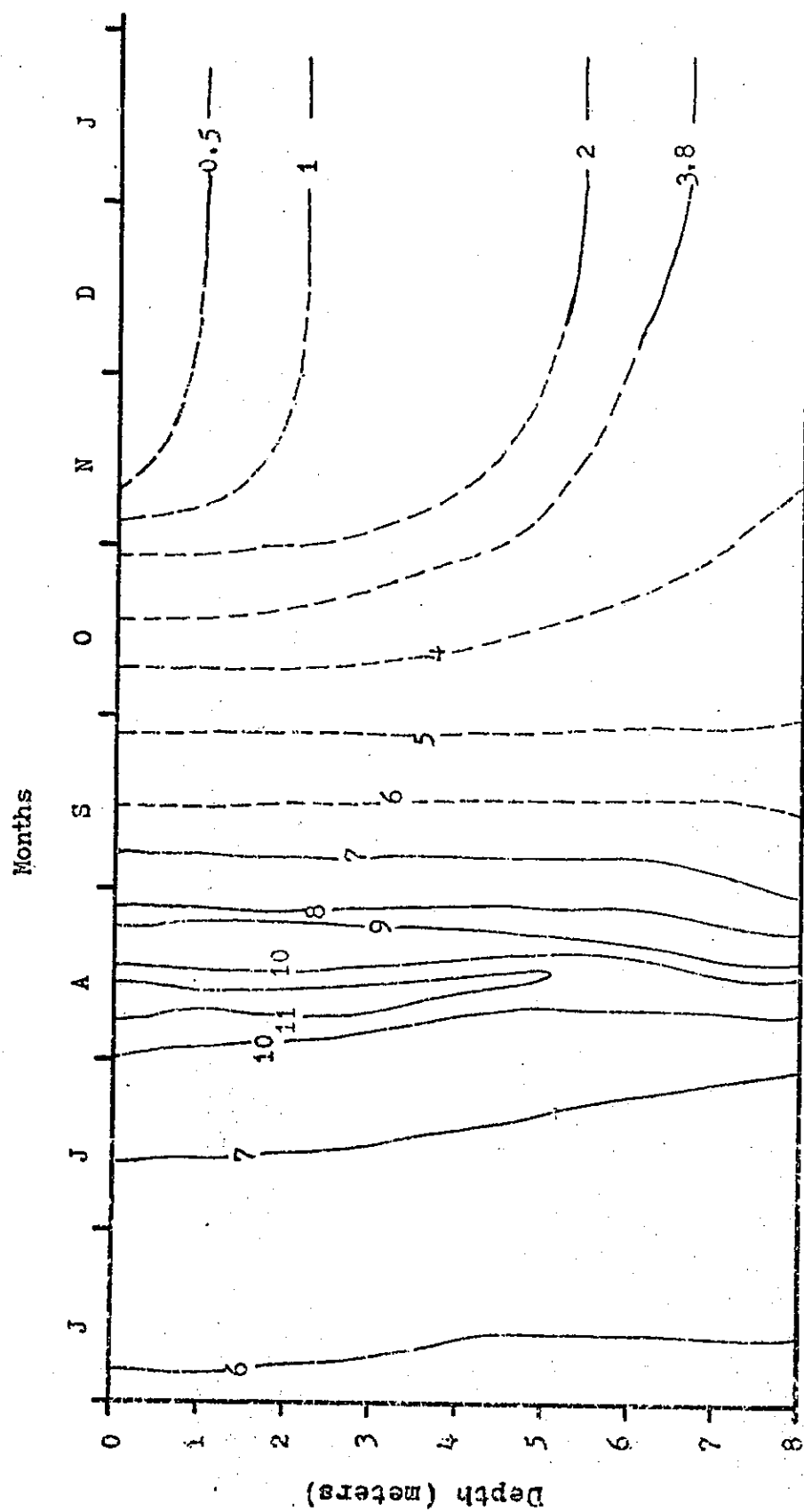


Figure 16

Temperature (°C) isopleths for Wapta Lake during 1973-74.

Windy conditions at both of these lakes during the spring and summer are the probable cause of the homeiothermic condition.

The second group of unstratified lakes includes shallow lakes and ponds such as Schaffer, Mary, South Narao, Mid Morning Glory, Upper Morning Glory, Ottertail Flats, Duchesnay, Sink, Summit, and the Lower Opabin Ponds (Figure 17). These lakes appear to fit into the polymictic group of Schindler (1971) which are shallow north temperature lakes which may stratify by heating during the day, then mix completely during nighttime cooling.

Winter sampling at Wapta Lake indicates an inverted stratification occurs under the ice with temperatures ranging from 0.0 at the surface to 3.5°C at the bottom when examined on January 3, 1974 (figure 15). All of the shallow (under 2 m) third order lakes probably become frozen solid during most winters while the others probably have temperatures close to 0°C as a result of their low heat storage capacity.

Streams. Thermal stratification is not a general characteristic of most streams because of their turbulence and shallow nature. When stream waters do stratify the process usually takes place in pools along the stream course. In general streams are more affected by short term environmental changes than are lakes or ponds. A major factor in the warming of stream waters is direct solar

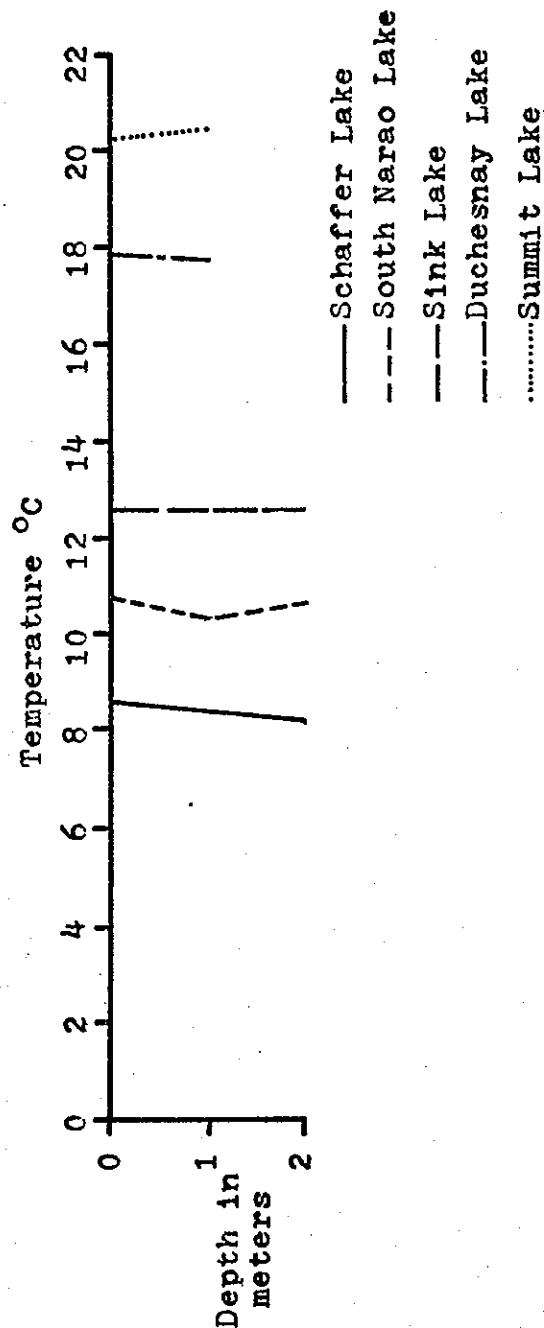


FIGURE 17

Temperature profiles of shallow third order

lakes in Yoho National Park.

radiation. A series of temperature curves recorded over several successive days of cloudless skies followed by an overcast day will show rather regular fluctuations from late afternoon maxima to early morning minima during the cloudless period, but the cloudy-day curve will be flattened (Reid 1961). Smith (1972) found the temperature of the Kicking Horse River in the Field reach fluctuated over a 4°C range from 1200 to 1500 hours when examined during August (Figure 9). Similar diurnal fluctuations at other stream sites are to be expected. With respect to size and water temperature fluctuations, a smaller stream will have greater temperature variation and more rapid response to environmental changes. Winter temperatures in streams which maintain a flow are undoubtedly close to 0.0 while maximum summer temperatures were found to be as high as 15.0°C in the upper reaches of the Kicking Horse River. Temperatures of the major streams in the Park are presented in Table 4.

Secchi Disc Visibility

Excluding shallow lakes where depth is the limiting factor Secchi disc visibility ranged from 1.0 m at Emerald Lake to over 12.0 m at Ross Lake (Table 5). In general Secchi disc visibility was lowest in those lakes such as Emerald, Sherbrooke, Oesa, Upper Opabin, and McArthur which are fed directly by glacial meltwater. These lakes had a mean visibility of 3.7 m. Secchi disc visibility was highest (mean of 7.7 m) in lakes such as Ross, Wapta, O'Hara,

Table 4. Summary of stream temperatures in Yoho National Park during 1973.

Site	Date	Temperature °C
102	19/IV	5.4
	28/VIII	7.8
104	19/VI	7.2
	10/IX	8.8
106	7/VIII	7.5
107	20/VI	4.0
108	19/VI	7.2
111	13/VI	7.8
112	13/VI	10.0
113	18/VI	6.2
114	10/VIII	9.4
118	12/VIII	9.8
119	18/VI	5.7
121	4/VII	5.0
	10/IX	7.5
122	4/VII	7.5
125	12/VI	6.2
126	6/VI	3.5
127	6/VI	3.5
128	8/VI	3.5
130	6/VI	3.0
132	5/VII	3.0
133	5/VII	2.8
134	8/VI	5.0

Table 5. Summary of Secchi disc visibility values (m)
for lakes in Yoho National Park.

Lake No.	Lake name	Date Day/Mo./Year	Secchi depth	Lake No.	Lake name	Date Day/Mo./Year	Secchi depth
6	Ottertail	6/8/74	1.5+	22	Mld Morn. Glory	8/7/70 12/7/73	2.5+ 3.0+
7	Schaffer	6/8/66 23/8/73	2.5+ 2.5+	23	Upr Morn. Glory	8/7/70 12/7/73	4.0+ 4.5
8	McArthur	6/8/66 10/8/72 23/8/73 7/8/74	8.2 12.0 6.1 12.5	24	Linda	8/7/70 12/7/73	12.0+ 11.0+
9	O'Hara	29/6/66 23/8/66 31/7/68 14/7/72 10/8/72 11/7/73 28/8/73	5.0 7.2 8.2 3.0 8.5 6.8 4.2	25	Vera	3/9/53	5.5+
				26	Emerald	5/7/66 23/8/66 17/6/71 4/8/71 10/9/73	3.0 3.1 2.0 1.0 5.2
10	Mary	8/7/70 6/7/73 11/7/73	3.5+ 3.5+ 3.5+	28	Ptarmigan	9/9/69	2.0+
11	Opabin	8/7/70	1.4+	29	Crystal	9/9/69	2.0+
12	Victoria	5/8/66	4.5+	31	Little Gem	9/9/69	5.8
13	Opabin	31/7/68 10/7/73	1.5+ 1.5+	35	Otto	9/9/69	6.4+
14	Opabin	6/8/66 31/7/68 10/7/73	2.7+ 2.7+ 2.7+	37	Kiwetinok	9/9/69	5.0
15	Opabin	6/8/66 31/7/68 10/7/73	2.0 2.0 3.0	38	Hamilton	9/9/69	10.0
15A	Opabin	10/7/73	1.2+	41	Celeste	9/9/69	5.7+
16	Oesa	5/8/66 21/8/73	6.0 3.5	42	Duchesnay	12/8/70 14/8/73	1.0+ 1.1+
17	Ross	18/6/71 5/8/71 13/6/73	12.0 12.5 10.0	43	Yoho	12/8/70	12.0+
18	South Narao	9/7/70 14/6/73 29/8/73	6.3+ 2.5+ 2.5+	44	Hidden	12/8/70	5.0
19	North Narao	9/7/70 14/6/73 29/7/73	1.2+ 1.2+ 1.2+	44E	Nr. Hidden	12/8/70	1.0+
20	Wapta	5/7/66 23/8/66 17/6/71 4/8/71 12/6/73	5.0+ 8.0+ 8.0+ 4.0 8.0+	47	Sherbrooke	5/7/66 5/8/66 11/7/71 13/7/73	2.0 0.75 3.5 2.2
21	Lwr Morn. Glory	8/7/70	3.5+	48	Sink	17/6/71 5/8/71 5/6/73	2.0+ 2.0+ 2.0+
				49	Summit	7/7/70 1/6/73 30/7/73	1.2+ 1.2+ 1.2+
				50	Fairy	9/9/69	7.0
				51	Waves	9/9/69	2.4
				55	Amiskwi	9/9/69	2.5
				61	Indigo	9/9/69	14.0

and Upper Morning Glory which are not directly fed by glacial meltwater.

Schindler (1971) found Secchi disc visibility (S) was related to light transmittance (T) by the equation

$$T = 0.055S + 0.172$$

with a correlation coefficient of 0.92 for lakes in the Experimental Lakes Area of Ontario. Figure 18 illustrates the relationship between photosynthetically useful light transmittance and Secchi disc visibility. As a general rule about 5% of surface light is available at depths of Secchi disappearance (Reid 1961). Similar results were obtained by Anderson (1974b) at Patricia Lake and Herbert Lake. Regression analysis of the light penetration data from depths of 1 and 4 m accurately predicted observed Secchi disc visibility in these two lakes (Figure 19). Use of Secchi disc visibility as an estimate of the depth of the euphotic zone has several limitations such as the selective absorption of different wavelengths of light and the potential error introduced when light is reflected from the bottom.

Climate

Mountainous terrain causes weather conditions to vary greatly within the Park and rapid changes are not uncommon. Temperatures during the 1973 collecting period (Figure 20) were above average while precipitation was below the ten year average (Table 6). The warmest months are July and

Figure 18

The relationship between light transmission per meter and Secchi disc visibility for several lakes in the Experimental Lakes Area, Ontario.

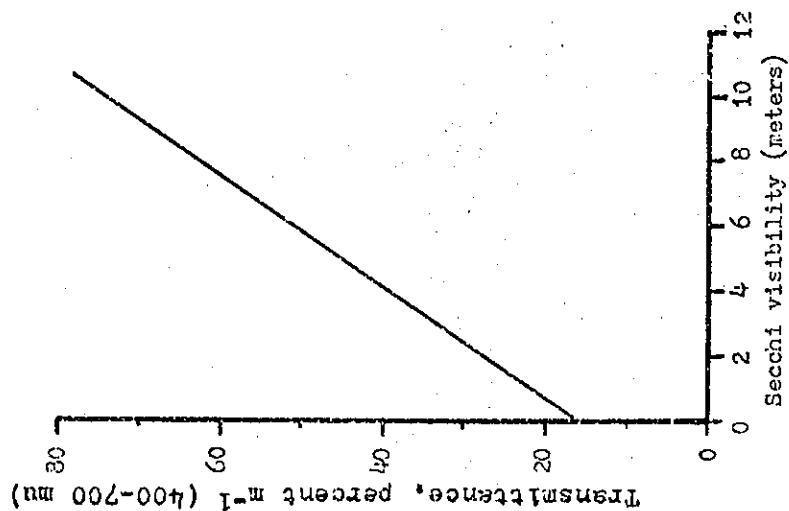
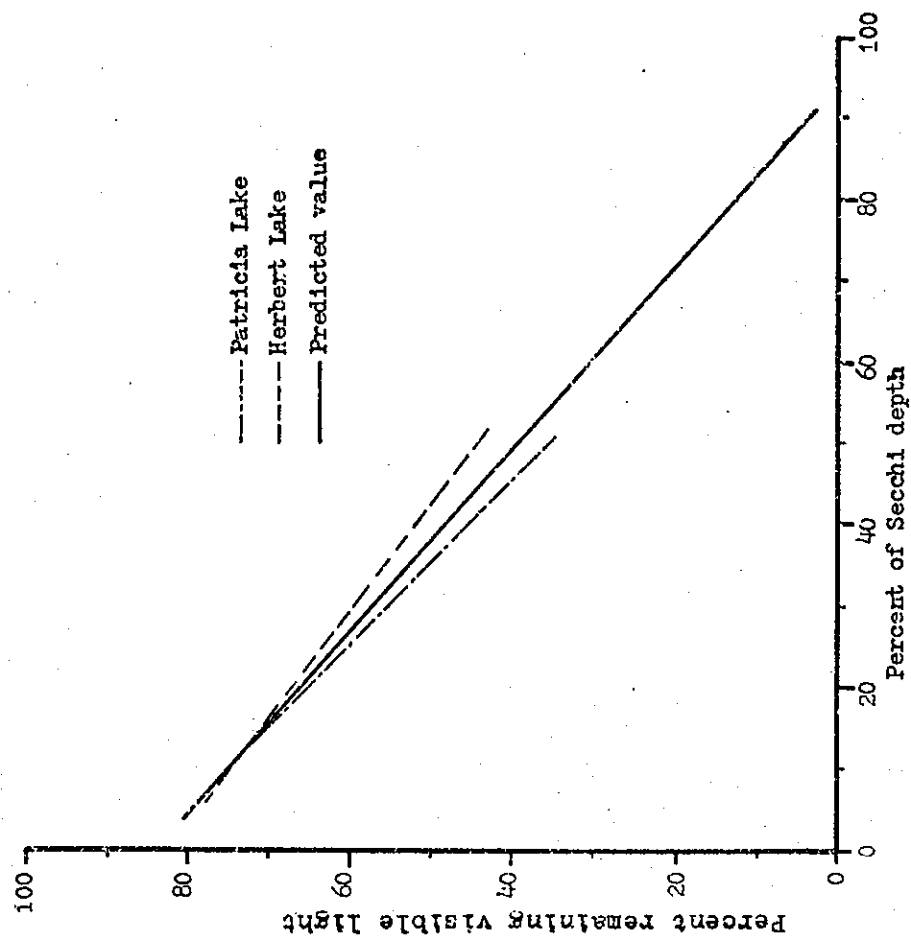


Figure 19

Calculated remaining visible light as a percent of Secchi disc disappearance in Patricia Lake and Herbert Lake.



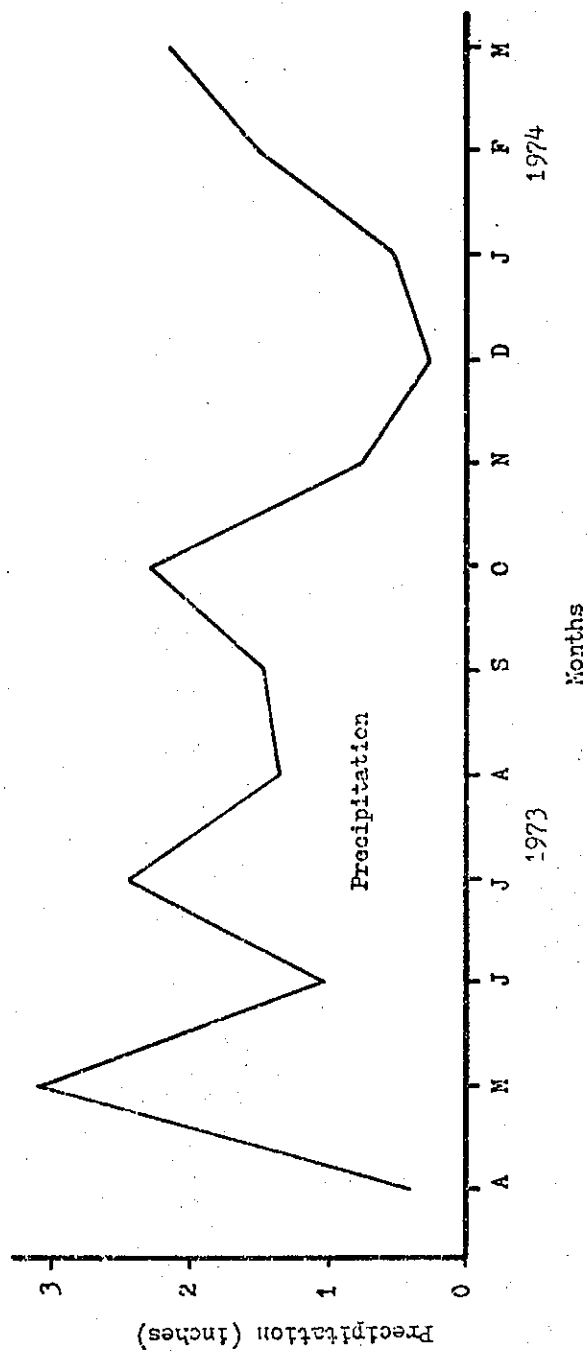
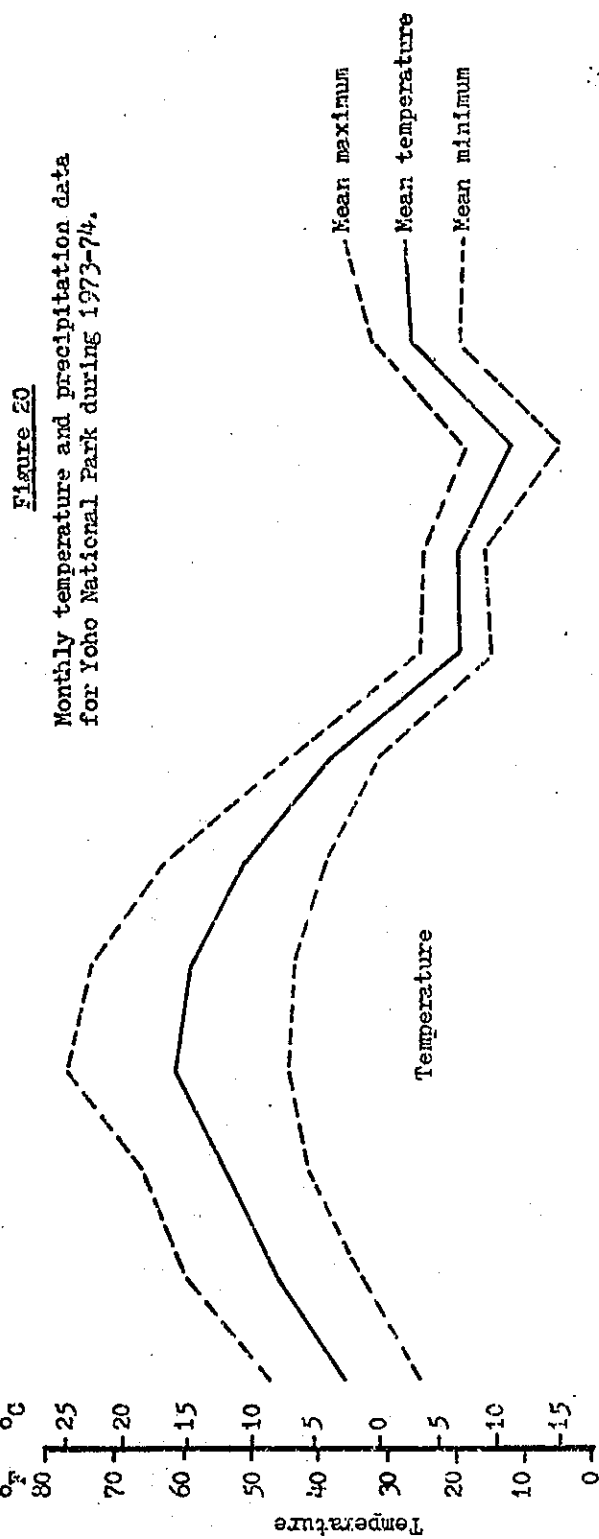


Table 6. Ten year (1962-1971) temperature and precipitation levels for Yoho National Park.

Month	Mean temperature °C		Precipitation (mm)	
	minimum	maximum	rain	snow
January	-12.5	-7.5		741
February	-10.0	0.0		266
March	-5.5	4.8		203
April	-3.8	9.5		50
May	2.0	15.0	44	
June	6.0	19.0	67	
July	7.0	21.4	90	
August	6.5	22.0	50	
September	2.2	16.0	49	
October	-0.5	9.0		121
November	-7.2	2.0		381
December	-12.2	-7.7		563

August with mean temperatures ranging from 7 to 22°C while the coldest month is January with a range of -12.5 to -7.5°C.

Pyrheliometer recordings taken between July 5 and August 27, 1973, indicate skies are generally clear in the morning with increasing clouds in the afternoon (Figure 21).

Figure 21. Pyrheliometer recordings in Yoho National Park during July 6-August 28, 1973. Recorder was located at Boulder Creek maintenance compound.

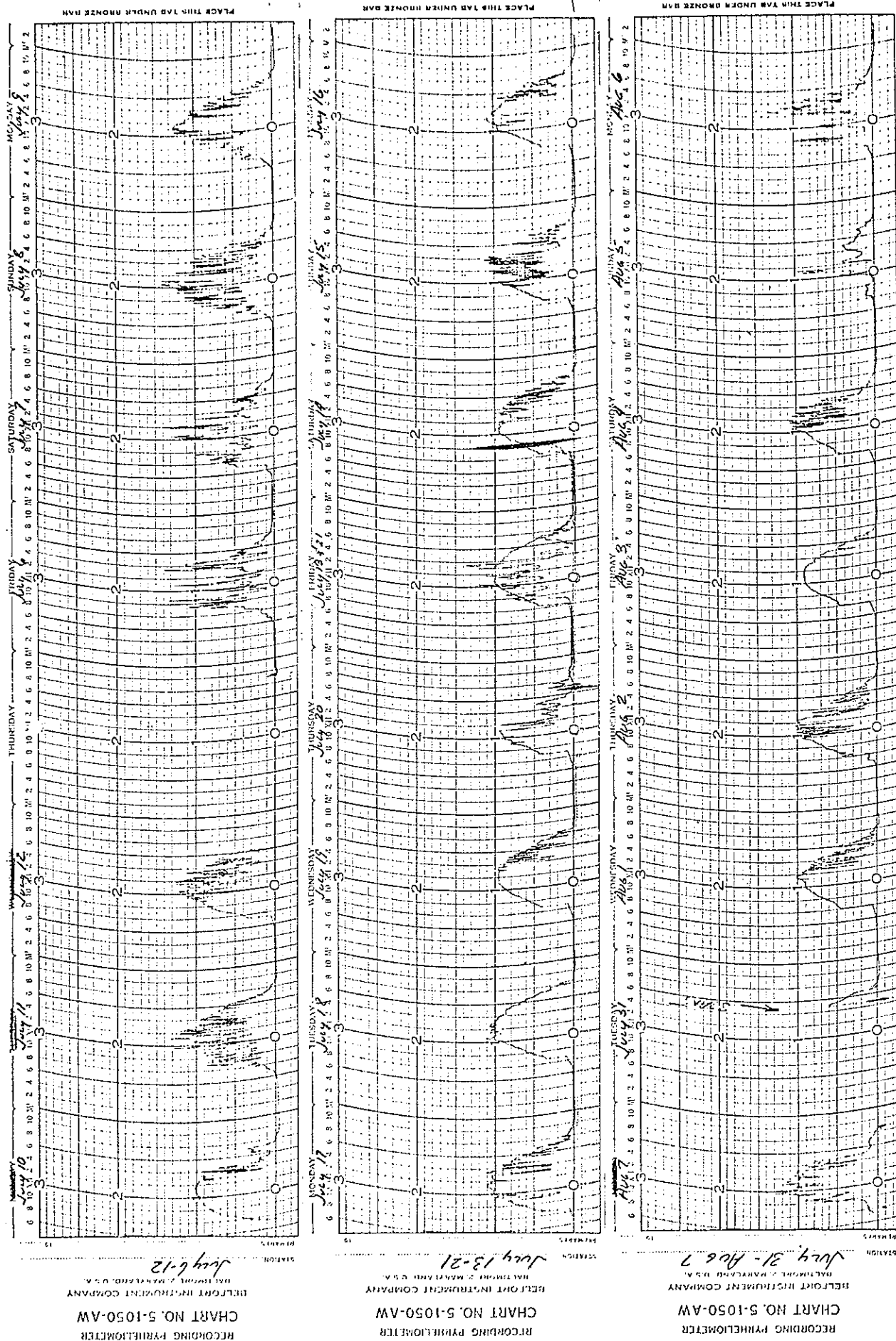
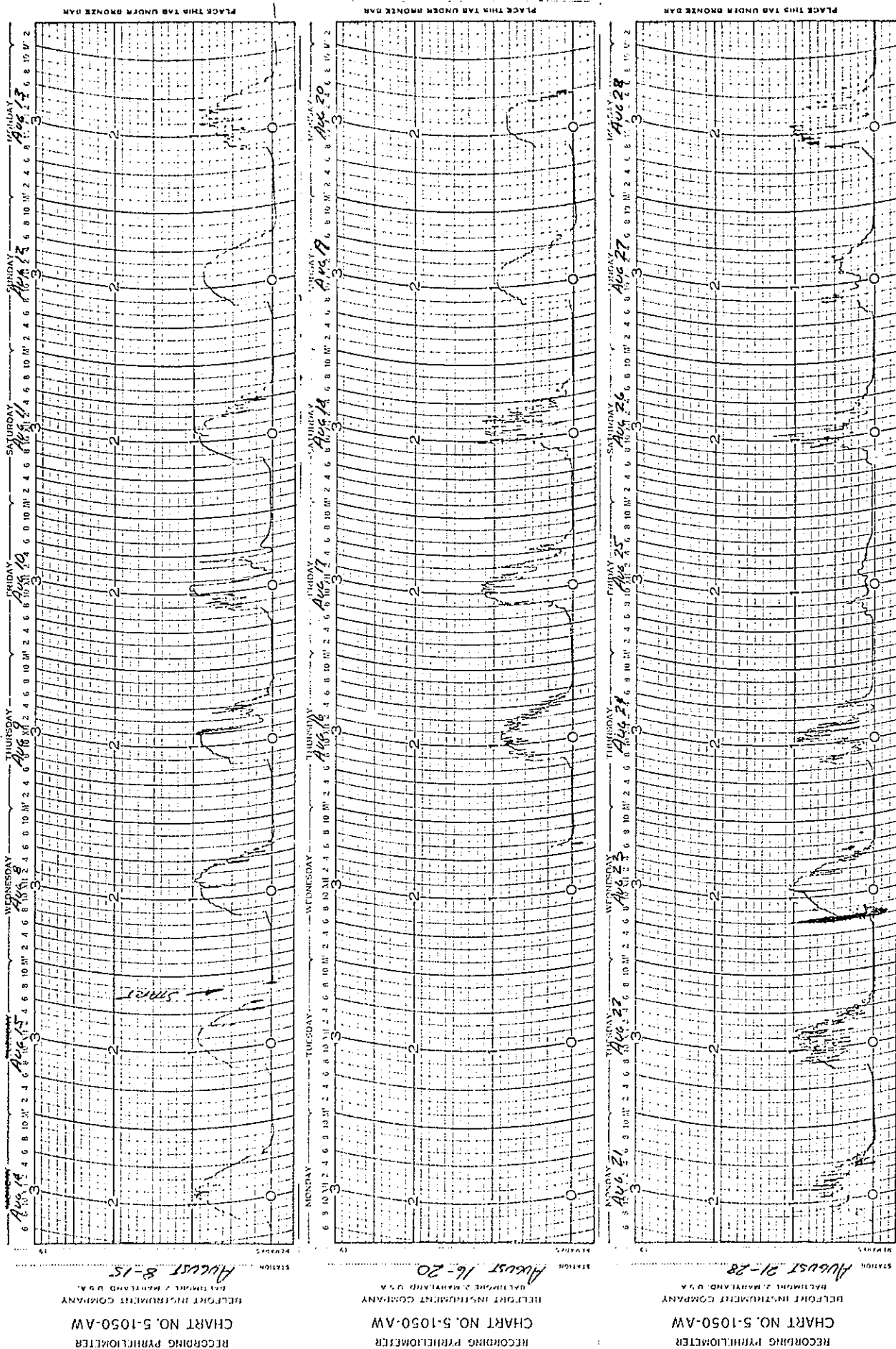


Figure 21. --Cont'd.



CHEMICAL LIMNOLOGY

Introduction

Although the number of elemental substances numbers well over 100 only about forty elements commonly combine to form organic matter. The carbohydrates, fats, and proteins which make up all living organisms are constituted from about twenty elements which can be considered essential. On a dry weight basis, only five elements (a) are present in the organic tissue of the majority of living organisms at levels greater than 1 per cent. These carbon, oxygen, hydrogen, nitrogen, and phosphorus, in that order. At levels ranging from 1 in 2000 to 1 in 100 we have eight more elements (b): sulfur, chlorine, potassium, sodium, calcium, magnesium, iron, and copper. Finally, at levels normally amounting to less than 1 in 2000 parts of the dry organic weight, but still apparently essential, are seven more elements (c): boron, manganese, zinc, silicon, cobalt, iodine, and fluorine (Russell-Hunter 1970). To recapitulate, ranked in these groups by their fractional weights, we have:

(a) C, O, H, N, P,

(b) S, Cl, K, Na, Ca, Mg, Fe, Cu,

(c) B, Mn, Zn, Si, Co, I, F.

Considering the usual availability of carbon dioxide and water (C, O, and H), it is obvious why the limiting nutrient salts for aquatic productivity are often the assimilable forms

of the two remaining primary constituent elements: nitrates and phosphates. In most fresh waters, all of the elements of the second and third groups require a considerable concentration by primary producers from the low levels which occur naturally in the environment. The availability of suitable salts of many of these elements can create limiting conditions for productivity.

Rigler (1974) has described the general relationship between nutrients and plant productivity as follows:

"The link between nutrients and primary productivity in temperate lakes is now firmly welded. It appears that if the supply of phosphorus is increased, the primary productivity and the biomass of phytoplankton will be increased. Although nitrogen is another scarce element, it is normally available in amounts exceeding the minimum requirements of phytoplankton. An exception to this rule is found in lakes enriched with human wastes. In these the ratio of N:P is sometimes low enough that production is stimulated by additional quantities of nitrogen instead of phosphorus. Yet another situation is found in lakes of granitic regions. These lakes have a low Ca^{++} content and consequently an exceedingly small CO_2 reservoir. If they are enriched artificially with phosphorus, inorganic carbon can become the substance in shortest supply. Less commonly we find lakes in which productivity is stimulated by the addition of one, or another trace element. In summary, we know that the supply of nutrients determines the productivity of temperate lakes, and that most frequently phosphorus is the substance in shortest supply."

Factors affecting water chemistry.

Precipitation. The waters of Yoho National Park have their origin as precipitation in the form of snow and rain. Snow and rainwater contain minute but significant amounts of dissolved gasses and solids which contribute to the general chemical nature of the resulting water bodies. A number of workers (see Hutchinson 1957 for review) have attempted to characterize the

chemistry of precipitation. In general it appears the ionic composition of rainwater resembles the ionic ratios found in seawater with absolute quantities varying with the distance from the sea. Table 7 presents data from Hutchinson (1957) and Armstrong and Schindler (1971) on observed values of cation composition of rainwater and gives some indication of the range of values which may be encountered.

Small water bodies which result primarily from melt water would be expected to have water chemistry not greatly different from snow. Second (No. 14) and third (No. 13) Opabin Ponds appear to be two such meltwater ponds. The catchment area for these two ponds is relatively small with no permanent influent streams. Table 7 contains water chemistry data from these two ponds for comparison with that of rainwater.

Geology. Concentration of major ions in surface runoff water is higher than in precipitation because of decomposition and solution processes in soils, glacial drift minerals, and exposed bedrock. For this reason most of the water bodies in the Park exhibit water chemistry characteristics which are different from precipitation and instead reflect the type of geology in which the watershed lies. The main patterns of bedrock geology in the Park are shown in Figure 22 (from maps prepared by J.C. Sproule & Assoc.). The rocks of the Park are of sedimentary origin with relatively soluble dolomitic limestone present throughout most areas. The relatively insoluble rock quartzite (silica fused sandstone) is found in the head-water region of

Table 7. Average dissolved major cations (mg l^{-1}) of rainfall in the Experimental Lakes Area and "English Lakes District" and in water samples from Mid and Lower Opabin Ponds, Yoho National Park. Supplementary data are from Armstrong and Schindler (1971) and Hutchinson (1957).

Cation	Experimental lakes area	English lakes district	Opabin Pond (13)	Opabin Pond (14)
Ca	0.1	0.2	1.0	2.0
Mg	0.1	0.3	0.3	0.5
Na	0.22	1.9	0.1	0.2
K	0.09	0.2	0.1	0.1

[illegible]

Cataract Brook. Figure 23 illustrates the main products expected from the weathering and dissolution of several geological types.

Dissolved gases.

Oxygen. The main sources of oxygen in natural waters are the atmosphere and plant respiration while major consumption of oxygen is in animal and plant respiration and organic decomposition. Measurements of oxygen levels in Park waters have been conducted only at Emerald, Wapta and O'Hara lakes (Anderson 1968b). These measurements, together with some made in other mountain parks (Anderson 1970e,g), give some indication of normal summer oxygen levels in lakes (Figure 24).

In thermally stratified (first and second order) lakes the epilimnetic layer normally has oxygen levels near saturation with lower levels in the hypolimnetic layer. Oxygen measurements in Emerald and O'Hara down to 14 m (epilimnion and metalimnion) indicates oxygen levels in the upper layers are rather uniform at about 10 ppm (90% saturation). The more intensive studies on Celestine and Patricia lakes (JNP) indicate the oxygen saturation levels of these second order lakes ranged from 60 down to 10% or lower in the hypolimnion (Anderson 1970e). Similar values are to be expected in the hypolimnion of Emerald and O'Hara as well as the Park's other first and second order lakes (Ross, Linda, Upper Opabin, Fairy, Oesa, and McArthur).

Anderson (1968b) found Wapta Lake had uniform oxygen levels

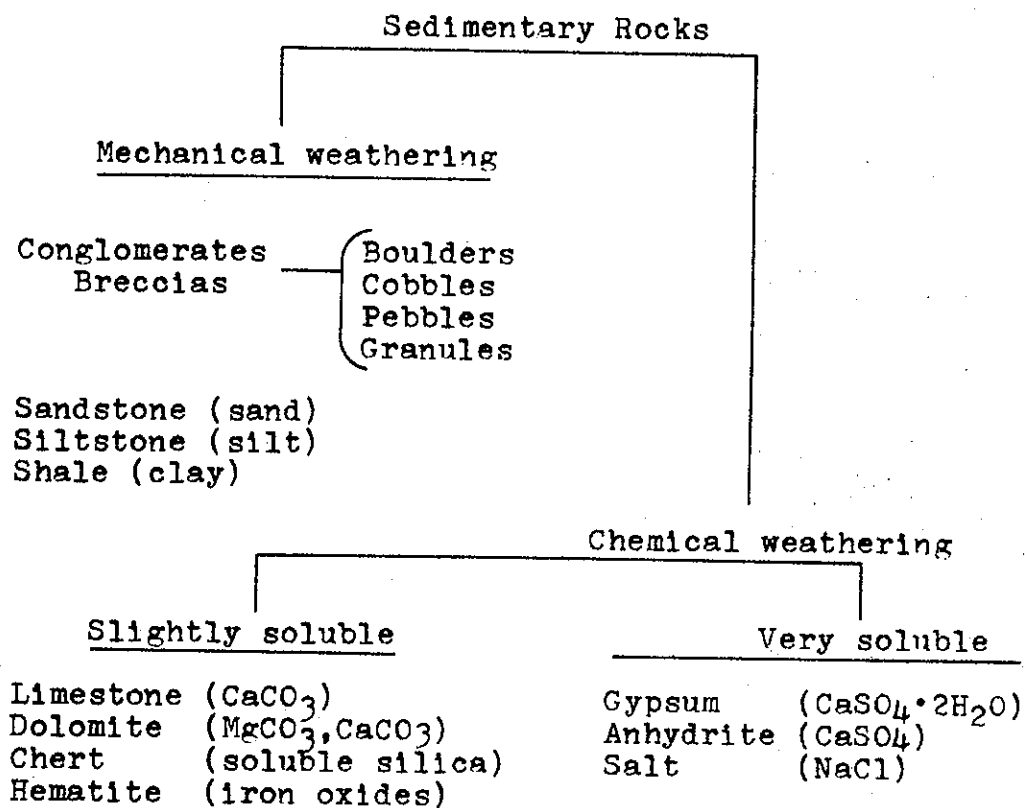


Figure 23

Main products expected from weathering and dissolution of sedimentary types of bedrock (from Branson, Tarr, and Keller 1952).

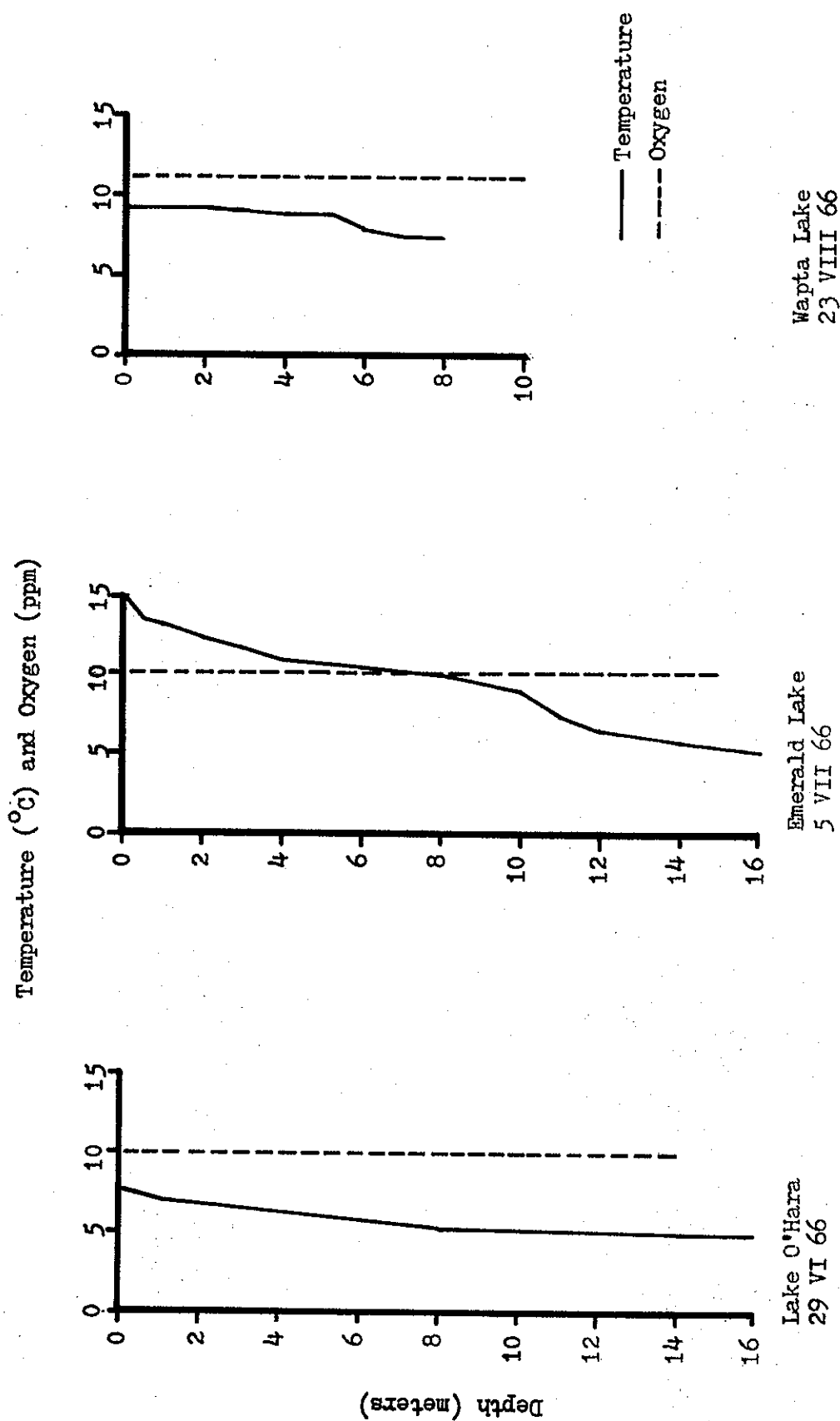


Figure 24

Normal summer oxygen levels in O'Hara, Emerald, and Wapta lakes.

from surface to bottom at about 11 ppm (95% saturation). These values are consistent with the holomictic (third order) nature of this lake and are to be expected in the other unstratified or polymictic lakes such as Sherbrooke, Shaffer, South Narao, Sink, Duchesnay, and Summit.

Winter oxygen measurements have not been conducted in the Park however data from two second order lakes (Snowflake and Herbert) in BNP indicate that oxygen levels beneath the ice could be expected to remain between 70-80% saturation in the upper layers and around 10% saturation in the lower layers (Anderson 1970g). This is especially true for those oligotrophic lakes with little plant growth where O_2 concentration may never drop below 50%, even at the bottom. Shallower lakes or lakes with abundant plant growth (mostly third order) such as Sink, Summit, North Narao, Shaffer, Lower Opabin Ponds (No. 13 and 14), and Duchesnay would be expected to show oxygen depletion in winter as a result of the decomposition of organic matter. Plants producing oxygen through photosynthesis during the summer would contribute to the oxygen debt of the lake during the nonphotosynthetic period of the winter. Evidence of anaerobic winter conditions at Sink, Summit, and North Narao was the odor of H_2S encountered when penetrating the ice for winter sampling.

Oxygen concentrations have not been determined for Park streams. Other studies (Mayhood and Smith 1972, Robinson and

Smith 1974) indicate oxygen levels in streams near Lake Louise (BNP) are usually near saturation (10-13 ppm). A similar condition would be expected to exist in the Park where most streams are of a turbulent nature and many are torrential. Beaverfoot River appears to be the only stream where a low gradient (Table 2) may produce laminar flow and reduce the amount of physical aeration.

Carbon dioxide, bicarbonate, and pH. Carbon dioxide in natural waters is derived from a number of sources. Bacterial decomposition of organic matter and respiration by animals and plants contribute to the concentration of carbon dioxide. In the case of plants the greatest net contribution occurs at night, when there is no light for photosynthesis. Ground waters flowing or seeping into lakes and streams may carry carbon dioxide, the amount being determined by the extent of decomposition in the topsoil and by the nature of the underlying bedrock. Finally, the atmosphere directly furnishes some carbon dioxide to natural waters.

Carbon dioxide is an important component of the water in that it acts as a "buffer" against rapid changes in pH, helps in the regulation of biological processes in aquatic communities, and is a source of carbon for the formation of biologically important compounds (Reid 1961).

Dissolved carbon dioxide is found in three states:

1. "free" i.e. CO_2 in solution plus carbonic acid (H_2CO_3)
2. "half-bound" i.e. bicarbonate (HCO_3^-)
3. "bound" i.e. carbonate ($\text{CO}_3^{=}$).

When carbon dioxide dissolves, the reaction and end products depend upon the nature of the solvent, particularly with relation to the hydrogen-ion concentration (or pH). The proportion of CO_2 , HCO_3^- , and $\text{CO}_3^{=}$ present at different pH levels is illustrated in Figure 25.

To summarize the activities of carbon dioxide and bicarbonate in relation to pH in lakes and streams: (1) the pH value varies inversely as the dissolved carbon dioxide concentration, and directly as the bicarbonate concentration; (2) the critical value relating to the presence or absence of free CO_2 is pH 8, the free gas being absent above that value. The absence of free CO_2 does not limit photosynthesis by certain algae and higher plants, some being adapted for utilization of CO_2 from carbonates, a process which usually results in very high pH values (Reid 1961).

Newly formed lakes in regions of weakly soluble rocks typically contain little carbon dioxide in any form. In these situations the low quantity of carbonates in the substrate results in little of the bound ($\text{CO}_3^{=}$) or half-bound (HCO_3^-) forms of CO_2 . Two Park lakes which lie in the relatively insoluble quartzite region and which appear to be of this type are the Lower Opabin

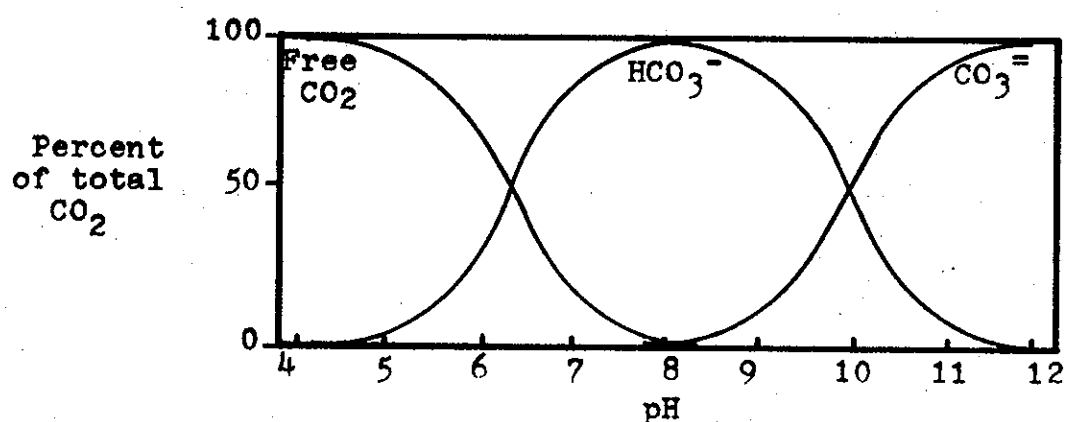


Figure 25

The relationship of Hydrogen ion concentration to the percentage of total Carbon Dioxide in each of its forms in water.

ponds (No.13 and 14). The small drainage areas of these lakes contributes to the paucity of soluble minerals as nutrients for biological processes and further inhibits the development of large biotic populations that would contribute carbon dioxide through respiration. These lakes exhibit the lowest pH found in the Park at 6.9 and 7.1 respectively. These pH levels indicate most dissolved CO_2 would be in the form of HCO_3^- with a small amount in the form of unbound CO_2 (from Figure 25) however none was detected due to the very low levels present. The (carbonate) hardness of these lakes (Table 8), at 3.6 and 7.1 ppm respectively, places them in the "very soft water" group of Thomas (1953).

Although pH values ranged from 6.9 - 9.35 most of the lakes in the Park fall into a group in which the pH ranges from 7.5 - 8.2 and may be called soft and medium water lakes (Table 8). In these lakes the CO_2 exists mainly in the form of HCO_3^- and total hardness ranges from 25-124 ppm. Within this group those lakes which are associated with quartzite areas have a lower pH and hardness as compared with those which lie in dolomitic limestone ($\text{CaMg}(\text{CO}_3)_2$) areas (Figure 22).

Duchesnay Lake has the highest pH at 9.35 and as expected from Figure 25 is the only one which exhibits an appreciable amount of carbonate ($\text{CO}_3^{=}$) at 6.8 ppm.

A few lakes in the Park can be considered the hard water type of Thomas (1953). These are Amiskwi, Fairy, Summit, Yoho,

Table 8. Summary of water chemistry data for lakes in Yoho National Park.
Units as follows: conductivity in umho cm⁻¹; turbidity in J.T.U.;
pH in pH units; all others as ppm.

Constituent	Site	6	8	9	10	13	14	15	15A	16	17	18	19	20	22	23	24	26
Conductivity		282.0	120.0	86.5	82.7	15.0	16.0	52.3	73.0	97.0	199.0	234.6	211.0	160.0	125.0	127.0	172.0	211.0
Turbidity		-	4.3	1.0	0.8	1.5	0.5	1.9	1.2	0.7	0.7	0.8	0.8	0.9	0.9	1.0	0.7	1.6
pH		-	8.0	7.8	8.1	7.1	6.9	7.7	7.8	7.9	8.2	8.3	8.4	8.1	8.2	8.2	8.1	8.1
Total alkalinity		-	52.0	35.5	29.0	1.0	3.0	20.4	29.0	44.8	94.7	119.0	102.0	71.9	62.0	63.0	75.9	100.7
Hardness		-	60.5	44.6	40.9	3.6	7.1	25.4	38.0	50.4	107.0	124.6	110.5	81.6	67.0	69.0	89.1	109.8
Calcium		-	16.6	11.7	8.6	1.0	2.0	5.9	8.3	14.9	28.1	38.0	33.2	21.4	20.0	20.0	27.0	28.7
Magnesium		-	4.6	3.7	4.7	0.3	0.5	2.5	4.2	3.2	8.9	6.9	6.7	6.8	4.1	4.6	5.2	9.7
Potassium		-	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.2
Sodium		-	0.13	0.17	0.15	0.1	0.2	0.3	0.1	0.25	0.3	0.36	0.4	0.16	0.4	0.4	0.4	0.32
Bicarbonate		-	65.6	43.4	35.0	1.2	4.0	24.9	35.4	54.6	115.4	144.6	123.1	87.5	75.6	76.8	92.5	117.0
Chloride		-	0.23	0.22	0.1	0.2	0.0	0.1	0.1	0.55	0.56	0.3	0.45	0.4	0.1	0.1	0.15	0.26
Nitrogen		-	0.06	0.45	0.04	0.06	0.02	0.09	0.09	0.3	0.12	0.04	0.08	0.05	0.1	0.1	0.2	0.16
Silica		-	1.5	2.9	1.7	0.6	1.4	15.6	1.4	1.4	2.6	3.2	2.0	2.7	2.1	2.1	2.3	2.3
Sulphate		-	6.2	9.4	13.1	1.1	2.4	7.7	15.0	5.1	9.5	4.0	6.1	8.9	5.1	4.9	10.9	10.2
Carbon dioxide		-	1.0	1.4	0.2	-	-	1.5	-	0.8	1.0	1.0	0.7	2.0	-	-	0.9	1.4
Total diss. solids		-	62.2	50.3	46.0	4.0	9.0	31.0	47.0	52.8	107.4	125.0	110.5	84.3	70.0	71.0	92.2	112.6

Table 8. -cont'd.

Constituent	Site	28	29	31	35	37	38	41	42	43	47	48	49	50	51	55	61	Mean
Conductivity		146.0	120.0	158.0	128.0	108.0	138.0	126.0	126.5	228.0	178.3	217.0	242.0	265.0	41.0	303.0	140.0	145.5
Turbidity		-	1.4	1.1	0.5	1.1	0.7	1.0	1.5	0.6	4.3	1.7	1.5	6.0	-	2.4	0.6	1.4
pH		8.2	8.1	8.2	8.3	8.2	8.2	8.1	9.3	8.4	8.2	8.1	8.3	8.0	8.3	8.1	8.2	8.1
Total alkalinity		55.0	57.7	67.4	59.5	49.2	67.0	67.5	55.6	111.0	81.7	102.5	110.0	64.0	27.0	77.7	63.6	62.8
Hardness		77.0	60.7	80.6	62.6	53.8	70.8	75.0	62.9	123.0	90.9	112.0	122.0	130.0	29.0	150.0	72.0	75.0
Calcium		-	23.5	15.7	17.9	13.6	19.3	16.5	11.8	29.8	22.0	28.7	32.7	34.0	-	38.4	18.7	20.2
Magnesium		-	0.5	10.1	4.4	4.8	5.5	8.2	8.1	11.8	8.8	9.7	9.8	11.0	-	13.2	6.2	6.3
Potassium		-	0.1	0.2	0.0	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.5	0.3	-	0.3	0.1	0.16
Sodium		-	0.3	0.6	0.1	0.1	0.3	0.4	0.25	0.4	0.36	0.25	1.2	0.4	-	0.3	0.1	0.3
Bicarbonate		-	70.3	82.2	72.5	60.0	81.7	82.3	71.9	135.0	99.0	124.9	134.1	78.0	-	94.2	77.5	78.3
Chloride		-	0.0	0.1	0.0	0.1	0.0	0.2	2.0	0.2	0.16	0.4	2.5	0.1	-	0.1	0.0	0.32
Nitrogen		-	0.02	0.32	0.14	0.09	0.14	0.04	0.01	0.01	0.09	0.00	0.00	0.25	-	0.18	0.16	0.11
Silica		-	1.3	1.7	1.1	1.2	1.6	2.0	2.3	2.1	2.2	2.1	2.0	1.7	-	1.9	1.7	2.3
Sulphate		-	3.1	12.4	2.9	3.4	3.4	3.5	4.7	8.9	10.9	8.2	10.6	62.2	-	74.5	6.6	7.0
Carbon dioxide		-	0.9	0.8	0.6	0.6	0.8	1.03	0.03	0.08	2.15	1.60	1.05	1.2	-	1.2	0.8	0.97
Total diss. solids		-	63.5	81.7	62.3	53.0	70.8	71.9	62.7	121.0	94.0	111.0	125.5	149.0	-	176.0	71.8	79.6

and South Narao with a range of hardness (as Calcium) from 122-150. The pH of these lakes range from 8.0-8.4 and have bicarbonate as the predominant form of dissolved carbon dioxide.

The relationships of $\text{CO}_2\text{-HCO}_3^-\text{-CO}_3^{=}$ and pH described above for lakes also holds true for streams. The pH values found in Park streams (Table 9) were of a much narrower range (7.8-8.3) than those for lakes (6.9-9.35). The lowest pH values at 7.8-7.9 were obtained from the upper reaches of Cataract Brook and its tributaries, Oesa and Opabin Creek. Slightly higher pH values of 8.0-8.2 are found in the lower Cataract Brook and in Sherbrooke Creek, lower Yoho River, Ross Creek, and upper Kicking Horse River (Figure 26). The Kicking Horse River and its tributaries downstream from Emerald Creek all have a uniform pH of 8.3.

As expected at these pH levels any excess CO_2 enters into combination with lime in the substrate to give a bicarbonate. The range of bicarbonate levels in streams is also much narrower than in lakes at 34-78 ppm in the Cataract Brook drainage area and from 62-143 ppm in the other drainage areas (Figure 27).

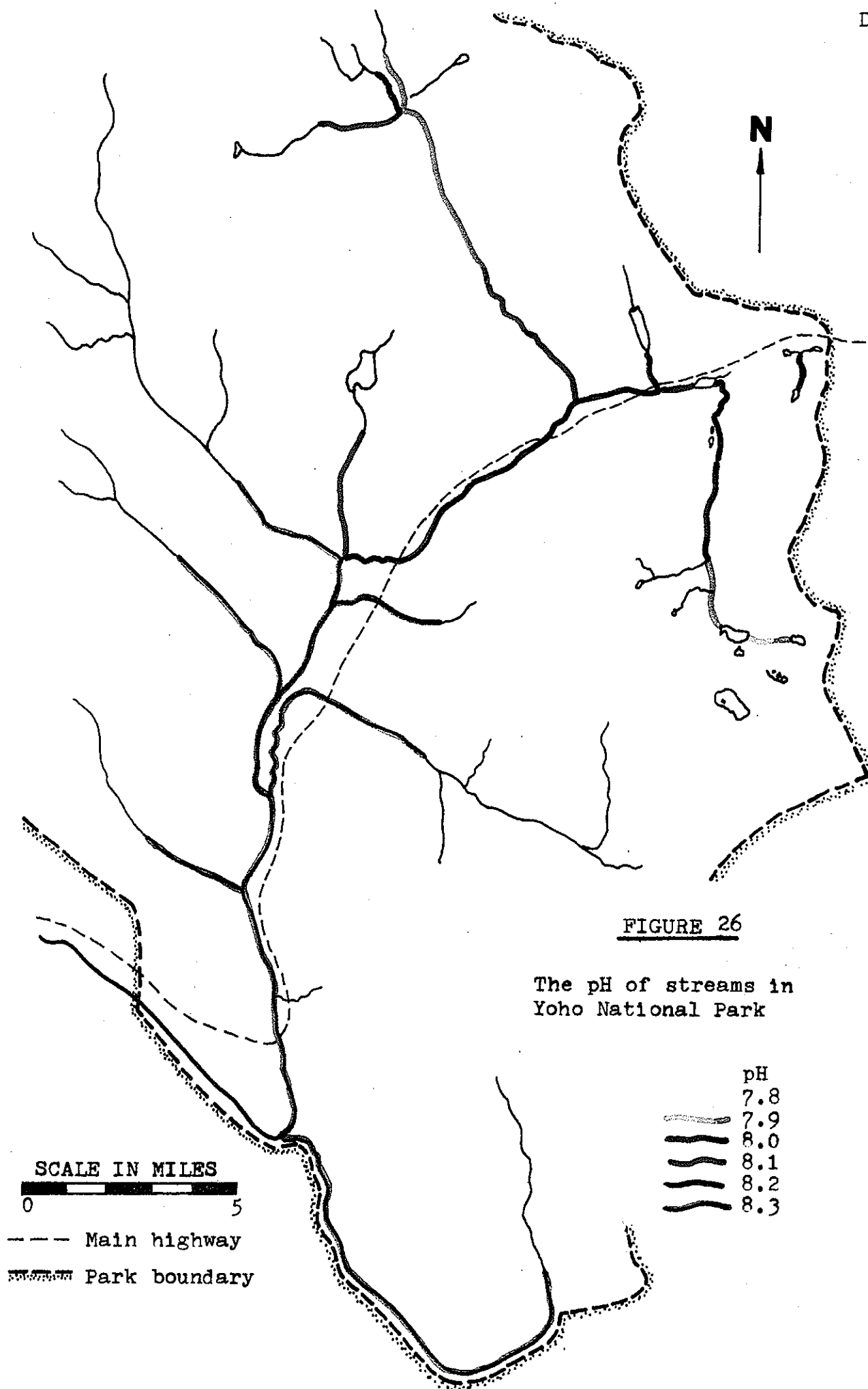
In general the bicarbonate levels of streams vary directly with the distance from the headwaters. This is an indication of the strong influence of the substrate type and its solubility. In the case of Cataract Brook and Kicking Horse River the soft water of the upper tributaries is destined to flow over carbonate rich sedimentary formations in the lower reaches (Figure 27). The

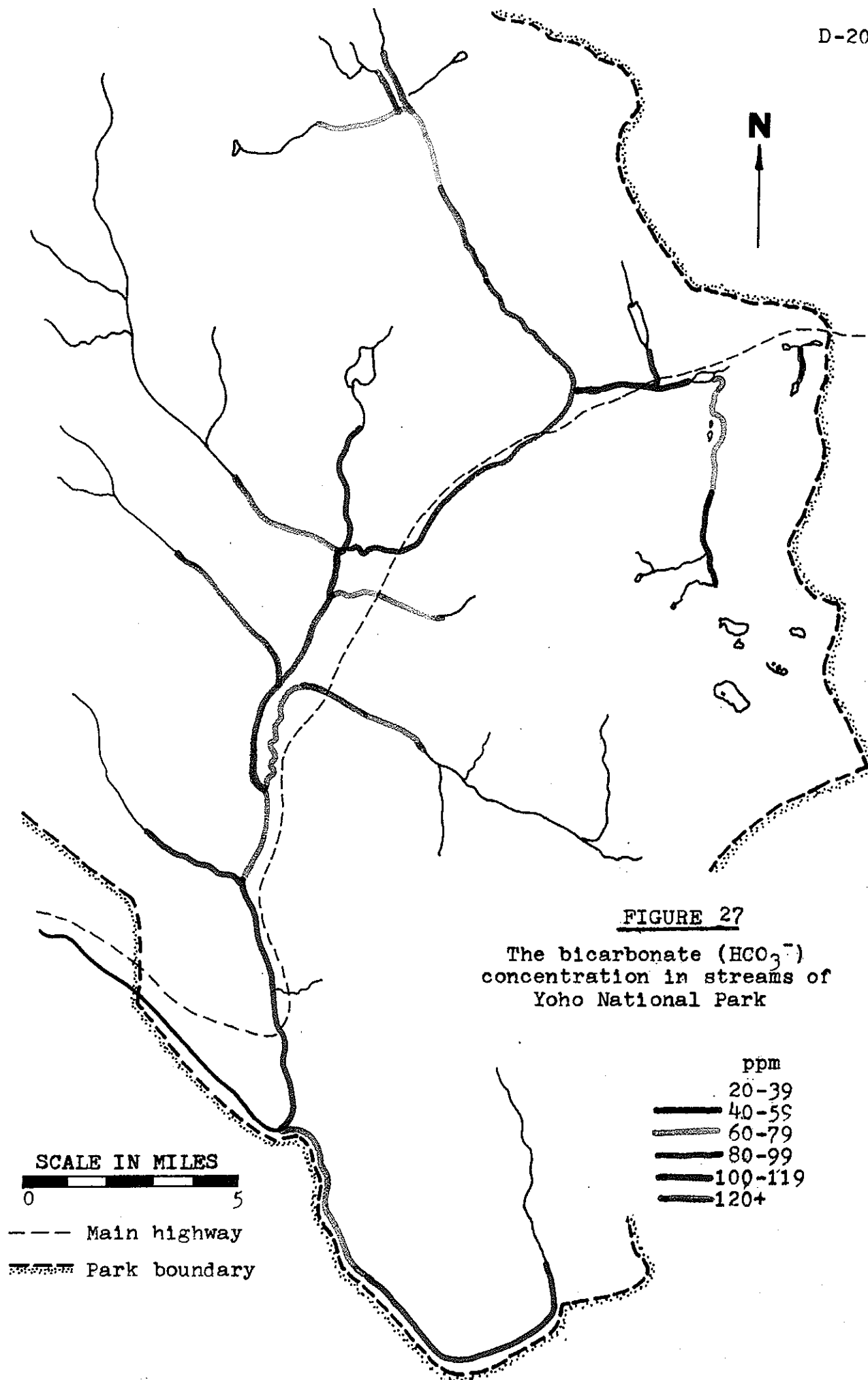
Table 9. Summary of water chemistry data for streams in Yoho National Park. Units as follows: conductivity in $\mu\text{mho cm}^{-1}$; turbidity in J.T.U.; pH in pH units; all others as ppm. (<= less than).

Constituent	Site	102	104	106	107	108	111	112	113	114	118	119	120	121
Conductivity		207.0	250.0	219.0	206.0	220.0	235.0	236.0	252.0	267.0	191.0	187.0	130.0	147.0
Turbidity		0.8	1.4	6.2	0.7	2.8	2.4	3.4	1.7	1.2	27.0	14.0	50.3	3.2
pH		8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	9.2	8.1	8.3	8.1
Total Alkalinity		92.7	118.0	97.0	95.0	103.0	113.0	105.0	116.0	119.0	79.0	78.2	57.0	63.0
Hardness		95.4	124.0	110.0	104.0	112.0	120.0	122.0	129.0	143.0	97.5	93.2	69.3	76.0
Calcium		30.8	38.6	28.9	26.3	29.6	34.2	31.8	26.8	36.9	24.7	23.6	19.6	19.0
Magnesium		4.5	6.7	9.1	9.2	9.3	8.4	10.4	15.1	12.4	8.7	8.3	4.8	6.9
Potassium		1.4	1.1	0.3	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.2	0.2
Sodium		3.3	2.3	0.9	1.4	1.0	0.7	0.7	0.7	0.5	0.4	0.4	0.3	0.3
Bicarbonate		113.0	143.9	118.0	115.9	125.6	137.8	128.0	141.4	145.0	96.0	95.3	70.0	76.8
Chloride		0.5	0.3	0.3	<0.1	<0.1	0.2	0.5	<0.1	<0.1	0.5	0.1	0.2	0.2
Nitrogen		0.15	0.02	0.14	0.08	0.06	0.13	0.17	0.08	0.45	0.11	0.07	0.21	0.16
Silica		4.2	4.3	2.9	3.8	3.5	4.0	3.5	3.3	3.4	2.4	1.9	1.3	1.9
Sulphate		7.6	7.7	11.0	6.1	5.8	6.5	13.6	10.1	21.7	14.6	10.8	10.2	12.0
Carbon dioxide		0.88	1.12	-	-	0.98	1.07	1.0	1.1	-	0.8	1.1	0.6	-
Total diss. solids		108.8	132.1	112.0	105.0	111.8	122.8	124.6	126.6	147.0	89.9	92.8	71.0	79.0

Table 9. -cont'd.

Constituent	Site	122	123	125	126	127	128	130	132	133	134	Mean
Conductivity		121.0	191.0	190.0	145.0	118.0	100.0	82.0	70.0	86.0	229.0	174.6
Turbidity		39.0	1.7	0.7	0.2	0.9	0.4	0.7	1.7	1.3	1.2	11.3
pH		8.2	8.2	8.1	8.2	8.0	7.9	7.9	7.8	7.9	8.2	8.1
Total alkalinity		51.0	83.0	83.0	64.0	49.4	37.9	32.4	28.0	40.0	104.0	77.4
Hardness		63.0	97.0	95.3	75.3	60.2	49.9	41.2	36.0	45.0	116.0	88.7
Calcium		18.0	27.0	25.1	20.7	14.3	12.7	11.0	6.8	12.0	32.5	23.6
Magnesium		4.3	7.1	7.9	5.7	6.0	4.4	3.3	4.6	3.6	8.5	7.2
Potassium		0.1	0.1	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.3	0.32
Sodium		0.2	0.4	0.5	0.3	0.3	0.2	0.2	0.1	0.1	0.6	0.66
Bicarbonate		62.2	101.0	101.4	78.3	60.2	46.2	39.5	34.1	48.8	126.8	94.4
Chloride		0.2	0.1	0.7	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.2	0.2
Nitrogen		0.13	0.1	0.06	0.1	0.1	0.11	0.08	0.06	0.11	0.06	0.11
Silica		1.3	2.7	3.1	3.0	2.8	2.5	2.0	1.4	1.6	3.6	2.7
Sulphate		10.0	12.3	9.9	9.7	10.6	10.6	8.0	11.0	4.3	7.1	9.9
Carbon dioxide		-	0.8	1.2	0.7	0.9	0.9	0.7	-	-	1.2	0.65
Total diss. solids		65.0	100.0	97.8	78.8	64.5	54.1	44.8	41.0	46.0	115.5	91.6





addition of carbonate ions serves to shift the pH level towards the basic range of the scale, usually to about pH 8.3. This increase in pH is accompanied by a marked rise in the total (bicarbonate) alkalinity, and a decrease in free carbon dioxide.

Total dissolved solids, conductivity, alkalinity. The total concentration of dissolved substances or minerals in natural waters is a useful parameter in describing the chemical density, and as a general measure of edaphic relationships that contribute to productivity within the body of water (Reid 1961). Coupled with a morphometric parameter such as mean depth to produce a morphoedaphic index (MEI) the total dissolved solids (TDS) has been of some value in predicting the yield expected for a wide range of lakes (Figure 28, for review see Henderson et al. 1973). Specific abiotic variables may also have significant effects on production. In Yoho National Park, for example, high levels of inorganic turbidity in the form of glacial silt may inhibit light penetration and hence suppress photosynthesis. High nutrient levels and low mean depth (a generally favorable condition for production) may be completely obliterated by the negative effects of this factor. The applicability of a MEI in the Park will be discussed later.

Dissolved substances included in the TDS are listed in Table 10. TDS levels (often termed "sum of constituents") are obtained by critical chemical analysis in the laboratory. A

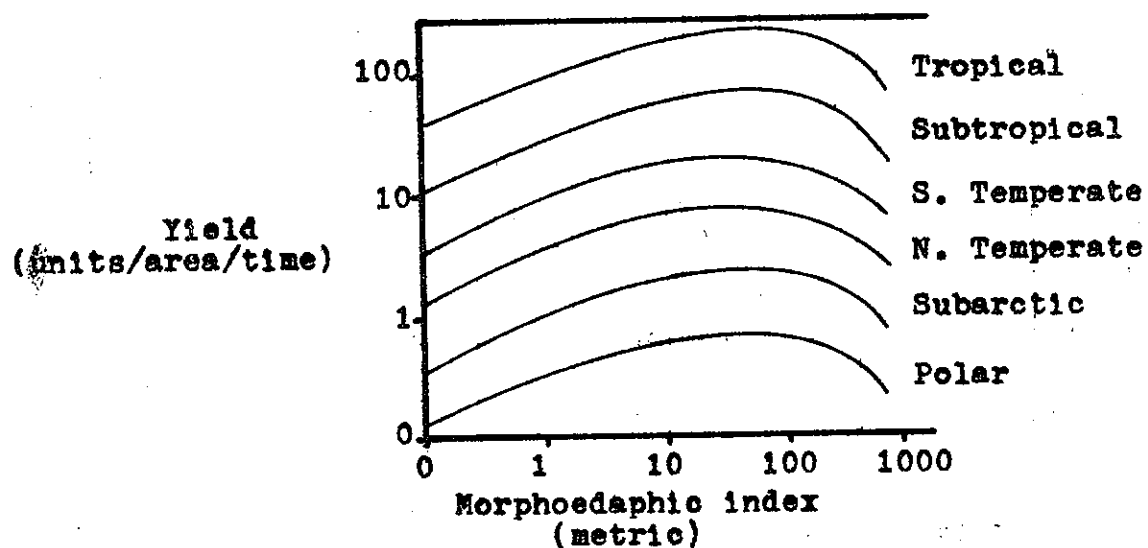


Figure 28

Predicted yield curves for six sets of natural lakes representing six of the world's climatic zones.

Table 10. Summary of major ionic constituents of water samples from lakes in Yoho National Park. Values shown are percent equivalents of total dissolved solids. The alkalinity:conductivity ratio is also given.

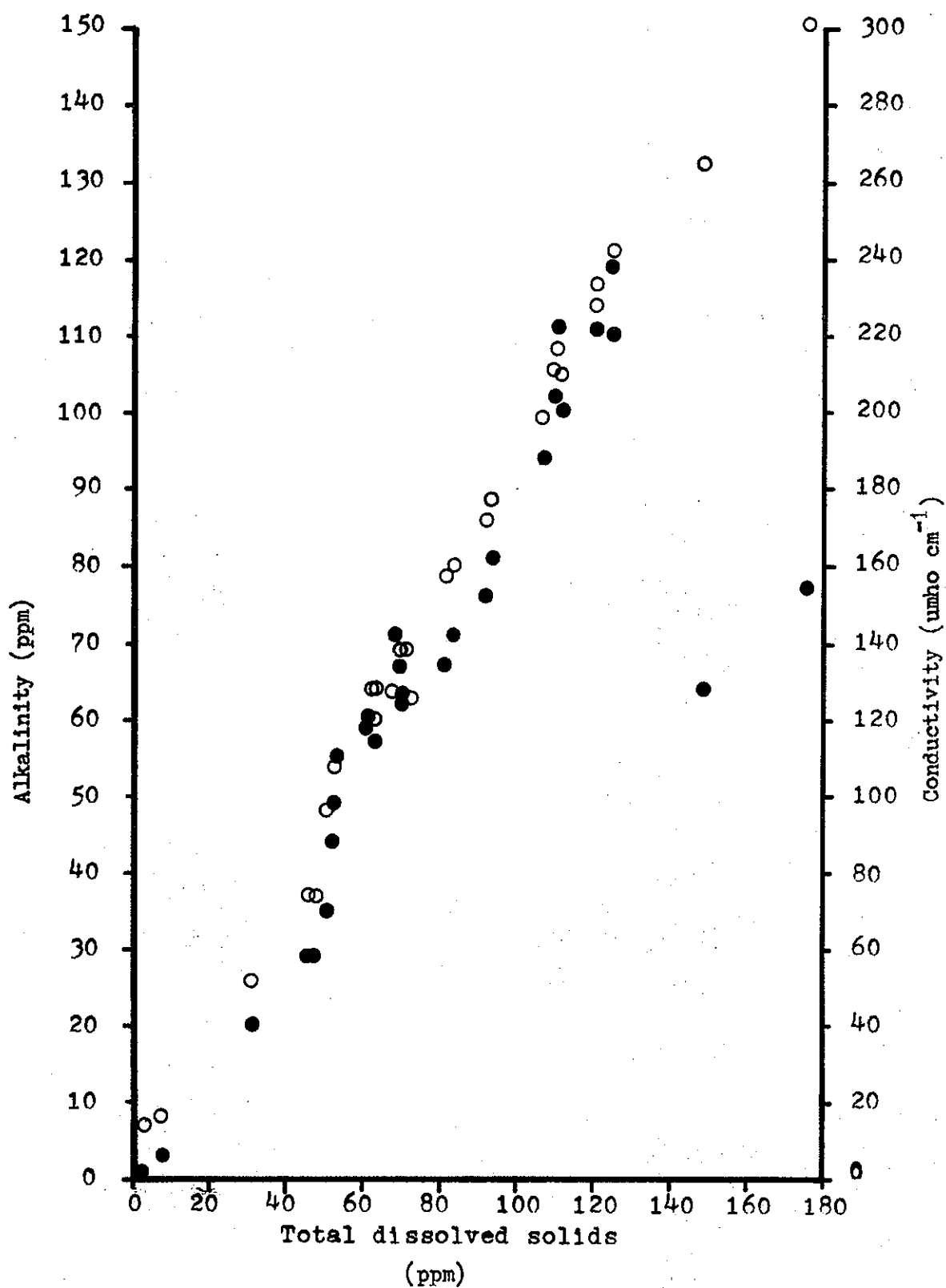
Lake	K	Na	Ca	Mg	SO ₄	Cl	HCO ₃	CO ₂	Alk:cond
8	0.10	0.23	34.2	15.6	5.3	0.26	44.1	0.0	43.3
9	0.21	0.40	32.2	16.9	10.8	0.34	39.0	0.0	41.0
10	0.15	0.40	26.3	24.2	16.9	0.17	35.3	0.31	35.0
13	1.98	3.37	38.7	19.0	17.7	4.34	14.7	0.0	6.6
14	0.95	3.25	37.3	15.3	18.6	0.0	24.3	0.0	18.7
15	0.46	1.18	27.1	19.1	14.6	0.25	37.0	0.0	39.0
15A	0.15	0.26	24.9	20.8	18.8	0.16	34.7	0.0	39.7
16	0.19	0.51	38.5	13.6	5.5	0.77	46.1	0.0	46.1
17	0.07	0.30	33.0	17.3	4.6	0.35	44.3	0.0	47.4
18	0.10	0.30	38.3	11.4	1.7	0.17	47.5	0.08	50.8
19	0.13	0.38	37.5	12.5	2.8	0.27	45.5	0.43	48.3
20	0.12	0.18	32.6	17.3	5.7	0.33	43.6	0.0	44.9
22	0.18	0.63	37.0	12.5	3.9	0.07	45.6	0.0	49.6
23	0.18	0.61	36.2	13.7	3.6	0.07	45.9	0.0	49.6
24	0.14	0.48	38.1	12.0	6.3	0.11	42.6	0.0	44.1
26	0.11	0.29	32.6	18.3	4.8	0.15	43.5	0.0	47.3
29	0.08	0.53	48.0	1.6	2.6	0.0	46.9	0.0	48.0
31	0.15	0.80	24.1	25.6	7.9	0.06	41.0	0.0	42.6
35	0.0	0.16	35.7	14.4	2.4	0.0	47.2	0.0	46.4
37	0.09	0.18	31.8	18.5	3.2	0.09	45.9	0.0	45.5
38	0.07	0.45	34.0	34.5	2.4	0.0	47.0	0.0	48.5
41	0.17	0.57	28.0	22.9	2.4	0.17	45.6	0.0	48.9
42	0.07	0.35	20.8	23.6	3.4	1.98	41.5	8.0	43.6
43	0.10	0.34	30.5	19.9	3.7	0.10	45.1	0.08	48.6
47	0.08	0.4	29.8	19.7	6.1	0.1	43.8	0.0	45.5
48	0.06	0.22	32.1	17.8	3.8	0.24	45.6	0.0	47.0
49	0.24	1.00	32.7	16.1	4.4	1.4	43.9	0.0	45.4
50	0.13	0.32	32.6	17.3	25.0	0.03	24.4	0.0	24.1
55	0.11	0.21	31.3	17.7	25.3	0.03	25.1	0.0	25.4
61	0.07	0.14	32.7	17.8	4.8	0.0	44.3	0.0	45.0
Mean	0.14	0.44	33.8	17.3	4.9	0.3	42.7	0.2	40.6

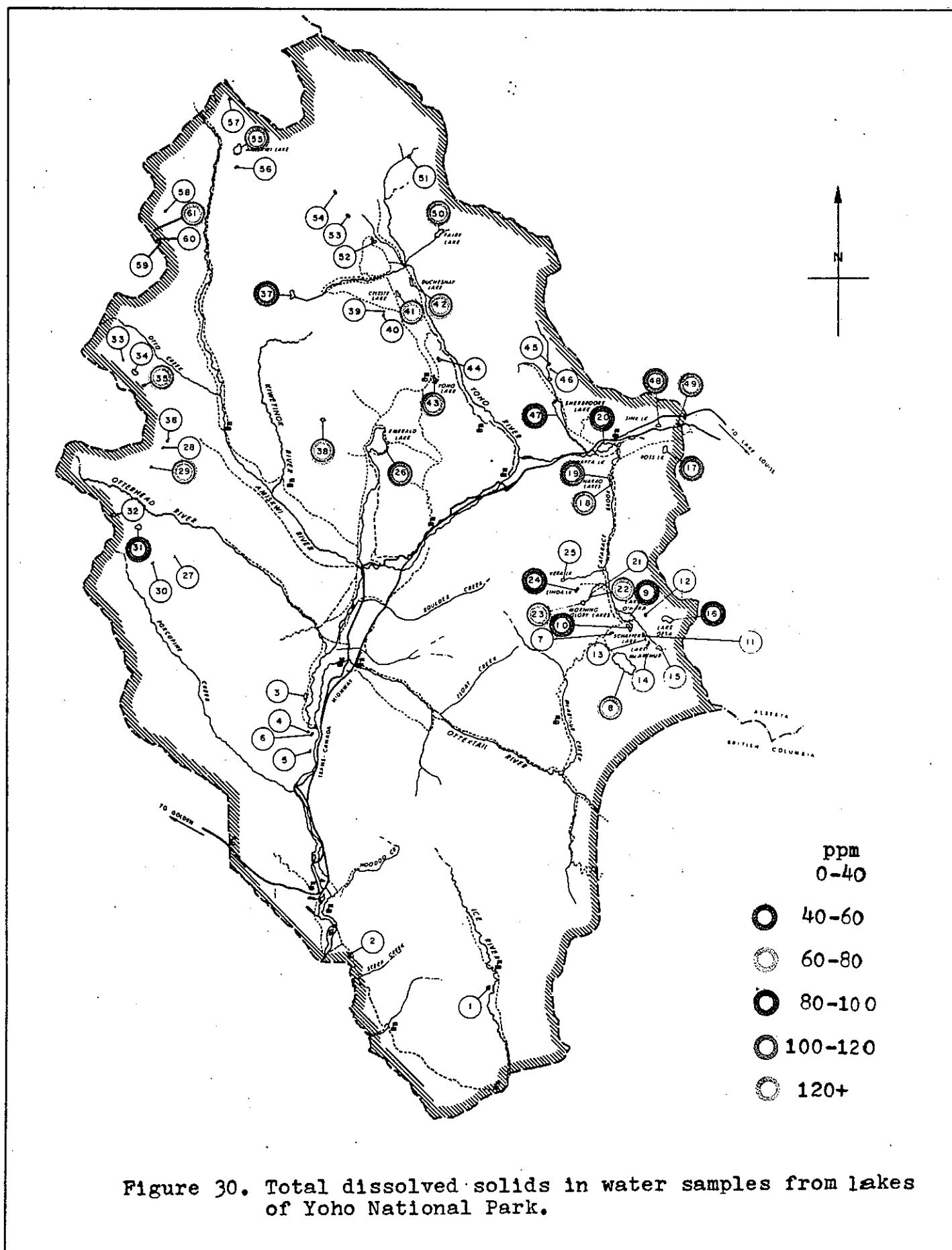
good indication of the amount of TDS and its composition may be provided by two other measurements which are more adaptable to field conditions: conductivity and alkalinity. Conductivity is a measure of the total amount of ionized materials in water and is obtained through a determination of the electrical conductance of the solution (generally expressed as μ mho cm^{-1}). Alkalinity is a measure of two of the major constituents of the TDS, the HCO_3^- and $\text{CO}_3^{=}$. Although not always the case alkalinity usually refers to the activity of CaCO_3 . A comparison of the correlation of alkalinity and conductivity with TDS is shown in Figure 29. As can be seen in the figure the conductivity is directly related to TDS with a high degree of correlation ($r=0.05$) in the Park waters examined. Within the Park TDS values range from 4 in Lower Opabin Pond to 176 in Amiskwi Lake. The general distribution of TDS values for lakes is shown in Figure 30. Low TDS values are generally restricted to the headwaters of Cataract Brook i.e. mainly in the quartzitic areas of the park. Kiwetinok Lake also has a rather low TDS value at 53 ppm which is probably due to its small drainage area in relation to surface area.

Conductivity of waters examined ranged from 15 to 303 and as previously noted is highly correlated with TDS. Alkalinity is also correlated with TDS especially in those lake where bicarbonate is the predominant anion present. In lakes such as Fairy, Amiskwi, Upper Opabin, and Lower Opabin Pond (No. 14)

Figure 29

The relationship of alkalinity and conductivity to total dissolved solids in lakes of Yoho National Park.





the presence of $\text{SO}_4^{=}$ makes the alkalinity a less reliable indicator of TDS. The alkalinity values can be used to advantage, however, to enable a rough estimation of the proportion of the TDS which is due to HCO_3^- in a given lake. In Figure 31 the ratio of alkalinity and conductivity are plotted against the percentage of bicarbonate ions in the TDS as determined by laboratory analysis. A very good correlation ($r=0.98$) is found which allows the prediction of per cent HCO_3^- from data on alkalinity and conductivity. Ptarmigan Pond, for example, has never had a complete chemical analysis which would give the type of ionic species present. From conductivity measurements an accurate estimation of the TDS can be made (estimated as 80 from Figure 29) and the ratio of alkalinity to conductivity allows an estimation of the relative amount of HCO_3^- which is contributing to the TDS (estimated to be 37.3% HCO_3^-).

The pattern of TDS values in streams is similar to that described for bicarbonate in which the lower values are usually found in headwaters with increasing amounts of dissolved solids picked up as the stream continues to flow over soluble substrates (Table 9). Both Cataract Brook and Yoho River show this pattern of increasing TDS (Figure 32). The relative pattern of TDS concentration is as follows for the Cataract Brook-Kicking Horse River complex: upper Cataract Brook < lower Cataract Brook < upper Kicking Horse River < Field reach < Ottertail flats.

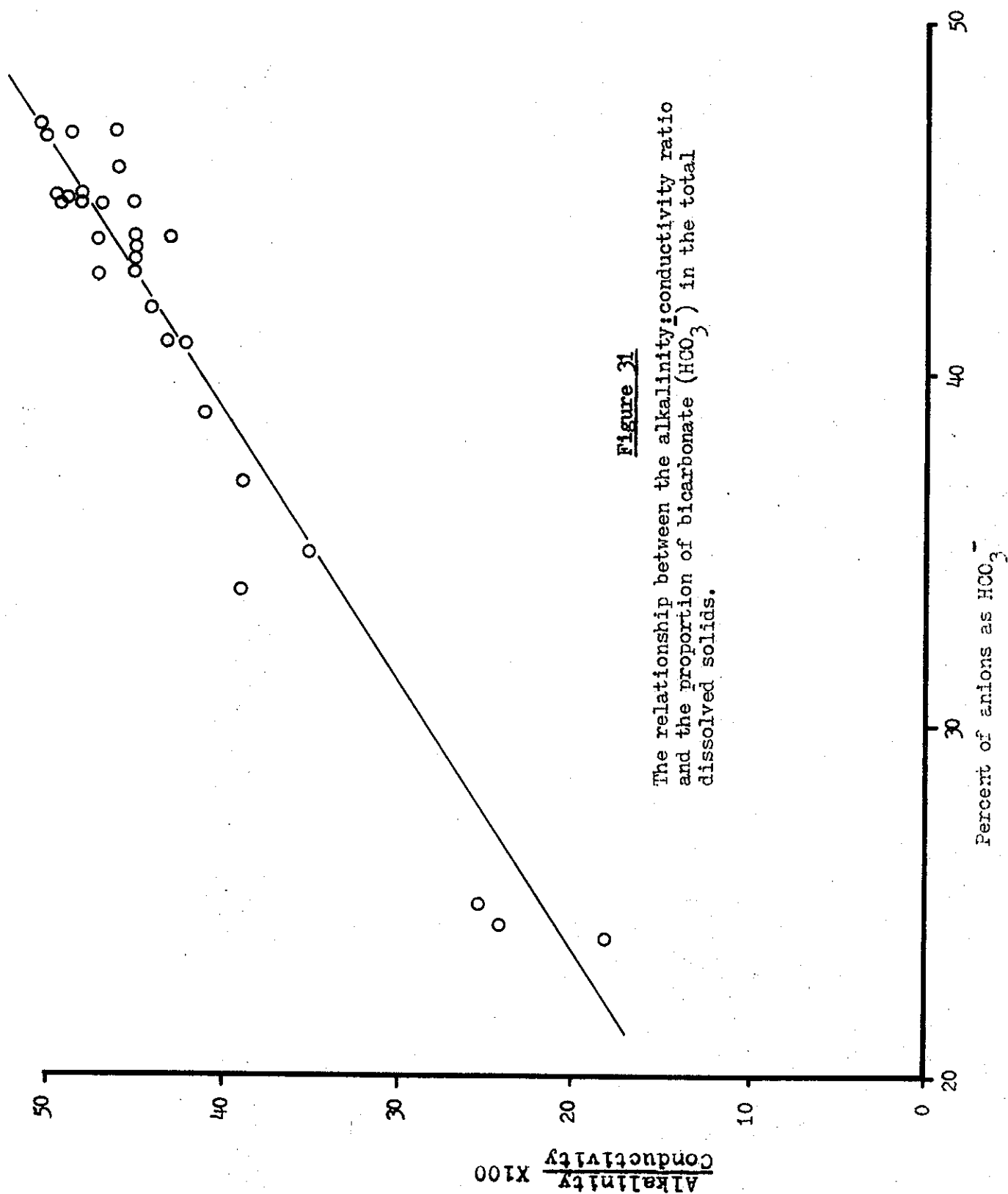
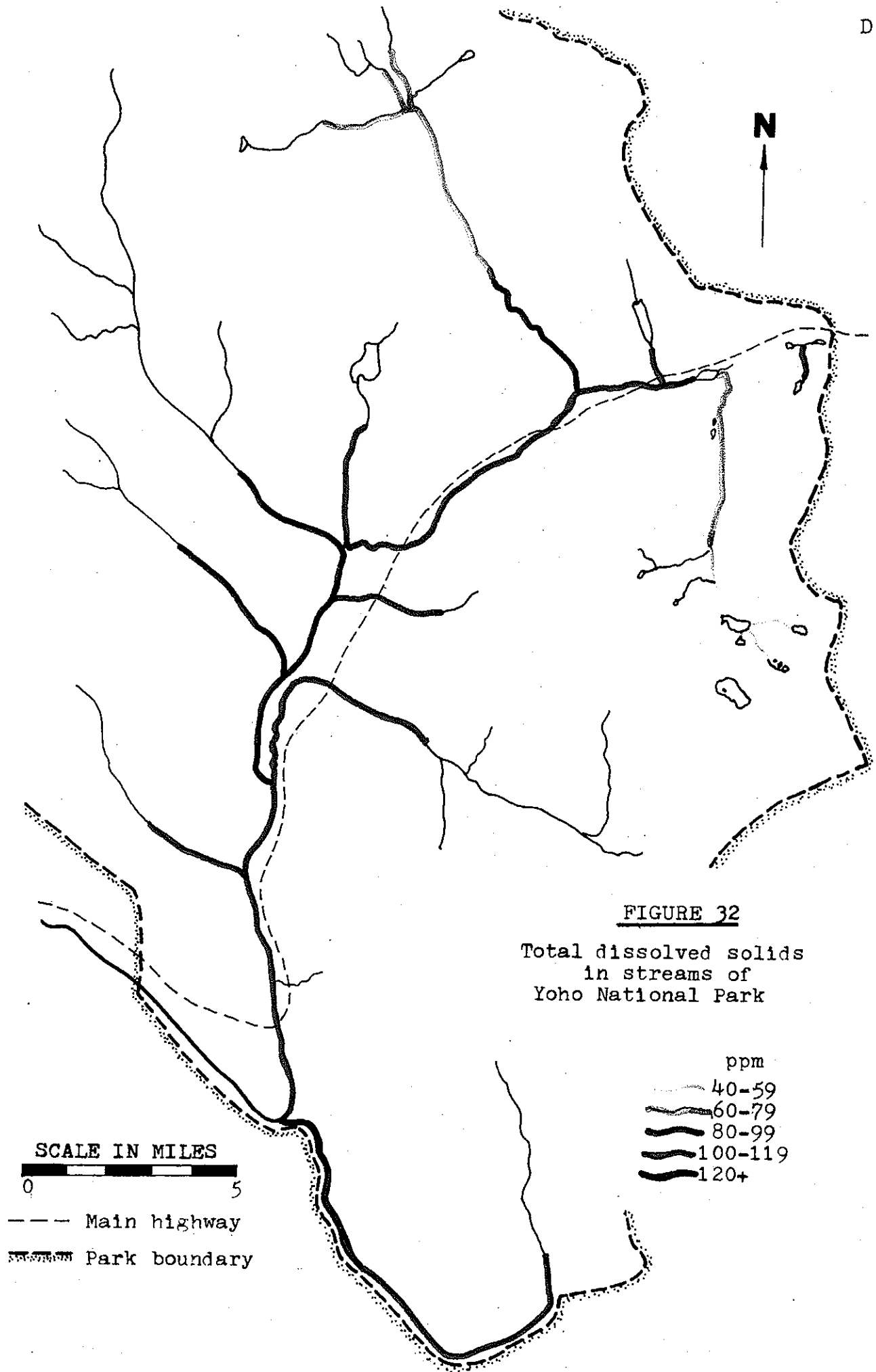


Figure 31

The relationship between the alkalinity:conductivity ratio and the proportion of bicarbonate (HCO_3^-) in the total dissolved solids.



Downstream from the confluence of the Ottertail River the Kicking Horse River again becomes lower in TDS very likely due to the more dilute nature of this tributary.

Lowest TDS values for Park streams are those of Opabin Creek (at 41 ppm) and Oesa Creek (at 44.8 ppm) while the highest values were in the Amiskwi River (147 ppm) and Beaverfoot River (132 ppm).

One interesting feature shown clearly by comparison of stream and lake TDS is the isolation of the Narao Lakes from Cataract Brook during certain times of the year. Cataract Brook flows quite close to these small lakes (within 10 m of North Narao) and may at times be connected due to the activity of beaver or other natural processes. At the time of sampling (June and August, 1973), however, it appears no flow from Cataract Brook enters these lakes as the TDS is more than double that of the brook (Table 8 & 9).

Ionic constituents. The ionic constituents of lake waters in the Park which make up the TDS are shown in Table 10. A comparison can be made with data on waters from sedimentary and igneous bedrock areas (Table 11, comparative data from Hutchinson 1957). The values for ionic species in Park waters are in approximately the same proportions as the mean value from sedimentary source material. Bicarbonate is the dominant

Table 11. Mean equivalent proportions of cations and anions in waters from Yoho National Park as compared with natural waters from sedimentary and igneous source material.

Ion	Yoho National Park	Sedimentary source material*	Igneous source material*
Na	1.3	4.8	30.6
K	0.4	8.0	6.9
Mg	51.6	34.0	14.2
Ca	98.9	53.2	48.3
$\text{HCO}_3^- + \text{CO}_3^{=}$	125.2	93.8	73.3
$\text{SO}_4^{=}$	16.9	6.2	14.1
Cl^-	0.9	0	12.6

*Data from Hutchinson (1957)

anion and calcium the dominant cation in both cases. The absence of igneous bedrock in the Park precludes the presence of high amounts of sodium and other constituents of that source material.

Individual variations in proportions of ionic constituents (Table 8) from lakes in different areas of the Park appear to be associated with differences in bedrock type. Calcium and magnesium are found in roughly equal amounts in waters from lakes in dolomitic ($\text{CaMg}(\text{CO}_3)_2$) areas of the Park (Figure 22). Crystal Lake is somewhat different from most lakes in dolomitic areas in having very low amounts of Mg which probably indicates the surrounding area of limestone (CaCO_3) is low in MgCO_3 . On the other hand three lakes Otto, Little Gem, and Duchesnay Lake had Mg in greater amounts (equivalents) than Ca which may be due to localized abundance of MgCO_3 . The upper Cataract Brook drainage area has Ca as the major cation with lesser amounts of Mg.

The cations Na and K are found only in small amounts in the Park as is expected from rocks of sedimentary origin. Sodium is always the dominant ion of the pair and the ratio of Na/K for different lakes appears to follow no definite pattern within the Park. Lakes as different as Fairy, Emerald, South Narao, and Upper Opabin all have approximately the same ratios (Table 8).

In most cases the Na and K make up an insignificant amount of the total dissolved solids except in the very dilute Lower Opabin Ponds where Na is about 3% (equivalents per million) of the ionic species.

The major anion in Park waters is HCO_3^- followed by $\text{SO}_4^{=}$ and very low amounts of Cl^- and $\text{CO}_3^{=}$. Generally speaking the high bicarbonate lakes lie within the dolomitic limestone areas of the Park with lakes low in bicarbonate restricted to those in the Lake O'hara area. Two lakes high in sulfate, Fairy and Amiskwi, lie in dolomitic formations which may contain gypsum or may be associated with sulfur springs. More detailed geological information is required in order to determine the exact cause of the high sulfate content of these waters.

The low amounts of chloride present indicates that the main source for this ion may be rainwater and snow (Hutchinson 1957).

General comparison of Park waters with other areas.

Table 12 presents data for some lake water analysis parameters as compared with waters from other mountain parks. In general one would expect to find that the range of values obtained for any particular parameter is proportional to the number of lakes examined. Such is the case in Yoho National Park where the number of lakes for which detailed chemical analysis is available is now 30 with two others having some

Table 12. Mean values and ranges for some lake water parameters in Yoho National Park as compared with waters from other mountain parks.

Parameter	Park*		
	Yoho	Banff	Waterton
	Mean (range)	Mean (range)	Mean (range)
Conductivity (μ mos cm^{-2})	145 (15-303)	150 (54-369)	157 (27-550)
Total dissolved solids (ppm)	79 (4-176)	79 (27-194)	84 (13-163)
Total bicarbonate alkalinity (ppm)	62 (1-119)	69 (22-174)	77 (11-251)
Total hardness (as ppm CaCO_3)	75 (3.6-150)	76 (27-188)	82 (11-291)
pH	8.1 (6.9-9.3)	8.1 (7.5-8.7)	8.1 (7.4-9.0)
No. lakes examined	32	21	25

*Supplementary data from Anderson, Donald, and Krochak (1972).

minimal data. The data available considerably increases the range of values for these parameters as compared to those previously reported from the Park (Anderson 1968b, 1970a).

Although a small and compact park, Yoho presents a more diverse picture of water quality than might be expected at first glance. As previously described, the lakes examined range in elevation from 1100 to 2455 m and span terrestrial plant zones from upper montane to alpine types. The water chemistry data reflects this diversity with ranges of values for conductivity, pH, TDS, alkalinity, and total hardness comparable to and in some cases exceeding those from the other larger Mountain National Parks (Table 12).

BENTHIC INVERTEBRATES

Introduction

Examination of biological aspects of Park waters requires the synthesis of a large amount of data collected by various methods. The detailed data presented in Volume III of this report are best handled by summarizing in a number of tables for easy examination and comparison. To that end we present the following tables which the reader may find of value in the discussion of the taxonomic groups which follow:

- Table 13. Summary of mean numbers m^{-2} of major invertebrate groups collected in dredge samples from lakes in Yoho National Park.
- Table 14. Summary of percentage composition of major groups of invertebrates collected in dredge samples from lakes in Yoho National Park.
- Table 15. Summary of mean numbers of major invertebrate groups collected in 30 minute shoreline samples from lakes in Yoho National Park.
- Table 16. Summary of percentage composition of major invertebrate groups collected in 30 minute shoreline samples from lakes in Yoho National Park.
- Table 17. Summary of mean numbers m^{-2} of major invertebrate groups collected in benthic samples from streams in Yoho National Park.
- Table 18. Summary of percentage composition of major invertebrate groups collected in benthic samples from streams in Yoho National Park.

Table 13. Summary of mean numbers m⁻² of major invertebrate groups collected in dredge samples from lakes in Yoho National Park. Mean total wet weight of invertebrates (m⁻²) and percent weight loss on ignition of bottom mud samples are also given.

Group	Site	6	7	8	9	10	13	14	15	15A	16	17	18	19	20	22	23	24	26	42	47	48	49
Oligochaeta	43	43	-	-	31	27	43	43	-	21	-	21	86	182	204	32	-	-	129	10	48	92	150
Hirudinea	43	43	-	-	-	-	-	-	-	-	-	-	-	26	10	-	-	-	-	10	-	150	154
Amphipoda	43	-	-	-	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	27	-
Ephemeroptera	-	-	-	3	-	-	-	-	-	129	-	-	-	-	-	-	-	-	-	-	5	-	43
Trichoptera	64	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35	12
Chironomidae	172	1225	1042	2067	-	124	688	397	64	-	2074	3096	5922	1268	14792	376	311	397	548	591	947	1726	1130
Misc. Diptera	-	-	-	-	-	21	21	-	43	-	-	10	32	-	-	-	64	10	-	53	21	21	163
Coleoptera	-	-	-	-	-	-	-	-	-	-	-	-	-	5	10	-	-	-	-	10	-	-	-
Misc. Insecta	-	21	-	-	-	-	-	-	-	-	-	-	-	-	-	32	-	-	-	32	5	-	4
Acarina	64	-	21	-	-	12	-	10	-	-	-	-	225	96	-	-	-	-	-	10	-	35	8
Pelecypoda	-	-	473	396	-	-	-	-	-	-	-	118	161	69	397	-	-	-	-	43	166	6	96
Gastropoda	-	-	-	-	-	-	-	-	-	-	-	-	-	263	-	-	-	-	-	-	-	-	-
Total wet weight (g)	4.3	6.0	3.6	10.7	2.1	12.9	1.7	1.7	0.2	1.9	7.7	6.4	56.3	44.0	21.5	2.5	3.2	0.2	21.5	6.6	11.6	16.9	42.1
Weight loss (%)	11.7	-	-	14.0	39.6	-	-	-	-	-	-	6.0	25.7	20.7	7.0	15.2	6.7	10.6	3.5	-	-	16.6	20.1

Table 14. Summary of percentage composition of major groups of invertebrates collected in dredge samples from lakes in Yoho National Park.

[illegible][illegible]

Table 15. Summary of mean numbers of major invertebrate groups collected in 30 minute shoreline samples from lakes in Yoho National Park. (+) indicates present in trawl samples.

Group	Site	7	8	9	10	13	14	15	15A	16	17	18	19	20	22	23	24	26	42	47	48	49
Turbellaria	-	6	-	-	-	-	-	-	-	7	-	-	2	-	-	-	-	-	-	-	-	-
Oligochaeta	+	-	-	1.5	+	+	-	2	4	-	6	+	-	1.3	+	-	+	+	-	2.5	+	+
Hirudinea	-	-	-	-	1	-	-	-	-	-	-	+	0.5	-	-	-	-	+	-	-	1.5	-
Amphipoda	-	-	-	-	-	-	-	-	-	-	-	+	-	2.3	-	-	6	51.6	-	3.5	73.5	-
Ephemeroptera	-	2	-	-	-	-	-	87	10	2	1.6	0.5	21	24	8	20	-	29	-	3.5	25	14
Plecoptera	2	-	-	-	-	-	-	15	-	9	1	-	-	5.3	-	1	-	6	-	3.5	-	4
Trichoptera	18	-	-	12.5	50	16	28	-	-	1	6	19	27	7.6	-	6	6	2.9	7	16	5.5	4
Chironomidae	-	1	13	10	10	7	13	2	1	-	4.2	7	9.5	1.2	24	6	123	2.9	6	6	1.5	3
Coleoptera	2	-	-	2	1	5	34	1	-	-	0.6	0.5	-	-	-	3	-	-	2	0.5	3	-
Heteroptera	-	-	-	-	-	-	-	-	-	-	-	1.5	-	-	-	-	-	-	+	-	-	+
Odonata	-	-	-	-	-	-	-	-	-	-	-	1.5	1.6	-	-	-	-	5.6	-	-	3	2
Misc. Insecta	2	1	1.5	72	50	-	-	-	-	8	-	1	0.5	17	7	-	4	0.6	+	5	1	4
Acarina	-	-	-	+	3	-	-	-	-	-	0.3	+	7.5	+	1	1	-	-	+	-	+	3
Pelecypoda	-	-	-	-	+	-	-	-	-	-	15.6	4	3.5	0.3	-	-	-	+	-	-	-	-
Gastropoda	-	-	-	-	-	-	-	-	-	-	33.6	-	15	-	-	-	-	34	3	-	2.5	1
Mean total wet wt. g	0.34	0.01	1.03	3.8	2.1	2.0	2.0	2.0	0.16	0.16	0.72	1.5	3.4	2.1	0.11	0.34	1.3	9.9	1.5	2.1	5.4	2.8

Table 16. Summary of percentage composition of major invertebrate groups collected in 30 minute shoreline samples from lakes in Yoho National Park.

Group	7	8	9	10	13	14	15	15A	16	17	18	19	20	22	23	24	26	42	47	48	49
Turbellaria	-	60	-	-	-	-	-	-	25.9	-	-	1.8	-	-	-	-	-	-	-	-	-
Oligochaeta	-	-	4.9	-	-	-	-	-	-	8.6	-	-	2.1	-	-	-	-	-	5.7	-	-
Hirudinea	-	-	-	0.7	-	-	-	-	-	-	-	0.4	-	-	-	-	-	-	-	1.2	-
Amphiroda	-	-	-	-	-	-	-	-	-	-	-	-	3.8	-	-	4.3	39.1	-	8	63	-
Ephemeroptera	-	20	-	-	-	-	81.3	90.9	7.4	2.3	1.4	19.8	40.6	19	62.5	-	22	-	8	21.4	45.1
Plecoptera	-	-	-	-	-	-	14	-	33.3	1.4	-	-	8.9	-	3.1	-	-	-	12.6	-	-
Trichoptera	8.3	-	40.9	36.4	20.5	41.7	-	-	3.7	8.6	54.2	25.4	12.8	-	-	4.3	4.5	38.8	36.7	4.7	12.9
Chironomidae	75	10	42.6	7.2	8.9	14.2	1.8	9.1	-	6.2	20	8.9	2.1	57.1	18.7	88.4	2.2	33.3	14.9	1.2	9.6
Coleoptera	8.3	-	6.5	0.7	6.4	37.3	0.9	-	-	0.8	1.4	-	-	-	9.3	-	-	11.1	1.1	2.5	-
Pteroptera	-	-	-	-	-	-	-	-	-	-	4.2	-	-	-	-	-	-	-	-	-	-
Odonata	-	-	-	-	-	-	-	-	-	-	4.3	0.9	-	-	-	-	4.2	-	-	2.5	6.4
Misc. Insecta	8.3	10	4.9	52.5	64.1	-	-	-	29.6	-	2.8	0.4	28.7	16.6	-	2.8	0.4	-	11.4	0.8	12.9
Acarina	-	-	-	2.1	-	6.5	-	-	-	0.4	-	7	-	2.3	3.1	-	-	-	-	-	9.6
Pelecypoda	-	-	-	-	-	-	-	-	-	22.5	11.4	3.3	0.5	-	-	-	-	-	-	-	-
Gastropoda	-	-	-	-	-	-	-	-	-	48.4	-	14.1	-	-	-	-	25.7	16.6	-	2.1	3.2

Table 17. Summary of mean numbers m⁻² of major invertebrate groups collected in benthic samples from streams in Yoho National Park.

Group	Site	102	104	106	107	108	109	110	111	112	113	114	115	116	117	118	119
Turbellaria		0.8	-	-	-	1.6	-	-	-	-	-	4.1	1.6	2.5	-	2.5	-
Oligochaeta		0.8	-	-	-	1.6	-	-	-	0.8	-	-	-	-	-	-	-
Ephemeroptera		361.8	49.5	223.0	133.0	110.0	215.5	697.0	219.0	242.7	53.0	134.5	600.0	181.0	339.0	333.0	390.0
Plecoptera		63.8	7.4	18.6	19.5	6.5	6.0	67.5	19.0	15.7	9.1	18.2	50.8	29.6	42.0	61.6	13.1
Trichoptera		21.6	5.5	20.5	3.0	11.0	8.0	34.5	8.6	9.9	0.8	3.3	38.0	14.8	31.4	14.0	4.9
Chironomidae		36.0	8.2	32.4	26.0	8.0	4.5	57.0	60.7	82.4	20.8	28.3	864.5	19.9	15.6	29.9	74.9
Misc. Diptera		8.0	7.1	2.5	-	17.5	3.0	7.5	6.3	5.5	3.3	1.6	-	11.6	14.3	8.6	2.4
Misc. Insecta		3.3	0.8	-	-	6.5	1.6	3.3	-	0.8	5.0	0.8	8.3	-	1.6	-	0.8
Acarina		1.6	1.6	0.6	-	-	-	1.6	0.8	-	-	-	-	2.5	15.5	1.6	-
Gastropoda		-	5.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Group	Site	120	121	122	123	124	125	126	127	128	129	130	132	133	134
Turbellaria		1.6	12.0	-	5.0	-	6.5	0.8	5.5	2.5	1.6	115.5	-	-	-
Oligochaeta		-	-	-	-	-	0.6	0.8	-	-	-	5.0	-	-	1.6
Ephemeroptera		364.1	437.0	100.5	222.2	211.0	279.5	322.0	342.0	345.5	109.8	103.5	472.5	447.5	16.4
Plecoptera		49.1	63.3	9.9	46.1	36.0	52.0	35.8	82.2	73.8	64.0	83.2	44.5	6.5	36.2
Trichoptera		8.2	4.9	0.8	8.1	1.5	34.8	95.7	97.7	36.7	106.0	3.2	-	1.5	48.7
Chironomidae		25.8	24.0	39.9	15.6	23.0	46.7	26.5	31.3	33.1	29.5	300.7	151.3	1241.6	9.1
Misc. Diptera		7.5	16.0	4.1	8.1	3.2	6.8	84.1	10.5	3.2	1.6	4.0	6.6	6.6	9.6
Misc. Insecta		1.6	3.0	2.5	3.7	-	1.2	1.6	-	1.6	-	1.6	-	6.5	1.6
Acarina		-	2.0	-	-	-	0.6	-	6.5	3.3	11.5	9.0	-	-	-
Gastropoda		-	-	-	-	-	-	0.8	-	-	-	-	-	-	0.8

Table 18. Summary of percentage composition of major invertebrate groups collected in benthic samples from streams in Yoho National Park.

Group	Site	102	104	106	107	108	109	110	111	112	113	114	115	116	117	118	119
Turbellaria		0.1	-	-	-	0.9	-	-	-	-	-	2.1	0.1	0.9	-	0.5	-
Oligochaeta		0.1	-	-	-	0.9	-	-	-	0.2	-	-	-	-	-	-	-
Ephemeroptera		72.8	58.1	74.9	73.2	67.6	90.2	80.2	69.6	67.6	57.6	70.4	38.4	69.2	73.8	73.8	80.2
Plecoptera		12.7	8.8	6.2	10.7	3.9	2.5	7.7	6.0	4.3	9.7	9.5	3.2	11.3	9.1	13.5	2.6
Trichoptera		4.2	6.4	6.8	1.6	6.7	3.3	3.9	2.7	2.7	0.6	1.7	2.4	5.6	6.7	3.1	1.0
Chironomidae		7.2	9.6	10.8	14.9	4.9	1.8	6.5	19.3	23.0	22.6	14.8	55.2	7.6	3.3	6.4	15.4
Misc. Diptera		1.6	8.3	0.8	-	10.7	1.2	0.8	2.0	1.5	3.5	0.8	-	4.4	3.1	1.9	0.4
Misc. Insecta		0.6	0.9	-	-	3.9	0.6	0.3	-	0.2	5.4	0.4	0.5	-	0.3	-	0.1
Acarina		0.3	1.8	0.2	-	-	-	0.1	0.2	-	-	-	-	0.9	3.3	0.3	-
Gastropoda		-	5.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Group	Site	120	121	122	123	124	125	126	127	128	129	130	132	133	134
Turbellaria		3.4	2.1	-	1.6	-	1.5	0.1	0.9	0.8	0.4	18.4	-	-	-
Oligochaeta		-	-	-	-	-	0.1	0.1	-	-	-	0.7	-	-	1.2
Ephemeroptera		79.5	77.7	63.7	71.9	76.8	65.2	56.6	59.4	69.1	33.8	16.5	70.0	26.1	13.2
Plecoptera		10.7	11.2	6.2	14.9	13.1	12.1	6.3	14.2	14.7	19.7	13.2	6.5	0.3	29.1
Trichoptera		1.8	0.8	0.5	2.5	0.5	7.9	16.8	16.9	7.3	32.7	0.5	-	0.1	39.2
Chironomidae		5.6	4.2	25.3	5.0	8.3	10.9	4.6	5.4	6.6	9.1	47.9	22.4	72.5	7.3
Misc. Diptera		1.6	2.8	2.5	2.5	1.1	1.5	14.8	1.8	0.6	0.4	0.6	0.9	0.3	7.7
Misc. Insecta		0.3	0.5	1.5	1.1	-	0.2	0.2	-	0.3	-	0.2	-	0.3	1.2
Acarina		-	0.3	-	-	-	0.1	-	1.1	0.6	3.5	1.4	-	-	-
Gastropoda		-	-	-	-	-	-	0.1	-	-	-	-	-	-	0.6

Turbellaria

Two species of fresh-water flatworms (Orders Tricladida and Rhabdocoela) were collected from lakes and streams in YNP. These small flatworms are typically found under rocks or debris where they may feed on either living or dead animal and plant material.

The triclad Polycelis coronata was found at 15 of the 30 stream sites (Table 17) and along the shoreline of Indigo Lake. Its preference for flowing waters has been noted by several authors (Hyman 1951, Macan 1963) and its distribution within the park supports those observations. Polycelis coronata was usually found in low numbers with an overall average density of 5.4 m^{-2} for the 30 stream sites. Highest numbers were found at the head of Cataract Brook (site 130) where there were 115.5 m^{-2} . In the study by Robinson (1972) of the streams near Lake O'Hara he also found P. coronata in high numbers (65.0 m^{-2}) at site 130. He found P. coronata only at one other site: Morning Glory Creek with 6.5 m^{-2} . Robinson and Smith (1974) found triclads (identified as P. coronata by the present authors) at 11 of 13 stream sites examined in the Bow-Pipestone area near Lake Louise. An analysis of the data presented by Robinson and Smith (1974) indicated an overall average density of $4.4 \text{ P. coronata m}^{-2}$ was found with a range of 0-43.2 m^{-2} . Highest numbers of P. coronata in that study were found at the

first station below the Lake Louise sewage lagoon outfall. This station was considered the most eutrophic of those sampled in the Lake Louise area, a condition attributed to unnatural nutrification.

Polycelis coronata was reported from both lakes and streams in WLNP (Anderson et al. 1972) and from Snaring River, JNP (Ball and Fernando 1968), however no quantitative data are available from these two parks.

The neorhabdocoele turbellarian Mesostoma sp. (probably M. arcticum) was collected in shoreline samples at three lakes in the Park: Oesa, McArthur and North Narao (Table 15). Hyman (1951) notes that rhabdocoeles are characteristic parts of the fauna of alpine lakes and species of Mesostoma are common in shallow waters in high altitudes and latitudes. The average number of Mesostoma sp. collected in the timed (30 minute) shoreline surveys from the three lakes ranged from 2-7.

No quantitative data are available on the distribution of Mesostoma sp. in the mountain National Parks although Anderson et al. (1972) noted the presence of M. eherenbergii in WLNP.

The turbellaria are seldom eaten by other animals as their surface secretions appear to be distasteful if not actually toxic (Hyman 1951). Bolen (1938) saw dragonfly and damsel fly

nymphs eat planarians, however their worst enemies are other turbellarians for the group is highly cannibalistic, promptly attacking weak or injured members (Hyman 1951).

Polycelis coronata made up less than 3.0% of the stream fauna at all stations except site 130 where 18.3% of all invertebrates were P. coronata making it a significant member of the aquatic community at that site (Table 14). Mesostoma sp. formed a significant part of the shoreline community (Table 16) in the two alpine lakes Oesa and McArthur (25.9 and 25.0% respectively) but only a minor part of the numbers in the subalpine North Narao Lake (1.8%).

Oligochaeta.

Aquatic oligochaetes have the same fundamental structure as the common terrestrial earthworms. They occupy a niche which is equivalent to that occupied by earthworms, and they feed on detritus in bottom mud and mix it much the same as earthworms mix surface soils (Pennak 1953). Several species, especially members of the genus Tubifex, are considered useful as indicators of organic pollution as a result of their ability to survive at low oxygen levels for extended periods (Brinkhurst 1971).

Three species of aquatic oligochaetes were frequently found in lake and stream samples in the Park (Table 19). Limnodrilus sp. was found in dredge samples from unstratified lakes (Mary,

Table 19. Summary of aquatic oligochaete distribution in lakes of Yoho National Park.

Lake No.	Lake name	<u>Limnodrilus</u>			<u>Tubifex</u>			<u>Rhynchelmis</u>		
		D	S	T	D	S	T	D	S	T
6	Ottertail				43					
7	Schaffer							43		+
8	McArthur									
9	O'Hara		1.5		10	0.4		7.1		
10	Mary	4.3						14.3		+
13	Opabin							43		+
14	Opabin				7.1			21.5		
15	Opabin		3							
15A	Opabin						+	21.5		
16	Oesa									
17	Ross							21.5	6	
18	South Narao				43		+	21.5		+
19	North Narao	28.6						93.2		
20	Wapta							204.2	1.3	+
22	Mid Morn. Glory						+	32.2		
23	Up. Morn. Glory									
24	Linda			+						
26	Emerald	129		+						
42	Duchesnay	10.7								
47	Sherbrooke	21.5	2		7.1			2.8	0.5	
48	Sink				92.4					+
49	Summit	63		+				37.2		

D= dredge (numbers m⁻²)

S= shoreline (numbers collected in 30 minute sample)

T= trawl (+ = present)

North Narao, Duchesnay, Sherbrooke, and Summit) and in one stratified lake (Emerald). It was present only in the shoreline samples of O'Hara and Upper Opabin lakes (first order).

Highest numbers (Table 19) of Limnodrilus were observed in dredge samples from Emerald, Summit and North Narao Lakes where they averaged about 5 per dredge sample or about 105 per square metre.

Limnodrilus sp. was the most common oligochaete in stream samples being found at 6 out of 30 stream sites (Table 19). The numbers of Limnodrilus sp. recovered in kick samples from streams were always low averaging less than 1 individual for 3 kick samples at any given station. No particular preference for stream type was noted for Limnodrilus as it was found in the swift flowing Otterhead River, the slower Cataract Brook (site 126), and the silty Kicking Horse River (site 112).

Tubifex sp. were found in 10 of 22 lakes with benthic data. Highest numbers of Tubifex were found in South Narao and Sink Lakes at 64.5 m^{-2} and 93.1 m^{-2} respectively (Table 19).

The only stream sample which contained Tubifex sp. was Cataract Brook (site 130) near its origin at Lake O'Hara.

Rhynchelmis sp. was the largest and most common oligochaete from lake benthic samples. It was found in dredge samples from 13 lakes and in the shore trawl sample from one other lake (see Table 19). This species was also found at three stream

sites: Ross Creek, Upper Kicking Horse River, and Ice River.

Very few data are available on the oligochaete fauna of mountain National Parks for comparison with the present data from Yoho National Park. Schultz (1953) undertook the only quantitative study of the benthic fauna of lakes in the Park. His results on the oligochaete fauna, summarized for comparison in Table 20, are generally similar to those found in the present study. Differences between his results and those of the present study are not considered significant due to differences in sampling techniques, time of sampling, sampling locality, and other factors.

The mean number of oligochaetes from benthic samples may be compared with results obtained in Waterton Lakes National Park where 44 lakes have been examined (Anderson et al. 1972). Results are compared below:

Park	Number of benthic sites	Number with oligochaetes	Mean number m^{-2}
YNP	22	17	54.9
WLNP	44	30	139.5

The higher mean number of oligochaetes per unit area found in lakes of WLNP may be accounted for by the lower elevation of many of the lakes in that park as compared to YNP. Lake altitude was found to have significant negative correlation

($p < 0.05$) with oligochaete numbers in YNP (Figure 33) and this relationship probably holds true for WLNP as well. The highest numbers of oligochaetes m^{-2} at approximately 150-200 in Wapta, Summit, and North Narao Lakes were considerably below the maximum value from WLNP in Crandell Lake (1907 m^{-2}). Several other lakes in WLNP have oligochaete numbers ranging from 200-600 m^{-2} . The relatively high numbers in benthic samples from Wapta Lake (204.2 m^{-2}) is of interest in that it is considerably lower in temperature than the next two highest in oligochaete numbers: Summit and North Narao. The holomictic nature of Wapta undoubtedly contributes to the increased number of oligochaetes as compared to other lakes of a similar size and depth in the Park.

Quantitative stream samples were not collected by Schultz (1953) but Robinson (1972) made several collections in the Lake O'Hara area and found oligochaetes at only one of six sites. Mary Creek was found to have 5 oligochaetes m^{-2} . In the present study oligochaetes were found at only 8 out of 30 stream sites and were always in low numbers usually averaging less than 1 in 3 kick samples (Table 17). Robinson (1972) and Robinson and Smith (1974) found streams near Lake Louise contained larger numbers of oligochaetes with numbers ranging up to 179.2 m^{-2} in Louise Creek.

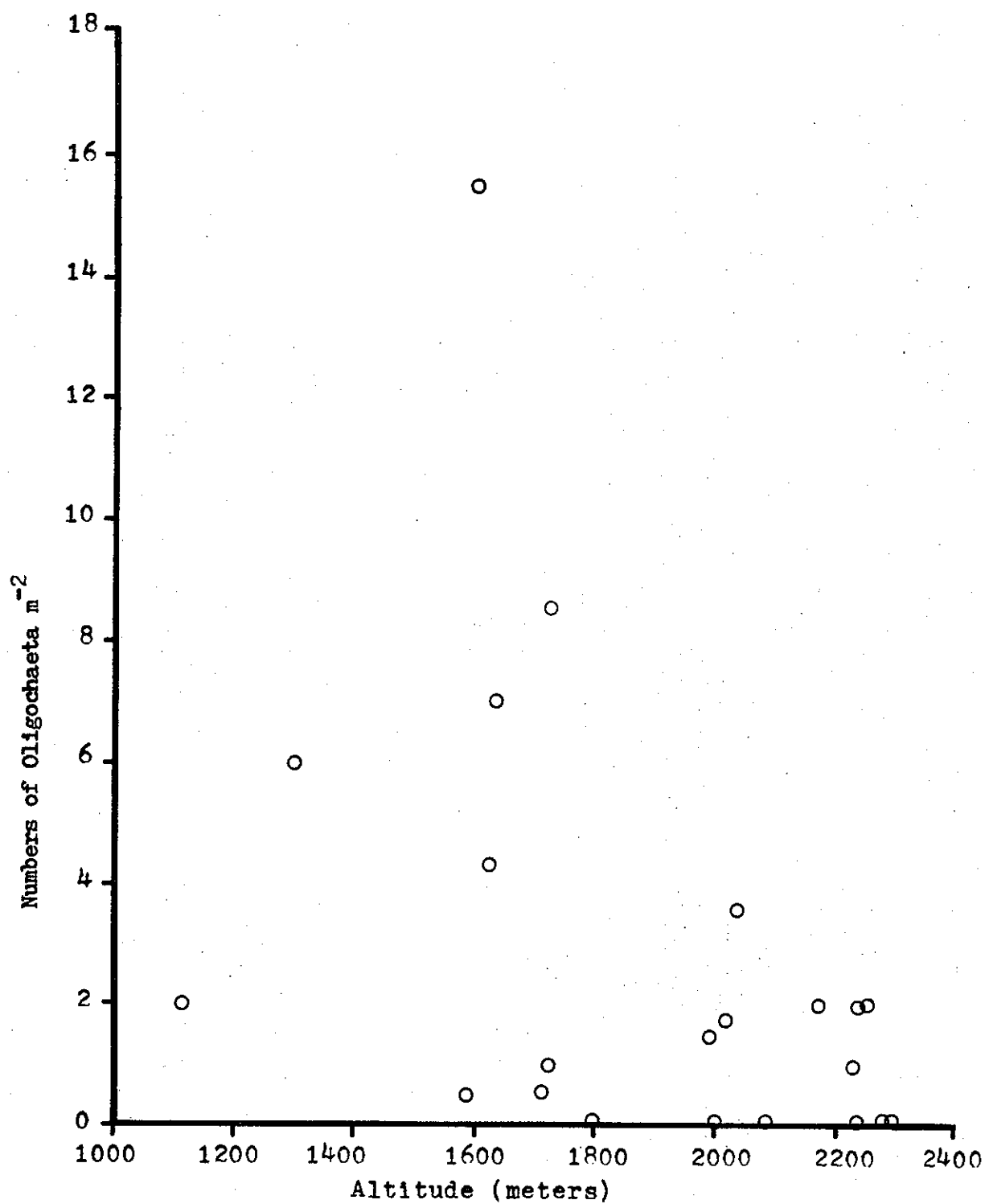


Figure 33

The relationship between altitude and the mean number of oligochaetes in dredge samples.

Eleven stream sites were examined in WLNP by Anderson et al. (1972) who found oligochaetes present at 8. As with the lake samples the oligochaete populations in streams of WLNP were found to be much higher than that of YNP. Comparative numbers of oligochaetes from stream sites examined in BNP, WLNP, and YNP are shown below:

PARK	No. of stream sites examined	No. with oligochaetes	Mean No. m ⁻²	Reference
WLNP	11	6	43.1	Anderson et al. (1972)
BNP	6	5	1.2	Robinson (1972)
BNP	13	13	5.8	Robinson and Smith (1974)
YNP	6	1	0.8	Robinson (1972)
YNP	30	8	0.3	Present report

In dredge samples from lakes the oligochaetes were found to be from 0-19% of the total number of invertebrates found with a mean for 22 lakes of 5.3% (Table 14). Highest values were for Emerald Lake where nearly 1/5 of the specimens from dredge sample were oligochaetes. In stream kick samples the oligochaetes never formed over 2% of the invertebrates present (Table 18).

The low numbers of oligochaetes recovered from most

sampling sites does not allow an accurate evaluation of the possible factors which determine distribution in the Park.

Hirudinea

The Class Hirudinea contains over 300 species of marine, fresh-water, and terrestrial worms, commonly known as leeches. Although they are all popularly considered to be bloodsuckers many species are scavengers which feed on dead animal matter, but more commonly they are carnivorous and feed on snails, oligochaetes, and other small invertebrates (Pennak 1953). These annelids are flattened, and usually possess sucking devices which aid in locomotion and in attachment while eating. Leeches reach maximum abundance in standing waters containing large amounts of debris (Reid 1961). Davies (1971, 1973) has reviewed the distribution and taxonomy of Canadian leeches. Six species, none of which are parasitic, were collected from lakes and ponds in YNP during the present study. A summary of the distribution of leeches in YNP is given in Table 21.

With the exception of Emerald Lake all of the lakes with leeches present were shallow and of a relatively eutrophic nature. Helobdella stagnalis was the most common leech being found in 6 of the 8 lakes which had leeches and was present in a dredge sample from Emerald Lake during a winter sample. Both Glossiphonia complanata and H. stagnalis are almost always

Table 21. Summary of the distribution of leeches in lakes of Yoho National Park.

Species	6*		10		18		19		26		42		47		48	
	Lake No.	Sample type	D	S	D	T	D	S	D	T	D	T	D	T	D	S
<i>Helobdella stagnalis</i>			28.6	-	+		14.0	0.5	7.0	+	-		83.1	105.0	+	-
<i>Glossosoma complanata</i>			-	1	-		-	-	-	-	-		2.8	-	-	-
<i>Erpobdella punctata</i>			-	-	-		-	-	-	-	7.1		5.7	-	-	1.5
<i>Nephelopsis (obscura ?)</i>			-	-	-		-	-	-	-	-		5.7	-	-	-
<i>Mooreobdella fervida</i>			-	-	-		-	-	-	-	-		5.7	-	-	-
<i>Dina (anoculata ?)</i>			-	-	-		-	-	-	-	7.1		-	-	-	-

*D= dredge sample, numbers m⁻²

S= shoreline sample, numbers collected in 30 minutes

T= trawl sample, (+) indicates species present

associated with snails upon which they feed and are consequently commonly called "snail leeches" (Pennak 1953). Reynoldson (1974) reviewed the literature on feeding behavior of H. stagnalis and noted this species appears to be an opportunistic feeder and will feed on a wide range of organisms including chironomid larvae, oligochaetes, aquatic insects, as well as snails. The largest numbers of H. stagnalis were found in Summit Lake where 154.8 m^{-2} were present in dredge samples from dense macrophyte (Chara) areas.

Erpobdella punctata was the most widely distributed member of the Family Erpobdellidae and was found in 3 lakes with numbers ranging around $25-50 \text{ m}^{-2}$. Specimens of Dina, Mooreobdella, and Nephelopsis were each found at only one lake site (Table 21).

Summit Lake had 5 of the 6 species of leech found in the Park, the only exception being Dina (anoculata?).

Rawson (1939, 1940) made extensive faunal surveys of lakes in BNP and JNP. In most cases his reports contain reference only to the most numerous species which were present and benthic counts are not strictly comparable to data in the present study. Rawson mentioned several species of leech from BNP including E. punctata and G. complanata. Leeches

were recorded most frequently from his group of "small, low altitude, highly productive lakes, mostly without permanent outflow". A large number of the lakes investigated by Rawson in JNP contained leeches but none were identified to genus level and no quantitative data are given. In the study by Schultz (1953) on benthic fauna in YNP he made no mention of leeches in any of the lakes examined.

Reynoldson (1974) has presented data on the possible correlation between conductivity and distribution of several leech species in Alberta. Table 22 gives a summary of the data on conductivity and leech distribution in Alberta, YNP, and WLNP.

Leeches may form an important part of the diet of fish as was demonstrated in a study of lake trout from Swan Lake, Alberta, by Paterson (1968) where leeches were found to make up about 15% of the stomach contents. Rawson (1940) noted that brown trout and suckers of Lake Annette (JNP) and eastern brook trout of Beaver Lake (JNP) consumed leeches in small numbers.

Amphipoda (see Plate 4).

Two species in the Order Amphipoda are found in several lakes in the Park. The amphipods, a group of small laterally flattened crustacea, form an important part of the food chain of the benthic and littoral areas where they are found. Anderson

Table 22. Summary of data on conductivity and leech distribution in Alberta, Yoho National Park, and Waterton Lakes National Park.

Species	Alberta		Yoho		Waterton	
	No. of lakes exam/present	Cond. range	No. of lakes exam/present	Cond. range	No. of lakes exam/present	Cond. range
<i>Glossophonia complanata</i>	-	190-2100	22/2	82-242	44/10	27-383
<i>Helobdella stagnalis</i>	-	190-2100	22/6	211-260	44/10	84-383
<i>Theromyzon rude</i>	-	250-4600	22/0	-	44/1	383
<i>Placobdella ornata</i>	-	-	22/0	-	44/1	209
<i>Marvinmeyerii lucida</i>	-	580-860	22/0	-	44/4	383
<i>Erpobdella punctata</i>	-	190-760	22/3	126-242	44/8	257-318
<i>Nephelopsis obscura</i>	-	190-360	22/1	242	44/10	209-318
<i>Mooreobdella fervida</i>	-	-	22/1	242	44/2	-
(Reference)	(Reynoldson 1974)		(present report)		(Anderson et al. 1972)	

and Rassveldt (1974) made both laboratory and field observations of the feeding habits of the two amphipods found in the Park: Gammarus lacustris lacustris and Hyalella azteca. Gammarus was found to be a voracious feeder rejecting plant material in favor of live animal prey. Types of prey eaten included Daphnia (Cladocera), Diaptomus (Copepoda), Helobdella stagnalis (Hirudinea), Branchinecta (Anostraca), and Clinotanypus and Chaoborus (Diptera). Experimental evidence and field data suggests that Gammarus predation may be an important reason why Gammarus seldom, if ever, co-occurs with fairy shrimp (Anostraca), and why co-occurrences of Gammarus and Chaoborus were rare in the waters investigated. No evidence of predatory feeding was observed with H. azteca and this species most likely maintains itself on detritus and plant material.

In addition to the important direct effects on the aquatic communities which results from the feeding habits of amphipods they also contribute in a large way to other trophic levels of the lakes in which they are found. Birds, fish, predaceous aquatic insects, and amphibians often rely heavily on amphipods for food. Amphipods also support populations of algae and sessile protozoa on all of their external surfaces and serve as intermediate hosts for a wide variety of parasites, including tapeworms of waterfowl and fishes, and a few nematodes, trematodes, and acanthocephala of birds, fishes, and

amphibians (Pennak 1953).

The distribution of Gammarus and Hyaella in YNP is shown in Table 23. Seven of the 22 Park lakes with adequate benthic and littoral sample data had one or the other of the two species while one (Sink Lake) had both species. An interesting fact which can be noted in Table 23 is the presence of Hyaella in 4 lakes all of which have rooted macrophytes Gammarus on the other hand, is found in 4 lakes which are relatively free of macrophytes as well as Sink Lake which has a macrophyte population. The data of Anderson and Raasveldt (1974) also show a close correlation between presence of rooted macrophytes and Hyaella. It is possible the feeding habits of this species make it more dependent on macrophytes for its habitat requirements.

In most cases the amphipods were collected in the timed shoreline (30 minute) collections or in trawl samples, a fact which makes accurate quantification difficult (Table 23). From dredge samples Ottertail Flats Lake (lake number 6) appears to have the largest population of Hyaella (at 43 m^{-2}) while Sink Lake has the largest population of Gammarus (at 27.9 m^{-2}). Amphipods usually made up less than 1% of the total numbers of invertebrates in dredge samples from lakes in the Park (Table 14). Rawson (1939) found much higher numbers in some of

Table 23. Summary of amphipod distribution in Yoho National Park.

Lake No.	Lake name	Species Sample type	Gammarus			Hyaletella		
			D	S	T	D	S	T
6	Ottertail		-	-	-	28.6	-	-
9	O'Hara		14	-	-	-	-	-
17	Ross		-	13	-	-	-	-
18	South Narao		-	-	-	-	-	+
20	Wapta		-	1	+	-	-	-
24	Linda		-	6	+	-	-	-
26	Emerald		-	-	-	-	-	+
47	Sherbrooke		3.5	3.5	+	-	-	-
48	Sink		4.7	-	-	14	73	+

D= dredge (numbers m^{-2})

S= shoreline (numbers collected in 30 minute sample)

T= trawl (+ = present)

lower clear lakes of BNP. In Herbert Lake, for example, amphipods made up about 80% of the invertebrate community with numbers ranging up to about 1800 m⁻². Recent samples from Herbert Lake indicate these numbers have been greatly reduced, possibly as a result of heavy fish stocking (R.S. Anderson, unpublished data).

Amphipods were present in stomach contents of lake trout, brook trout, cutthroat trout, or rainbow trout in all lakes listed in Table 23 except for Emerald Lake. In addition to those lakes where amphipods were collected by normal sampling methods examination of stomach contents of brook trout from Ross Lake also yielded amphipods in rather large numbers. Unfortunately specific identification of these amphipods was not made. Schultz (1953) reported amphipods were also present in Mary, Marpole, and Yoho lakes although no quantitative data or specific identifications were given.

Mysidacea (see Plate 4).

The Mysidacea, or opossum shrimp, is an almost exclusively marine Order of the Class Crustacea. One species, Mysis relicta is found in deep, cold, oligotrophic lakes in many parts of the holarctic region formerly connected with or covered by proglacial lakes (Pennak 1953, Hutchinson 1967).

Mysis relicta is not native to waters of YNP as it is not

naturally found west of the continental divide (Lindsey and Franzin 1972) but this species was introduced to Emerald Lake in 1967. Sixty thousand M. relicta collected in Waterton Lake (WLNP) were introduced (Ward 1967) in the hope of improving the rather poor fishery then existing in Emerald Lake. Specimens of Mysis relicta were found in stomach contents of brook trout collected in Emerald Lake during the present study and these findings prompted special collections of Mysis from that lake. The results of these collections are discussed with the zooplankton.

The success of M. relicta transfers to lakes in the mountain National Parks has been in question with no documented recovery of Mysis from any of the lakes. From 1963-1967 over 5 million Mysis were transferred to lakes in the mountain National Parks (Ward 1967). The finding of Mysis in Emerald Lake represents the first indication that the transfers have established breeding populations in any of the lakes and indicates the possible need for an immediate examination of the other receiving lakes. A number of reports and publications are available on the importance of Mysis as a food organism (Clemens et al. 1939), methods of collection (Sayer and Stout 1965, Colbeck and Goble 1967, Anderson 1970c), successful transfers (Sparrow et al. 1964), and evaluation of effects in areas of introduction (Richards et al. 1974, Northcote 1972, Zyblut 1970).

Kootenay Lake, B.C., has often been used as a prime example of the value of Mysis introductions to cause an increase in fish production in lakes lacking a source of large invertebrates (Hanson 1965). Northcote (1972) however, has pointed out that during the period of time when Mysis was thought to be the sole reason for an increase in the growth of fish in the lake a major acceleration in eutrophication occurred as a result of operations at a fertilizer plant. The effect of this eutrophication was to increase the abundance of zooplankton and which effectively masked the contribution of Mysis to the striking increase in size, weight, and growth rate of fish.

Unfortunately it is only in recent investigations that studies have been conducted on the life history (Lassenby and Langford 1972, Carpenter et al. 1974), population characteristics (Reynolds and Degraeve 1972), and feeding and assimilation of Mysis (Lassenby and Langford 1973). Perhaps the most significant finding in these studies, from a management point of view, is that Mysis may not truly "fill the gap" in the food chain between microscopic plankton and forage fish. Instead, Mysis has been found to be a benthic detritivore during the day and is a voracious carnivore in the limnetic zone at night (Lassenby and Langford 1973). These studies on the biology of Mysis and its interspecific relationships have changed the

general tone of the literature from one of unqualified optimism on the potential increase of lake productivity (Hanson 1965) to one where the value of addition of one trophic level (Mysis) only to cause the loss of another (eg. Daphnia and Bosmina) is seriously questioned (Richards et al. 1974).

In any case it is apparent that Mysis can have an important effect on the structure of the zooplankton and phytoplankton communities of lakes where it is present. For this reason we should assume that changes to the population structure of the zooplankton community of Emerald Lake are taking place at the present time and may be expected to continue for some time. A discussion of the effects of the Mysis introductions on the zooplakton of Emerald Lake is included in the zooplankton section of this report. A similar situation may exist in some or all of the other park lakes where transplants have been attempted.

Ephemeroptera.

The Ephemeroptera, or mayflies, are the familiar insects with fragile bodies and slender tails which swarm in the vicinity of ponds and streams. The nymphs of mayflies occupy an important place in the economy of aquatic communities. They are herbivorous and transform plant tissue into animal

tissue. Mayfly nymphs are practically defenseless, making up in numbers for their vulnerability. Since they are so readily available, mayfly nymphs are preyed upon by practically every aquatic predator.

Mayfly nymphs respire primarily by means of articulating gills which are situated at the sides of abdominal segments. Of the ten abdominal segments, from four to seven bear gills at their posterolateral corners (Day 1963). Mayfly nymphs are remarkably differentiated in adaptation to diverse environments. While there are gradations, the forms of body shape fall into categories that match their habitat as follows (Needham et al. 1935):

A. Still water forms

1. Climbers amid vegetation (eg. Siphonourus, Ameletus, Centroptilum)
2. Sprawlers on the bottom (eg. Cinygmula)
3. Burrowers in the bottom (eg. Paraleptophelbia, Habrophelbiodes)

B. Rapid waters forms

1. Agile, free ranging streamlined forms (eg. Parametetus, Ameletus, Baetis)
2. Close-clinging, limpet forms found under stones (eg. Epeorus, Rithrogena, Cinygmula, Ephemerella)
3. Stiff-legged trash-, silt-, and moss inhabiting forms (eg. Ephemerella)

Eighteen species of Ephemeroptera were collected from lakes and streams in the Park (Table 24). Of these 18 all but 2 (Siphonourus sp. and Paraleptophelbia bicornuta) were found

Table 24. Ephemeroptera species found at lake and stream sites in Yoho National Park.

Species	Lake sites examined/present		Stream sites examined/present	
F. Heptageniidae				
<u>Rithrogena robusta</u>	22	1	30	29
<u>Cinygmula</u> sp.	22	0	30	29
<u>Epeorus</u> (<u>Iron</u>) sp.	22	1	30	26
<u>E.</u> (<u>Iron</u>) <u>deceptivus</u>	22	0	30	1
<u>E.</u> (<u>Ironopsis</u>) <u>grandis</u>	22	0	30	22
F. Baetidae				
<u>Ameletus</u> sp.	22	6	30	10
<u>Parameletus</u> sp.	22	7	30	15
<u>Paraleptophelbia bicornuta</u>	22	1	30	0
<u>Habrophelbiodes</u> sp.	22	1	30	1
<u>Ephemerella doddsi</u>	22	0	30	16
<u>E. coloradensis</u>	22	0	30	11
<u>E. inermis</u>	22	0	30	6
<u>E. proserpina</u>	22	0	30	6
<u>E. mararita</u>	22	0	30	2
<u>Baetis</u> sp. A	22	2	30	30
<u>Baetis</u> sp. B	22	0	30	2
<u>Centroptilum</u> sp.	22	5	30	2
<u>Siphonourus</u> sp.	22	7	30	0

in streams. Nine species were found in lakes.

In lakes the Ephemeroptera were usually collected in shoreline and trawl samples and were normally absent from dredge samples. In the four lakes where dredge samples produced Ephemeroptera two were from depths of 1.0m or less and contained considerably larger numbers than in the other two lakes which had deeper dredge depths as shown in the following table:

Lake	Dredge depth	Ephemeroptera No. m ⁻²	% of inverts	Species
O'Hara	5.0	21.5	0.1	<u>R. robusta</u>
Lwr Opabin (15A)	0.6	126.0	85.7	<u>Ameletus</u> sp.
Sherbrooke	8.0	21.5	1.7	<u>Parameletus</u> sp.
Summit	1.0	215.0	2.6	<u>Centroptilum</u> sp.

Only in lower Opabin Pond (15A) did the Ephemeroptera form a significant part of the fauna from dredge samples. This particular pond is characterized by a very shallow depth and a high flushing rate.

The timed shoreline samples present a different picture where the Ephemeroptera often formed a significant part of the fauna. A comparison of numbers of Ephemeroptera collected along

the shore of different lakes and ponds is shown in Table 25. Largest numbers were collected along the shoreline of Upper Opabin, Wapta, and Emerald Lakes where the predominant species was different in each case, a possible indication of the different habitats available in these three lakes. Indeed, a general trend can be seen in the distribution of the predominant species shown in Table 25. In general Parameletus sp. is found in lakes of high altitude, low conductivity and few macrophytes; Ameletus sp. and Siphonourus sp. are found in lakes of moderate altitude and conductivity; Centroptilum sp. is found in more eutrophic lakes of low altitude, high conductivity and large numbers of macrophytes. In all cases the predominant shoreline Ephemeroptera are the types which are usually regarded as "climbers amid vegetation" or "agile, free ranging streamlined forms" described by Needham et al. (1935). Very few of the dorsoventrally flattened close clinging types such as Rithrogena, Epeorus and Baetis were found in lake samples (Table 25).

In the only other examination of lake Ephemeroptera in the Park, Schultz (1953) made only a few references to their presence as follows:

Table 25. Comparison of numbers of Ephemeroptera collected in 30 minute shoreline samples from lakes in Yoho National Park.

Lake number	Lake name	Number collected	Percent of total inverts collected	Predominant species
7	Schaffer	0	0	-
8	McArthur	2	8.3	<u>Parameletus</u> sp.
9	O'Hara	0	0	-
10	Mary	0	0	-
13	Opabin	0	0	-
14	Opabin	0	0	-
15	Opabin	87	81.3	<u>Parameletus</u> sp.
15A	Opabin	10	90.9	<u>Parameletus</u> sp. <u>Ameletus</u> sp.
16	Oesa	2	7.4	<u>Parameletus</u> sp.
17	Ross	1.6	2.3	<u>Ameletus</u> sp.
18	South Narao	0.5	1.4	<u>Centroptilum</u> sp.
19	North Narao	21	19.8	<u>Siphonourous</u> sp. <u>Parameletus</u> sp.
20	Wapta	24	40.6	<u>Ameletus</u> sp.
22	Mid Morn. Glory	8	19	<u>Siphonourous</u> sp. <u>Ameletus</u> sp.
23	Upper Morn. Glory	20	62.5	<u>Siphonourous</u> sp.
24	Linda	0	0	-
26	Emerald	29	22	<u>Paraleptophelbia</u> sp. <u>Centroptilum</u> sp.
42	Duchesnay	0	0	-
47	Sherbrooke	3.5	8.0	<u>Parameletus</u> sp.
48	Sink	25	21.4	<u>Centroptilum</u> sp.
49	Summit	14	38.8	<u>Centroptilum</u> sp.

Lake	Notes on Ephemeroptera from Schultz (1953)
Up. Morn. Glory	"large numbers of nymphs" seen along shore
Mid Morn. Glory	"moderate numbers of nymphs"
South Narao	"rich in mayfly nymphs"
Mary	nymphs in fish stomach contents
Sherbrooke	nymphs in shore coll. & fish stomach contents
Vera	several adults found along shore
Wapta	Nymphs in fish stomach contents

No quantitative data or species lists were provided by Schultz (1953).

Anderson et al. (1972) examined 44 lakes in WLNP and found Ephemeroptera in timed shoreline samples from 27. A general comparison is given below:

Park	No. of lake sites	No. with Ephemeroptera	Mean No. collected in 30 minutes
YNP	21	14	11.7
WLNP	44	27	19.2

The stream Ephemeroptera fauna is numerically dominated by the "close-clinging, limpet forms found under stones" such as Rithrogena robusta, Cinygmula sp., Epeorus (Iron) sp.,

E. (Ironopsis) grandis and a single "agile, free ranging streamlined form", Baetis sp. "A". Lesser numbers of other species were found as shown in Table 26. Baetis sp. "A" was found at all 30 stream sites examined while R. robusta and Cinygmula sp. were both found at 29 stations. Epeorus (Iron) sp. and E (Ironopsis) grandis were not found at 4 and 8 of the 30 sites examined, respectively.

All five of the predominant species were found in greatest numbers at fast flowing stream sites of moderate to high elevation such as Ice River, Porcupine Creek, Upper Ottertail River, Upper Yoho River, Sherbrook Creek, and Cataract Brook. They frequently averaged 100-200 m⁻² at these sites. The numbers were lowest at upper Cataract Brook (site 130), Twin Falls Creek (site 122), and in the lower reaches of the Kicking Horse River. An exception is E. (Iron) sp. which was found in high numbers in the lower Kicking Horse River. Figure 34 illustrates the relative changes in numbers m⁻² of Ephemeroptera at stations in the upper Cataract Brook drainage, Cataract Brook, and the Kicking Horse River. Absence of three of the dominant species from site 130 and the general decline in numbers of most species as one proceeds downstream may be noted.

A similar decline is apparent when proceeding downstream at all of the major tributaries of the Kicking Horse River

Table 26. Summary of mean numbers m⁻² of Ephemeroptera from stream sites in Yoho National Park.

Species	Site	102	104	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	132	133	134	Mean
<i>Rithrogena robusta</i>		205.5	5.5	10.5	110.0	60.0	78.0	158.0	79.0	11.5	27.0	51.5	51.5	64.0	122.5	46.5	41.5	192.5	151.0	43.0	128.0	30.0	27.5	34.0	150.0	168.0	16.5	0.0	58.0	3.0	2.5	70.8
<i>Cinygmula</i> sp.		21.5	10.0	30.0		3.0	13.0	108.0	22.5	57.5	3.0	24.0	263.0	41.5	33.0	115.5	168.0	91.5	7.0	24.0	43.5	111.5	135.0	152.5	77.5	15.5	0.8	7.5	8.0	271.5	1.5	52.0
<i>Epeorus</i> (Iron) sp.		62.5		148.5		14.5	91.5	191.5	47.5	75.5	2.0	46.5	50.0	21.5	36.5	55.5	76.5	8.0	8.0	3.0	3.7	3.0	2.5	64.0	43.0	24.0	50.0		276.5	1.5		46.9
<i>Epeorus</i> (Iron) <i>deceptivus</i>			0.5																												0.01	
<i>Epeorus</i> (Ironopsis) <i>grandis</i>		12.5		11.5	1.5	1.5	1.5	36.5	21.5	13.0	6.0	2.5	10.0		31.5	22.5		4.1	19.0	2.5	17.5	46.5	15.5	11.5	45.0	1.5					11.5	
<i>Aesletus</i> sp.		0.5	1.5											5.5	0.5												15.0	35.5	5.0	10.5	2.8	
<i>Parasetus</i> sp.			2.5		1.5				0.5	2.5			1.5	5.5	0.5	0.5		31.0	3.0	3.5		5.5				16.5	1.5				2.5	
<i>Habrophelbiodes bicincta</i>																											2.5				0.09	
<i>Ephemerella daddsi</i>		3.0		5.5	2.5	2.5	5.0	6.5	0.5	0.8		0.5		4.0		30.0	5.0					5.0	7.5	1.5	5.5	23.0					3.7	
<i>Ephemerella coloradensis</i>		9.0		0.5						3.0			2.5		3.0	5.5	1.6						6.0	5.0		2.5	1.5				1.3	
<i>Ephemerella inermis</i>		0.8	3.0	3.0					2.5							9.0								14.0							1.0	
<i>Ephemerella prosperina</i>			20.0						1.2						26.5	0.5	0.8						0.5								1.6	
<i>Ephemerella margarita</i>				2.5																											0.08	
<i>Baetis</i> sp. A		46.5	1.5	11.0	21.5	25.0	26.5	196.5	49.0	67.5	15.0	10.5	221.5	39.0	85.5	48.0	96.5	68.0	221.0	25.0	25.5	61.5	26.5	50.0	49.0	67.5	8.0	58.0	130.0	165.0	1.9	63.9
<i>Baetis</i> sp. B			5.0							0.5																						0.1
<i>Centroptilum</i> sp.																					0.5											0.03

(Figures 34, 35, and 36). This trend does not appear to be due only to a change in altitude as no significant correlation ($p > 0.05$) was found between this factor and numbers of Ephemeroptera. Rather it appears changes in numbers and species composition may be more closely related to stream gradients and water chemistry. The decrease in stream gradients in the lower reaches of most streams may be responsible in part for an increase in the number of species present at the downstream stations (Figure 37). The close clinging forms which dominate the faster waters are present in the slower waters along with those additional nonflattened species which are able to invade the areas of more moderate gradient. This latter group of Ephemeroptera includes Ameletus, Parameletus, and Ephemerella coloradensis, all of which were usually found in relatively low numbers (Table 26).

The possible correlation of the stream water chemistry parameters (shown in Table 9) with numbers of ephemeroptera was examined and produced some interesting results. The Ephemeroptera as a group were found to vary inversely with the TDS, for example, as shown in Figure 38. The numbers of Ephemeroptera at any given site also show a rather constant and predictable decline with an increase in parameters such as conductivity, total alkalinity, hardness, bicarbonate, calcium, and silica. Two sites are notable exceptions. Site 130 at the

Figure 34

Numbers and species of Ephemeroptera collected at sites in the Cataract Brook-Kicking Horse River system.

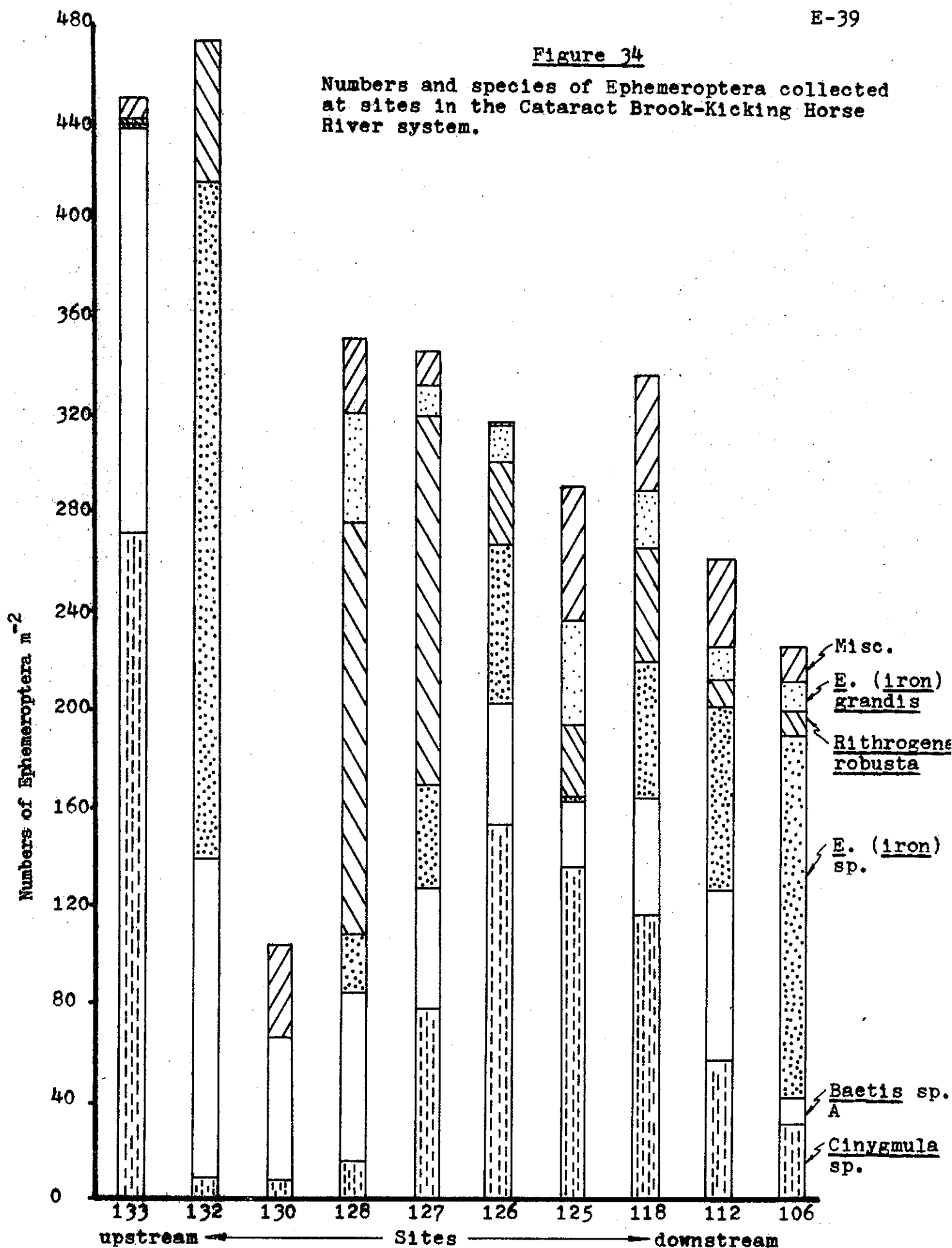


Figure 35

Numbers and species of Ephemeroptera collected
at sites in the Yoho-Kicking Horse River system.

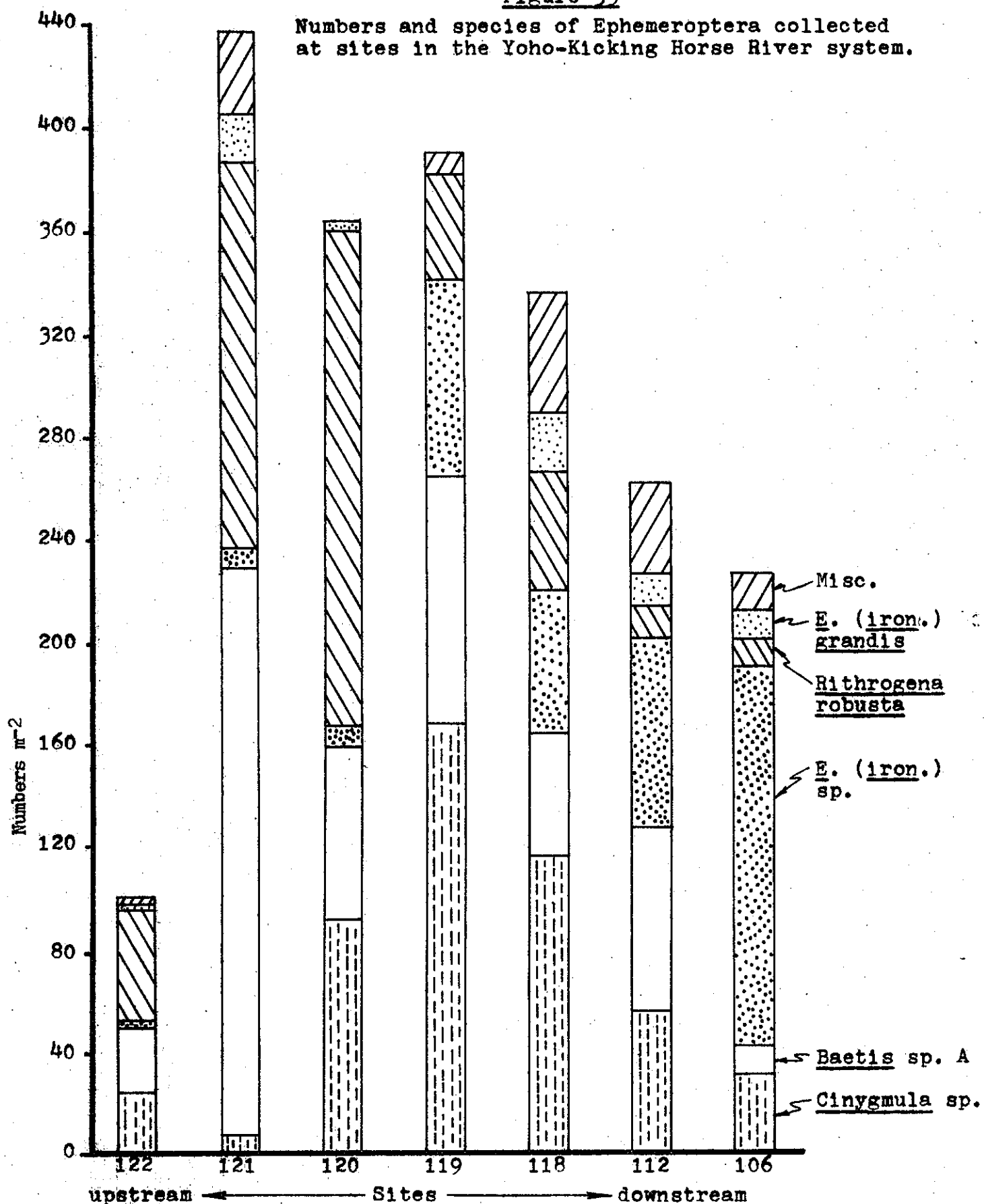
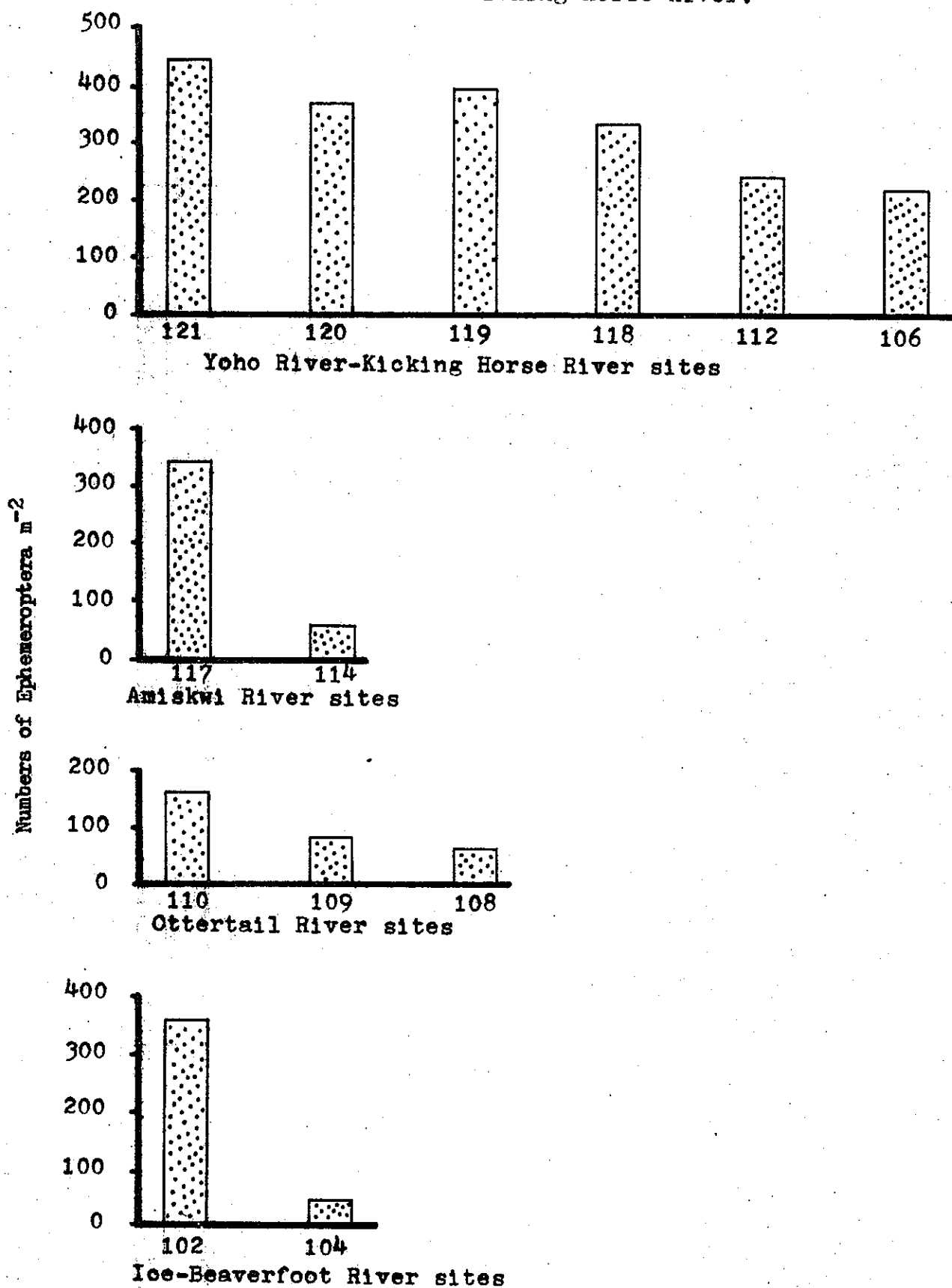


Figure 36

Numbers of Ephemeroptera collected at sites in
tributaries of the Kicking Horse River.



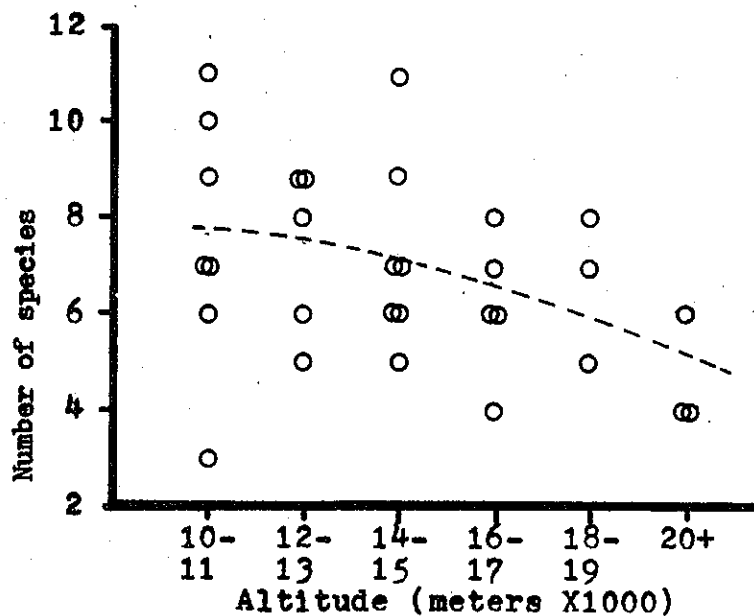


Figure 37

The relationship between altitude and numbers of Ephemeroptera species at stream sites in Yoho National Park.

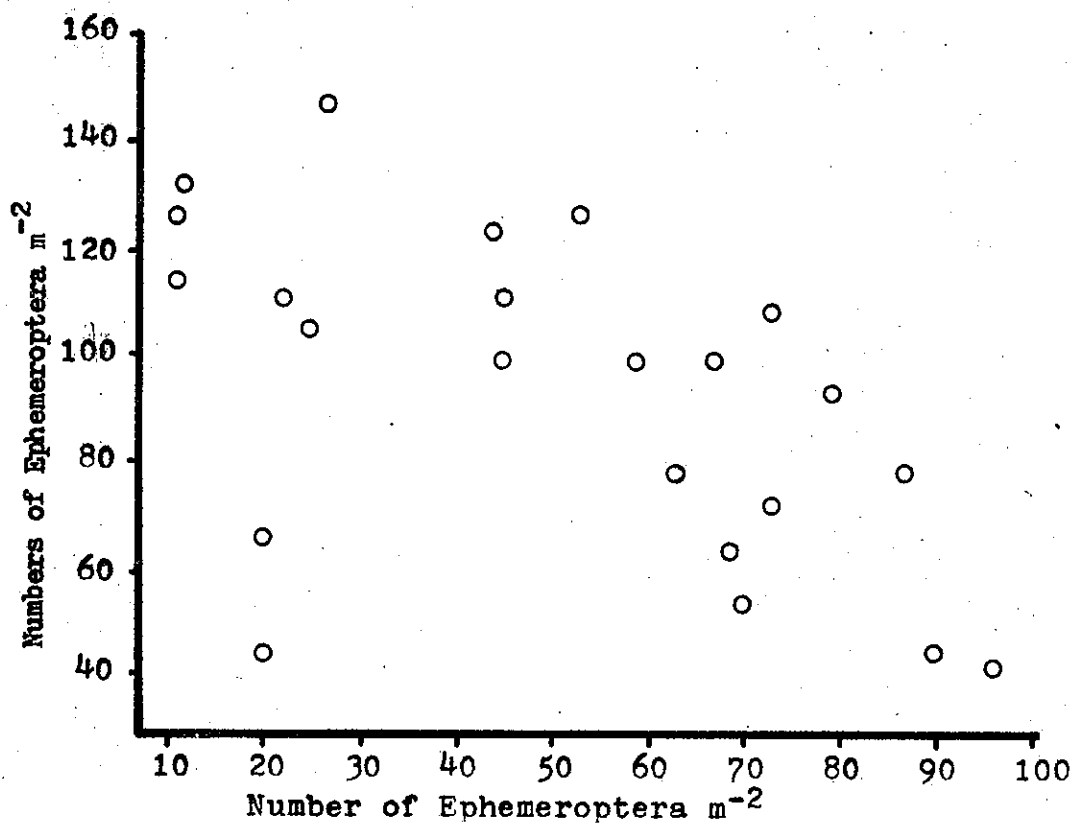


Figure 38

The relationship between the numbers of Ephemeroptera collected and total dissolved solids at stream sites in Yoho National Park.

origin of Cataract Brook and Twin Falls Creek (site 122) produced fewer Ephemeroptera than would be expected following the trends shown in the graph. The anomaly presented by site 130 may be explained by the relatively eutrophic nature of this site as a result of its close proximity to the Lake O'Hara Lodge (Wishart 1970, Robinson 1972, Mudry and Anderson 1973). Robinson and Smith (1974) found Ephemeroptera made up a smaller percentage of the invertebrate population in "eutrophic" stations as compared to "oligotrophic" stations in the Lake Louis area. A similar situation exists in YNP where Ephemeroptera generally make up about 60-80% of the invertebrates in streams while at site 130 they make up only 16.4% of the total number of organisms present (Table 18).

A different situation seems to be operating at site 122 where the percentage of Ephemeroptera is high but their actual numbers are considerably lower than would be expected. The possibility of nutrient enrichment due to upstream activities associated with the tea house cannot be ruled out, but one would expect changes in the percentage composition of invertebrate groups if eutrophication was the cause of the low numbers observed.

With the exception of 5 sites the Ephemeroptera usually made up more than 50% of the invertebrates collected at stream

sites. For all streams a mean value of 63.0% Ephemeroptera was obtained (Table 18). Robinson (1972) examined several sites in the Lake O'Hara area and obtained results very similar to those of the present study:

Site	Present study		Robinson (1972)	
	Mean percent Ephemeroptera	No. m ⁻²	Mean percent Ephemeroptera	No. m ⁻²
126	56.4	322	39.5	115
129	33.8	109	45.5	100
130	16.4	103	13.1	57
132	70.7	472	55.6	243
133	26.2	447	28.0	265

Streams in WLNP had a mean of 732 (200-1750) Ephemeroptera m⁻² at 11 sites examined by Anderson et al. (1972). They found a total of 15 species at stream sites which ranged in elevation from 1281-1707m as compared to 16 species at stream sites ranging from 1094-2014m in YNP.

Plecoptera.

Adult Plecoptera, or stoneflies, are aerial insects, but they are seldom found very far from running water, the habitat of the immature stages. The nymphs are all strictly aquatic, and, as a group, are remarkably homogeneous in structure. They resemble the adults but may be distinguished

from them by the structure of the mouth parts, lack of genitalia, and often by the presence of filamentous tracheal gills, and wing pads instead of wings (Pennak 1953). The "two-tailed" (two cerci) appearance would be a distinctive mark of the order in aquatic habitats, except that nymphs of a few genera of mayflies lack the central caudal filament. Stonefly nymphs are most abundant in rapid stony parts of streams, less common in quiet reaches. They seem to avoid bare mud bottoms completely, but are often numerous on logs or stumps which protrude above the mud. A few species occur along the stony shores of large and small alpine and subalpine lakes (Edmondson 1963). The Perlidae, Perlodidae, and some Chloroperlidae are carnivorous and feed on other aquatic insects including mayfly nymphs and Diptera larvae. The other forms feed on algae and vegetable debris (Pennak 1953).

A total of 14 stonefly species were collected in the Park, 7 each in the carnivorous and herbivorous groups noted above. As is the case with mayflies they are sparsely represented in lakes with only one common species and 4 rare species from shoreline and trawl and samples (Table 27). Alloperla fidelis(?) was found in shoreline and trawl samples of 5 alpine and subalpine lakes with highest numbers at upper Opabin Lake where 15 individuals were collected along the rocky shore. Lower but still significant numbers were collected

Table 27. Summary of mean numbers of Plecoptera collected from lakes of Yoho National Park.

Species	Lake No. Sample type	15*		16	17	20	23	47		49
		S	T	S	S	S	S	S	T	T
<i>Arcynopteryx aurea</i>		-	-	-	-	-	1	-	-	-
<i>Alloperla fidelis</i>		15	+	9	1.6	2.3	-	1	+	-
<i>Isoperla ebria</i>		-	-	-	-	2.6	-	4.5	+	-
<i>Acroneuria pacifica</i>		-	-	-	-	0.3	-	-	-	-
<i>Nemoura oregonensis</i>		-	-	-	-	-	-	-	-	+

*S= shoreline sample, numbers collected in 30 minutes
 T= trawl sample, (+) indicates species present

along the shore at Oesa, Sherbrooke, Ross, and Wapta lakes where logs and other debris apparently supplied suitable habitat.

Of the remaining species found in lakes only one, Isoperla ebria, was found in more than one lake. This species was found in small numbers at Sherbrooke and Wapta lakes.

The Plecoptera formed a large proportion of the total shoreline invertebrate fauna at only one lake, Oesa, which is alpine and characterized by a rocky shoreline and very oligotrophic conditions (Table 16). The only species found at this site was A. fidelis. In the remaining lakes the Plecoptera made up approximately 0-14% of the total shoreline fauna.

In the study of Park lakes conducted by Schultz (1953) no mention was made of Plecoptera except for the presence of one adult collected along the shore of Vera Lake. No other studies are available on the Plecoptera of lakes in the Park.

Plecoptera were found at all 30 stream sites examined in the Park with numbers ranging from 6.0-83.2 m^{-2} (Table 17 & 28). Nemoura oregonensis and A. fidelis were the most common species being found at 24 and 25 of the 30 sites, respectively. Nemoura oregonensis was the most numerous species averaging 11.5 m^{-2} with a range of 0-46.5 m^{-2} .

Table 28. Summary of mean numbers m⁻² of Plecoptera from stream sites in Yoho National Park.

Species	Site	102	104	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	132	133	134	Mean	
Peltoperla Earlana											0.8		28.0								0.8					5.0	15.8	5.0		1.5	1.5		1.9
Nesoura catractae	0.8							3.0						1.5							0.8		1.8		7.6	3.3	11.5	6.6			14.1	1.6	
Nesoura cinatipes					1.5										0.8						0.8							25.0					0.9
Nesoura colubiana	14.1						1.5	5.0	4.1			2.5		0.8	0.8	0.8		0.8	22.5	0.8		1.5	1.8	5.0	1.6								2.1
Nesoura oregonensis	34.1	0.8				5.0	3.0	46.5	5.0	6.6		3.3	1.5	12.5	5.8	40.8	7.5	30.8	20.0	2.5	19.0		21.8	13.3	5.0	4.0	28.0		30.0		0.6	11.5	
Nesoura Sp.						1.5			2.5	2.5			1.5	0.8	2.5						0.6	1.5	0.6					5.0				0.6	
Carnia Sp.	3.3				6.5			6.5	5.8		0.8	0.8	6.5	9.1	19.1					0.8		6.5	2.5	0.8	28.3	25.0	10.0	0.8				4.4	
Arcynopteryx aurea	3.3		0.6				1.5	6.5		0.8		5.0	10.0	3.3		5.0	0.6	10.0	3.3	2.5	15.0	1.5	1.2	4.1	7.5	5.8	1.5		5.0			3.3	
Isonenus Sp.										0.8														9.3									0.3
Isonerla Sp. C																						0.6				4.1	1.5	37.5			2.5	1.5	
Isonerla stria																												0.8				0.02	
Isonerla tilva			1.8																						1.6						0.8	0.1	
Allonerla fidella (?)	9.0	5.0	16.2	11.5					1.6	5.0	7.5	6.6	3.3	1.6	13.0	15.0	5.0	7.5	17.5	3.3	3.3	25.0	18.7	3.3	26.6	10.8	5.0		8.0		0.8	7.5	
Acronerula pacificae																					5.8		3.0			5.0	1.5	17.5			17.5	1.5	

Plecoptera made up an average of 9.7% of the total fauna of the stream sites examined with a range of 0.3-29.1% (Table 18). This figure compares favorably with that obtained from an analysis of the data presented by Robinson and Smith (1974) from BNP where Plecoptera averaged 9.8% (range 5-15%) of the total fauna of streams examined in the Lake Louise area. As noted previously their study was conducted in areas of oligotrophic and eutrophic conditions and indicated the Plecoptera form a rather constant proportion of the total invertebrate fauna under variable conditions. Analysis of the data for streams of WLNP presented by Anderson et al. (1972) indicates the Plecoptera made up a slightly lower proportion of the invertebrate population at 6.0%.

At site 130 in YNP the Plecoptera made up 13.2% of the total fauna. Although this percentage was not unusually high for the Park, this site was characterized by the absence of the more common species and the presence of 3 species only rarely found at other sites in the Park (Table 28). Robinson (1972) found 15 species of Plecoptera in the streams of the Lake O'Hara area. Analysis of his data indicated the species dominant in most areas were absent from site 130 and were replaced, as in the present study, by several species not usually found at other stations. A general comparison with the present data is given below:

Site	Robinson (1972)		Present study	
	No. species	Mean No. m ⁻²	No. species	Mean no. m ⁻²
133	4	60	2	6.5
132	4	23	4	44.5
131	3	105	-	-
130	11	90	6	83.0
129	3	12.5	8	64.0
126	5	27.5	6	35.8

Distribution of stream Plecoptera in the Park appears to differ somewhat from that described previously for Ephemeroptera. The relationship of altitude to the number of species present is quite different with a general trend for more species at higher elevations (Figure 39). With only a small number of sites in each altitudinal range, it is difficult to determine statistical significance of the data available. However, one may note there are nearly twice as many species from sites at 1800-2000 m as at 1200-1400 m. The 3 highest sites (above 2000 m) had a lower number of species which may indicate the presence of more clearly defined upper environmental limits. These observations on the relationship of altitude and number of Plecoptera species compare favorably with those of Knight and Gaufin (1966) who found a similar relationship in the Gunnison River drainage of Colorado.

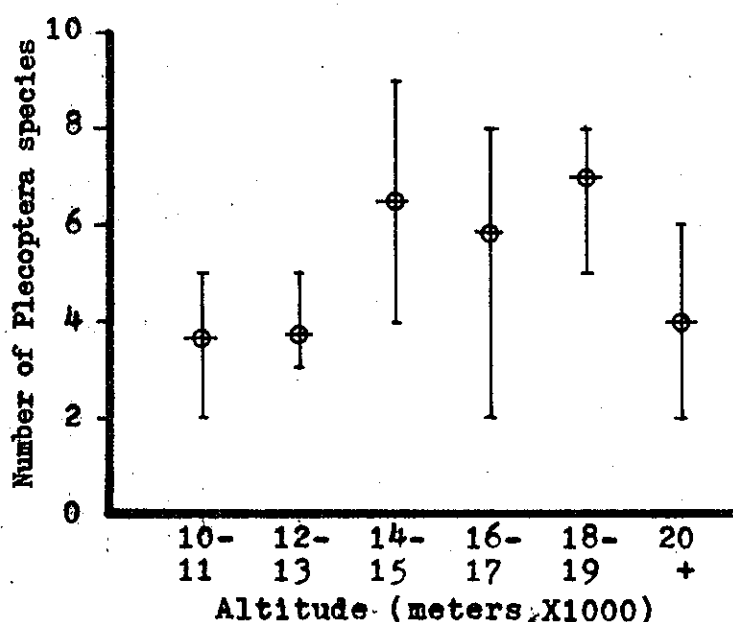


Figure 39

The number of Plecoptera species present at stream sites of different altitudes in Yoho National Park. Mean value and range shown.

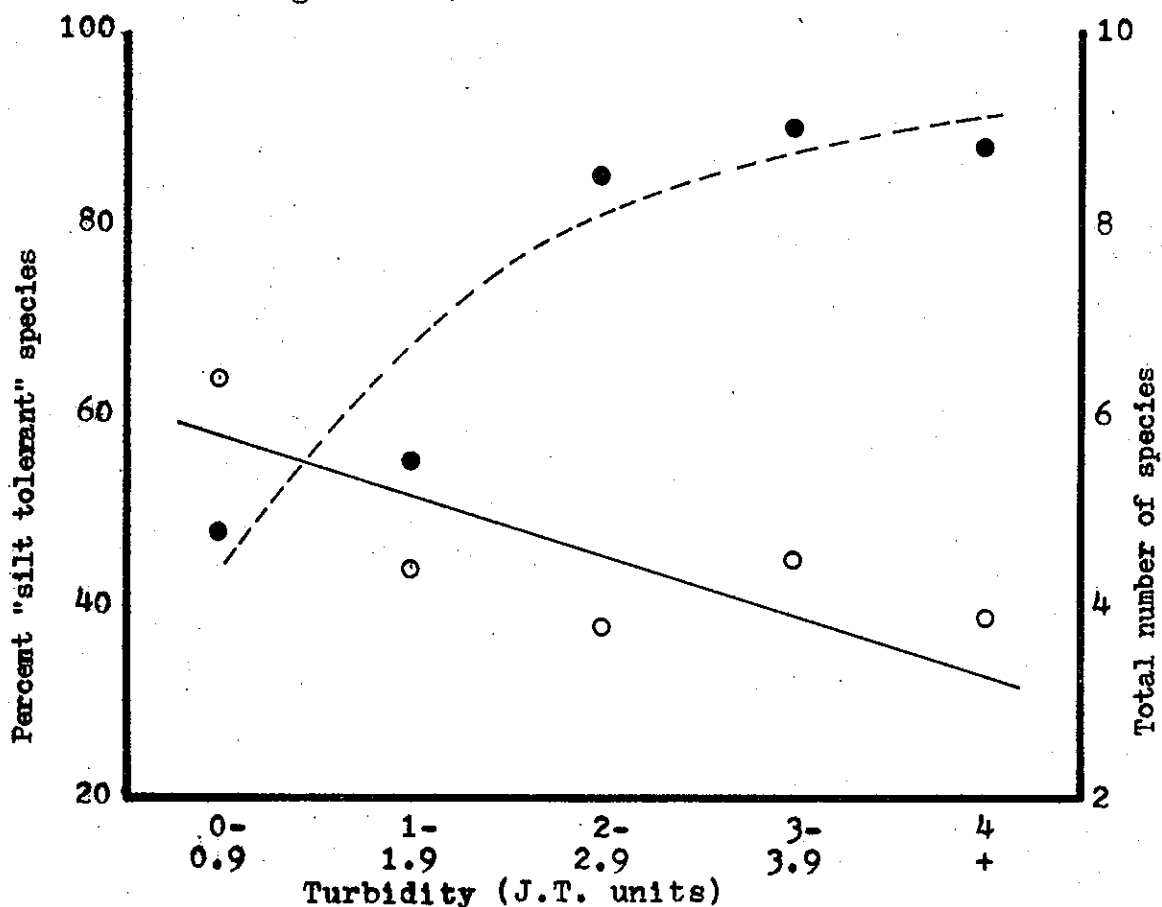


Figure 40

The total number of Plecoptera species and the percentage of "silt tolerant" species present at different levels of turbidity in streams of Yoho National Park.

A second environmental feature, not altogether unrelated, which appears to have some effect on the types of stoneflies present at any given site, is turbidity. Several of the species in the Park are present in a wide range of altitudes (e.g. Peltoperla mariana, N. cataractae, N. cinctipes, Capnis sp.) but are absent from stations which are moderately to heavily silted (see turbidity levels in Table 9). Likewise, there are several species which appear to be unaffected and are found under conditions of both high and low turbidity (e.g. N. columbiana, N. oregonensis, Nemoura sp., Arcynopteryx aurea, A. fidelis). This latter group of stoneflies we may refer to as silt-tolerant since their numbers remain high through a wide range of turbidity values. Figure 40 illustrates the changes in the number of species present at various turbidity levels as well as the dominance of silt-tolerant species at the higher turbidity levels. At turbidities of 0-1 and 1-2, silt-tolerant species make up 45-55% of the total, while at higher turbidities they constitute over 85% of the species present. A further indication of this trend is seen in the population size of each group at different turbidities (Figure 41).

Knight and Gaufin (1966) found a general change in the composition of species with a change in altitude. Members of the Suborder Setipalpia (mostly carnivorous species) were

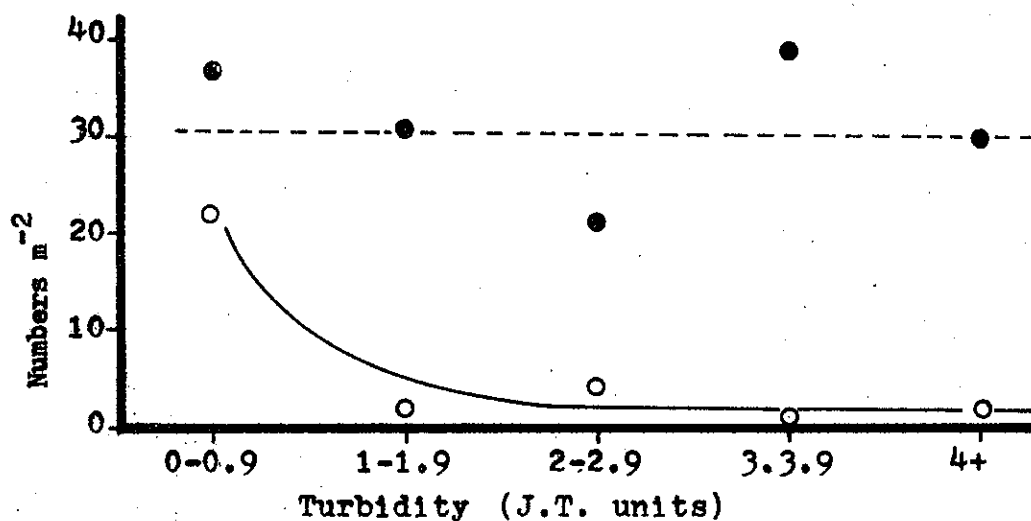


Figure 41

Numbers of "silt tolerant" (●) and other Plecoptera (○) at different levels of turbidity.

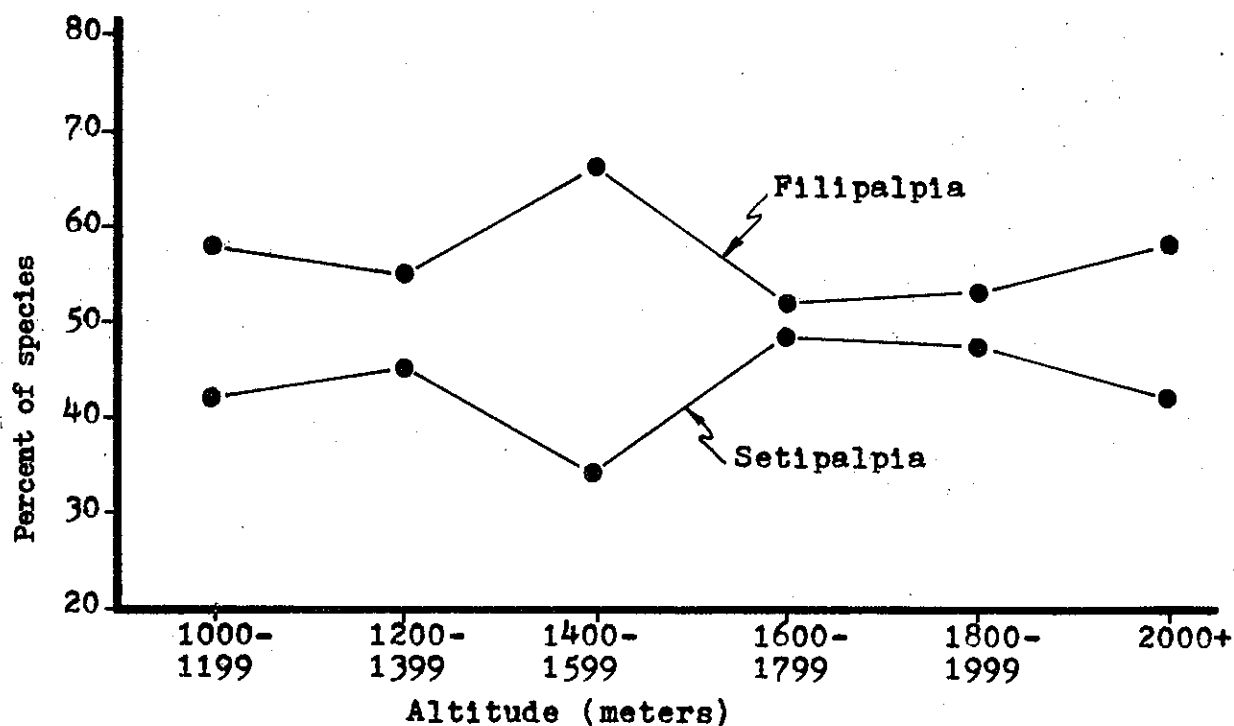


Figure 42

Distribution of the Plecoptera Suborders Setipalpia and Filipalpia relative to altitude in Yoho National Park.

dominant at all elevations examined but became more so at higher elevations. In the present study the Setipalpia were found to be subdominant at all elevations and no particular trend was noted (Figure 42).

Trichoptera.

Insects of the Order Trichoptera (caddis flies) are represented in aquatic habitats by their larvae and pupae which may be found in all types of fresh-water habitats. The aerial adults are short-lived, and in most species it is likely that this stage lasts about 30 days or less. The greater portion of the life history is spent as a larva, and it is usually this stage that overwinters. Many species build hollow cylindrical cases composed of sand grains, gravel, small pieces of leaves, grass, bark, or twigs. Other species may build silken nets for the collection of food. Species of the genus Rhyacophila build no case or net.

Caddis fly larvae are chiefly omnivorous although the Limnephilidae, Hydropsychidae, and many Hydroptilidae feed mainly of diatoms, other algae and higher plants. The genus Rhyacophila and some Psychomyiidae, on the other hand, are thought to be generally carnivorous; for these groups food consists of small crustaceans, annelids, and insect larvae. Most

stages of one or more species of Rhyacophyllia.

Twelve or more species of Trichoptera were present in the lakes and streams of the park. In lakes, Trichoptera were usually found in shoreline collections and trawl samples while dredge samples producing Trichoptera were usually taken from depths of 1m or less. Altogether, one or more of six species were present in 17 lakes. An unidentified member of the family Limnephilidae (probably Limnephilus sp.) was the most common lake caddis fly, occurring in 16 of 22 lakes examined (Table 29). This species was present in highest numbers in shallow third-order lakes such as Mary, North Narao, Duchesnay, and Mid Opabin (site 14). Hesperophylax sp., found in 6 lakes, was the second most common species, but averaged less than one specimen per 30 minute shoreline collection in the lakes where it was found. Trichoptera in lake shoreline samples made up an average of 16.7% of the total number of invertebrates with the largest percentage at South Narao, Mid-Opabin, Sherbrooke, Duchesnay, and Mary Lakes. For these lakes, the Trichoptera are an important group, making up roughly 1/3 to 1/2 of the total numbers of invertebrates in shoreline collections (Table 16).

Schultz (1953) included some references to the presence

Table 29. Summary of mean numbers of Trichoptera collected from lakes in Yoho National Park.

Species	Lake No. Sample type	6*		7		9		10		13		14		16		17		18	
		D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S
Banksiola sp.		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glyptotaelius sp.		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.5	6
Hesperophylax sp.		-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Limnephilidae		-	2	0.4	12.5	50	+	15	38	1	6	6.5	4						
Mystacides sp.		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phrynganea sp.		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Species	Lake No. Sample type	19		20		24		26		42		47		48		49	
		S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
Banksiola sp.		-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	+
Glyptotaelius sp.		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hesperophylax sp.		-	-	0.3	-	1	0.3	-	1	0.6	-	1	0.6	-	-	-	-
Limnephilidae		7.5	4.5	7.5	1	5	8.5	7	15	5.5	1	-	4	8			
Mystacides sp.		-	-	-	-	-	-	-	-	-	-	-	-	+	4.3	-	-
Phrynganea sp.		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*D= dredge sample, numbers m⁻²

S= shoreline sample, numbers collected in 30 minutes

T= trawl sample, (+) indicates species present

of Trichoptera in 8 of the 20 lakes he examined. A summary of his comments are included below:

Lake	Comment on Trichoptera (Schultz 1953)
Marpole	"abundant"
Mid Morning Glory	"moderate numbers"
South Narao	"rich in...larvae"
Ross	"rich supply"
Mary	"abundant"
Sherbrooke	"a few specimens"
Yoho	"abundant"
Vera	"relatively good in...larva"

Schultz's comments are in general agreement with the present data although he provided no quantitative data for comparison.

Very little overlap was found in the species inhabiting lakes and streams. Four species (Rhyacophilia sp., Glossosoma sp., Parapsyche sp., and Neothremma sp.) dominated the stream kick samples, where a total of 9 species were found.

Rhyacophilia sp., Glossosoma sp., and Parapsyche sp. were present in most of the stream habitats in the park including both clear and silty sites (Table 30). Neothremma sp. appears

Table 30. Summary of mean numbers m⁻² of Trichoptera from stream sites in Yoho National Park

Species	Site	102	104	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	132	133	134	Mean
<i>Prospertilia</i> sp.		10.0	-	-	1.5	1.5	6.5	26.5	3.0	1.6	-	-	15.0	5.8	20.8	3.3	3.3	6.6	4.1	0.8	0.6	1.5	4.3	8.3	15.0	21.0	5.5	1.6	-	1.5	23.7	6.4
<i>Dioszegia</i> sp.		7.5	-	18.7	1.5	6.5	-	1.5	1.5	5.8	-	-	15.0	4.1	2.5	6.6	0.8	-	-	-	-	20.6	7.5	-	0.8	1.5	-	-	-	-	-	3.4
<i>Evania</i> sp.		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-	-	0.02
<i>Fannia</i> sp.		4.1	-	1.8	-	3.0	1.5	6.5	4.1	2.5	-	2.5	-	3.3	5.8	3.3	0.8	1.6	-	-	7.5	-	8.7	8.3	6.6	11.6	8.0	-	-	2.5	3.1	-
<i>Eckonia</i> sp.		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	-	-	-	-	-	-	-	-	-	-	-	-	0.02
<i>Hydrophylax</i> sp.		-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05
<i>Neoboreia</i> sp.		-	-	-	-	-	-	-	-	-	-	0.8	8.0	-	-	0.8	-	-	-	-	-	-	0.6	71.6	73.6	3.3	88.0	0.8	-	-	22.5	8.9
<i>Trichopterus</i> sp.		5.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
Unid. Limnephilidae		-	-	-	-	-	-	-	-	-	0.8	-	-	1.6	0.8	-	-	-	-	-	-	-	-	-	2.5	-	3.0	0.8	-	-	-	0.2

to avoid silty sites and was confined mainly to the Amiskwi and Cataract drainages. This species produced the highest numbers of Trichoptera with numbers ranging from 70-88 m^{-2} at lower Cataract Brook sites.

The Trichoptera averaged 6.4% of the total stream fauna for all stations with values of approximately 16-30% in Ross Creek and the lower Cataract Brook sites (Table 18). Data on stream Trichoptera in the Lake O'Hara area from the present study compares well with that presented by Robinson (1972), a summary of which is given below:

Site	Robinson (1972)		Present report	
	Mean No. m^{-2}	% of fauna	Mean No. m^{-2}	% of fauna
133	21.5	2.1	1.5	0.08
132	0.0	0.0	0.0	0.0
130	5.0	0.5	3.2	0.5
129	45.0	27.2	106.0	38.7
126	80.0	27.3	95.7	16.7

Comparison of the data indicates the differences between sites are of a rather consistent and long standing nature.

Anderson et al. (1972) found many of the same genera of Trichoptera in WLNP streams as were found in YNP. In general

WLNP streams were dominated by Glossosoma and Rhyacophila sp., both of which are common in YNP. Lineham Brook (WLNP) produced 327 Trichoptera m^{-2} (mostly Glossosoma sp.), considerably more than the most dense populations found in Yoho National Park (105 m^{-2}).

Chironomidae (midges).

The Diptera are highly specialized two-winged flies, including such common insects as houseflies, mosquitoes, midges, crane flies, horseflies, hoverflies and botflies. In aquatic communities of the Park, the most important group of Diptera, from a numerical point of view, is the Chironomidae (Chironomids or midges, see Plate 5).

Chironomid larvae are elongated, cylindrical, slender, and range from about 2 to 30 mm in length. They have a pair of prolegs on both the first thoracic and last abdominal segments (Pennak 1953). Chironomid larvae are most abundant in the shallow water areas of lakes, ponds, and streams favored by a heavy growth of aquatic plants. Sandy bottoms are much less suitable for chironomids than soft mucky bottoms upon which most bottom dwelling species depend for building their tubes. The herbivorous and microphagous habit is characteristic, as is the building of flimsy tubes of organic detritus, algae, or small sand grains and silt. Such tubes are lined with a silky substance of salivary secretion. Usually the tubes are attached, but in a very few species they are portable (Pennak 1953).

Feeding habits of chironomids differ widely. The Tanypodinae, for example, are usually considered to be carnivorous (Pennak 1953) but, whereas many species do attack and consume aquatic invertebrates, probably very few are obligate carnivores (Oliver 1971). Some chironomid species are leaf miners and ingest plant tissue whenever they extend their tubes. Several species of

Cricotopus feed entirely on the leaves of potomageton (Berg 1950). Most chironomid larvae are microphagous, feeding on small plants, animals, and detritus. Most of the microphagous species can be placed in three noncarnivorous groups as defined by Coffman (1967) in his study of species living in a stream. These groups are algal, detrital, and algal-detrital feeders. Most of the Orthocladinae and Chironominae are either algal or algal-detrital feeders and only one genus (Cryptochironomus) is classed as a detrital feeder. Most of the algal feeders feed mainly on diatoms. The intestinal contents of several Diamesa from an Amiskwi River tributary (site 115) were examined and found to contain diatoms which presumably make up part of the periphyton of that stream. Diatom species found were as follows:

Hannea arcus
Meridion circulare
Fragilaria sp.
Achnanthes sp.
Diatoma hemale

Throughout the Family Chironomidae, diatoms are one of the most important sources of food. Brundin (1966) has suggested that the primitive habitat was rich in diatoms and that early chironomid evolution could have proceeded independently of other types of plants (Oliver 1971).

Chironomid larvae are preyed upon by larger insects, fish, and birds, especially those which are bottom feeders (Wirth and Stone 1963).

Although dipterists are agreed on the higher taxonomic categories, the classification of the chironomid larvae at the species level is confused and difficult. This situation is due

chiefly to the fact that the differences between species are sometimes relatively small and that there may be considerable variation within a single species or genus (Pennak 1953). The classification used in the present study is that presented by Mason (1973) which incorporates features from Hamilton et al. (1969) and Roback (1971). Of the five subfamilies of Chironomidae, four were found to have representatives in the Park as follows:

Subfamily Tanypodinae -predaceous species which do not build cases but are sometimes found in cases of other chironomid species. Most commonly found in lakes and ponds.

Procladius

Pentaneura

Subfamily Chironomini -a subfamily with great variability of characters. Most members are found in weedy areas of lakes and ponds while a few species are found at great depths.

Chryptochironomus

Chironomus

Tanytarsus

Pseudochironomus

Phaenopsectra

Subfamily Diamesinae -characteristic of mountain brooks or other swift streams where they live at the splash line or on smooth rocky bottoms in the shallow water of rapids (hygropetric environment).

Diamesa and Pseudodiamesa

Subfamily Orthocladinae -a large subfamily with many species of diverse habits. Most often associated with macrophytes in lakes and ponds or slower moving streams.

Corynoneura

Brillia

Eukiefferiella

Psectrocladius

Cricotopus

Orthocladus

Metrocnemus

Fifteen chironomid species were found in dredge samples from lakes in the Park. The chironomids made up an average of 76.3%

of the total numbers of invertebrates collected in lake benthic samples (Table 14). For several lakes the number of chironomids was over 1000 m^{-2} on the bottom (Table 13). The highest number found was 14792 m^{-2} in Wapta Lake where two species (Procladius sp. and Tanytarsus sp.) dominated the benthic fauna. Benthic chironomids in Wapta Lake were nearly 3 times the number found in the next highest lake (South Narao) at 5922 m^{-2} .

Tanytarsus sp., the most common chironomid, was found in 19 of 22 lakes where benthic data are available (Table 31). This species formed a significant part of the total number of chironomids in these lakes where it frequently made up approximately 20-50% of the chironomids found (Table 32). Tanytarsus sp. was found in lakes representing a very wide range of trophic levels including the oligotrophic McArthur, Oesa, and Upper Opabin lakes as well as the relatively eutrophic Ottertail Flats, Duchesnay, Sink, and Summit lakes.

Procladius sp., the second most common chironomid, was found in 15 of 22 lakes where it frequently constituted an important fraction of the total number of chironomids present (Table 31). The lake benthic samples which did not contain Procladius were all very oligotrophic in nature and of generally low productivity (Table 31). Highest numbers of Procladius were found in Wapta Lake (6483 m^{-2}) and North Narao Lake (435 m^{-2}).

In addition to those species already mentioned Phaenopsectra, Chironomus, Psectrocladius, Cricotopus, and Pentaneura were also common. Lake O'Hara had the most diverse species composition

Table 31. Summary of mean numbers m⁻² of Chironomidae collected in dredge samples from lakes in Yoho National Park.

Species	Site	6	7	8	9	10	13	14	15	15A	16	17	18	19	20	22	23	24	26	42	47	48	49
Procladius sp.		21.5	365.5	-	6.0	27.9	129.0	290.0	-	-	-	43.0	107.0	435.3	6482.	139.8	-	-	-	43.0	34.4	86.0	161.1
Pentaneura sp.		-	-	-	39.7	-	-	-	-	-	-	53.7	-	-	-	-	-	-	32.2	-	-	136.1	100.9
Cryptochironomus sp.		-	-	-	-	-	-	-	-	-	-	-	-	53.7	-	-	-	-	-	-	-	-	-
Chironomus sp.		-	-	-	-	-	-	-	-	-	-	1999.	5547.	209.6	-	-	-	-	215.0	-	5.3	-	4.3
C. (Limnochironomus) sp.		-	-	-	221.0	-	-	-	-	-	-	-	-	-	-	-	-	-	301.0	21.5	107.0	286.0	-
Tanytarsus sp.		21.5	494.5	86.0	1027.7	34.4	-	75.2	64.5	-	1311.0	903.1	225.7	198.8	8084.	215.0	129.0	64.5	-	279.5	5.3	250.8	8.7
Pseudochironomus sp.		-	-	-	-	-	-	-	-	-	-	-	-	32.2	-	-	-	-	-	-	-	-	-
Phaenopsectra sp.		129.0	-	-	460.7	55.9	559.0	-	-	-	677.2	-	-	209.6	-	-	150.5	-	-	172.0	795.0	78.8	624.5
Diauesia sp.		-	-	-	3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.9	-
Corynoneura sp.		-	-	-	9.0	-	-	32.2	-	-	-	-	-	-	-	-	-	301.0	-	-	-	-	-
Brillia sp.		-	-	-	43.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	926.0	-
Eukiefferiella sp.		-	365.5	-	3.0	-	-	-	-	-	-	-	-	-	-	-	32.2	-	-	-	-	-	-
Psectrocladius sp.		-	-	946.0	-	6.4	-	-	-	-	-	-	-	123.6	-	-	-	-	-	-	-	-	152.0
Metrocnemus sp.		-	-	-	46.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75.2	-	-	-
Unidentified		-	-	10.7	43.0	-	-	-	-	-	10.7	96.7	-	-	226.0	10.7	-	32.2	-	-	-	150.0	25.8

Table 32. Summary of percentage composition of chironomids in dredge samples from lakes in Yoho National Park.

Species	Site	6	7	8	9	10	13	14	15	15A	16	17	18	19	20	22	23	24	26	42	47	48	49
Procladius sp.		12.5	29.8	-	0.2	22.3	18.7	72.9	-	-	-	1.3	1.8	34.3	43.8	37.1	-	-	-	7.2	3.6	4.4	14.1
Pentaneura sp.		-	-	-	1.9	-	-	-	-	-	-	1.7	-	-	-	-	-	-	5.8	-	-	7.0	0.8
Cryptochironomus sp.		-	-	-	-	-	-	-	-	-	-	-	-	4.2	-	-	-	-	-	-	-	-	-
Chironomus sp.		-	-	-	-	-	-	-	-	-	-	64.5	93.6	16.7	-	-	-	-	39.2	-	0.5	-	0.3
C. (Limnochironomus) sp.		-	-	-	10.6	-	-	-	-	-	-	-	-	-	-	-	-	-	54.9	3.6	11.2	14.8	-
Tanytarsus sp.		12.5	40.3	8.2	49.6	27.6	-	18.9	100	-	63.2	29.1	3.7	15.6	54.6	57.1	41.4	16.2	-	47.2	0.5	12.9	0.7
Pseudochironomus sp.		-	-	-	-	-	-	-	-	-	-	-	-	2.5	-	-	-	-	-	-	-	-	-
Phaenopsectra sp.		75.0	-	-	22.2	44.8	81.2	-	-	-	32.6	-	-	16.5	-	-	48.2	-	-	29.0	83.9	4.0	55.5
Diamasa sp.		-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.9	-
Corynoneura sp.		-	-	-	0.4	-	-	8.1	-	-	-	-	-	-	-	-	-	75.8	-	-	-	-	-
Brillia sp.		-	-	-	2.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48.1	-
Eukiefferiella sp.		-	29.8	-	0.1	-	-	-	-	-	-	-	-	-	-	-	10.3	-	-	-	-	-	-
Psectrocladius sp.		-	-	90.7	-	5.1	-	-	-	-	-	-	-	9.7	-	-	-	-	-	12.7	-	-	13.3
Metrocnemus sp.		-	-	-	2.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified		-	-	1.0	2.0	-	-	-	-	-	0.5	3.1	-	-	1.5	2.8	-	8.0	-	-	-	7.7	2.2

with 11 different chironomids being found there. The heavy sampling schedule for this lake no doubt contributed to the large number of species found (Table 31). A second factor may be the enrichment of the small bay adjacent to the Lake O'Hara Lodge which widened the range of habitat types available. Other lakes with high numbers of chironomid species were the comparatively eutrophic North Narao, Sink, and Summit lakes, each with 8 species (Table 31).

In shoreline samples the chironomid species collected generally reflected the species collected in the benthic samples (Table 33). Tanytarsus sp. was found in 2 of the lakes where it was absent from benthic samples leaving only Lower Opabin Pond (site 15A) without this species.

Schultz (1953) reported values for benthic chironomid numbers in several lakes in the Park. A comparison with the present data from the same lakes is given below:

Lake	Mean number of chironomids m^{-2}	
	Schultz (1953)	Present report
Emerald	202	548
McArthur	0	1042
O'Hara	4907	2067
Ross	3870	3096
Sherbrooke	1806	947
Yoho	1433	(no data)
Wapta	9696	14792

A similarity is seen in the data even though collected 20 years apart. The absence of chironomids from McArthur Lake in the 1953 collections is most likely due to the single very deep (53 m) dredge sample obtained by Schultz. Other differences in the data

Table 33. Summary of mean number of chironomids collected in timed shoreline samples from lakes in Yoho National Park.
(+) indicates present in trawl sample.

Species	Site	7	8	9	10	13	14	15	15A	16	17	18	19	20	22	23	24	26	42	47	48	49
Procladius sp.	1	-	-	-	-	4	-	2	-	-	1.6	+	+	+	-	-	-	+	-	-	+	+
Pentaneura sp.	-	-	-	2	1	-	-	-	-	-	-	-	-	0.6	-	-	1	1.3	1	-	1.5	1
Cryptochironomus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	0.3	-	-	-	-
Chironomus sp.	-	-	-	-	-	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-	+	-
C. (Limnochironomus) sp.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tanytarsus sp.	17	-	-	+	5	2	6	-	-	-	-	2	3	+	3	2	-	1.3	2	3	+	+
Phaenopsectra sp.	-	-	-	-	2	1	-	-	-	-	-	3	6.5	-	-	2	-	-	-	2.5	-	+
Diamesa sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corynoneura sp.	-	-	-	1.5	-	-	6	-	-	-	-	1	-	-	9	-	122	-	2	0.5	-	-
Brillia sp.	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eukiefferiella sp.	-	-	+	+	-	-	-	-	1	-	0.3	-	-	-	9	-	-	-	-	-	-	-
Psectrocladius sp.	-	-	-	4.5	-	-	-	-	-	-	-	+	-	+	-	-	-	-	+	-	-	+
Cricotopus sp.	-	-	5	2	-	-	1	-	-	-	-	0.5	-	-	-	-	+	-	1	-	-	2
Unidentified	-	1	-	-	-	-	-	-	-	-	2.3	-	-	0.6	3	2	-	-	-	-	+	-
Total	18	1	13	10	7	13	13	2	1	0	4.2	7	9.5	1.2	24	6	123	2.9	6	6	1.5	3

may be considered minor and most likely due to differences in sampling site, time of year, or other factors.

In stream kick samples the dominant types of chironomids differed considerably from those found in lakes (Table 34). Eukiefferiella, Metrocnemus, Diamesa, and Orthocladius dominated the stream collections and were found at 28, 18, 11, and 10 of the 30 sites, respectively. The only species prominent in both lakes and streams is Tanytarsus which was found at 11 stream sites. Chironomids averaged 15.2% of the total number of invertebrates collected at all stream sites with a range of 1.8-72.8% (Table 18). Eukiefferiella sp. was the most common stream chironomid being found at 28 stream sites and reached very high numbers at two sites (115 and 133) where it numbered 66 and 945 m⁻², respectively (Table 34).

Analysis of the data presented by Robinson and Smith (1974) indicates Diptera (mostly chironomids) made up about 19% of the total number of invertebrates in streams of relatively low productivity while the more productive sites (eutrophic) averaged about 47% Diptera. The average figure of 15.2% chironomids for YNP streams compares favorably with the streams of low productivity examined by Robinson and Smith (1974). These authors did not identify chironomids beyond the family level so that no comparison can be made of the species present.

Analysis of the data presented by Anderson et al. (1972) from WLNP streams indicates the chironomids make up about 22% of the invertebrates present. Eleven species were found at

Table 34. Summary of mean numbers m⁻² of chironomids collected in benthic samples from streams in Yoho National Park.

Species	Site	102	104	106	107	108	109	110	111	112	113	114	115	116	117	118
Procladius sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pentaneura sp.	-	-	-	-	-	-	-	-	0.8	-	-	-	-	-	-	-
Tanytarsus sp.	5.8	-	-	-	-	-	-	-	-	-	-	-	-	-	5.0	-
Phaenopsectra sp.	-	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diamesa sp.	-	-	-	-	3.0	-	-	-	-	-	15.0	0.8	161.5	-	-	1.6
Pseudodiamesa sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corynoneura sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	-	-
Brillia sp.	-	1.6	-	-	5.0	-	-	-	-	-	5.8	-	-	-	1.6	-
Eukiefferiella sp.	28.3	0.8	4.3	18.0	8.0	8.0	1.5	38.0	44.1	11.6	-	16.6	666.5	7.5	-	15.8
Psectrocladius sp.	-	3.3	-	-	-	-	-	-	-	-	-	-	-	0.8	-	4.1
Cricotopus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6	-	-
Orthocladius sp.	-	-	-	-	-	-	-	-	9.1	53.3	-	-	-	-	5.8	-
Metrocnemus sp.	0.8	-	24.3	-	-	-	1.5	-	5.0	7.5	-	10.8	36.5	6.6	-	8.3
Unidentified	1.6	-	3.7	-	-	-	1.5	13.0	1.6	10.0	-	-	-	2.5	3.2	-

Species	Site	119	120	121	122	123	124	125	126	127	128	129	130	132	133	134
Procladius sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8
Pentaneura sp.	-	-	-	-	-	-	-	5.6	-	-	-	-	26.6	-	-	-
Tanytarsus sp.	-	1.6	-	-	-	1.2	1.5	-	5.8	15.8	8.3	23.0	50.0	-	-	2.5
Phaenopsectra sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diamesa sp.	-	2.5	9.6	1.6	11.2	-	-	-	-	-	-	-	101.5	26.6	-	-
Pseudodiamesa sp.	-	-	7.0	36.6	-	-	-	-	-	-	-	-	21.6	16.6	-	-
Corynoneura sp.	-	-	-	-	-	-	-	1.2	-	-	-	-	-	-	-	-
Brillia sp.	-	5.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eukiefferiella sp.	9.1	12.5	6.6	0.8	1.2	21.5	32.5	15.8	8.0	18.3	1.5	21.6	36.6	945.0	5.0	-
Psectrocladius sp.	-	-	-	-	-	-	-	-	-	3.3	-	88.3	-	-	-	-
Cricotopus sp.	-	-	-	-	-	-	-	-	-	-	-	50.8	-	-	-	-
Orthocladius sp.	53.3	-	-	-	-	-	-	2.5	2.5	0.8	-	41.6	-	180.0	0.8	-
Metrocnemus sp.	2.5	4.1	0.8	0.8	1.2	0.6	-	5.6	1.6	5.0	1.6	5.0	-	13.0	73.3	-
Unidentified	10.0	-	-	-	-	-	-	1.8	0.8	-	0.8	-	-	-	-	-

stream sites in WLNP including representatives of all the common genera found in YNP streams with the exception of Metrocnemus which was absent from WLNP collections.

Miscellaneous Diptera.

In addition to the Family Chironomidae several other families of Diptera were identified from samples from lakes and streams in the Park. Although frequently found in low numbers, these Diptera represent a large and diverse group of insects whose adult stages are commonly known as flies, gnats, midges, and mosquitoes. With the exception of the mosquito larvae, the identification of most aquatic diptera larva is quite difficult below the family level if not impossible. A short description of the habits of each group and their occurrence in the Park is given below and in Tables 35, 36, and 37.

Tipulidae (crane flies).

The true crane flies, or Tipulidae, are a large and diverse family whose worm-like larvae were frequently found in stream samples. Aquatic crane fly larvae may be easily identified by the spiracular disc (used for breathing) at the extreme posterior end. The larvae exhibit a wide range of habitat preferences; many are semi-aquatic and occur in damp sand, organic mud, and wet mosses. The family has both carnivorous and herbivorous representatives (Pennak 1953).

Tipulid larvae were found at 20 stream sites where they

Table 35. Summary of mean numbers m^{-2} of miscellaneous Diptera collected in dredge samples from lakes in Yoho National Park.

Species	Site	8	10	13	16	17	18	23	24	47	48	49
Unidentified pupae		21.5			43.0			64.0	10.7			116.1
Tipulidae						10.7						
<u>Chaeoborus</u>				21.5								
<u>Alluadomia</u>			6.4				32.0			21.5	12.9	47.3

Table 36. Summary of mean numbers m^{-2} of miscellaneous Diptera collected in 30 minute shoreline samples from lakes in Yoho National Park.

Species	Site	10	13	16	18	19	20	24	26	47	48	49
Unidentified pupae		17	13		1		14	1			1	2
Tipulidae							3		13.9	4		
<u>Aedes</u>		50										1
<u>Chaeoborus</u>			13									
<u>Alluadomia</u>					1.5	0.5						1

Table 37. Summary of mean numbers m⁻² of miscellaneous Diptera collected in benthic samples from streams of Yoho National Park.

Group	Site	102	104	106	107	108	109	110	111	112	113	114	115	116	117	118
Tipulidae		1.5	1.5	-	-	1.5	-	1.5	1.5	1.5	-	-	-	4.1	-	4.1
Blepharoceridae		0.8	-	2.5	-	-	1.5	1.5	-	1.5	-	0.8	-	1.5	-	3.0
Tabanidae		-	0.8	-	-	-	-	-	-	-	-	-	-	3.0	3.0	-
Simuliidae		2.5	-	-	-	-	-	1.5	2.5	-	0.8	-	-	-	2.5	-
Empididae		0.8	2.5	-	-	3.0	-	-	1.5	-	-	-	-	-	-	-
Ephydriidae		0.8	1.5	-	-	13.0	-	-	-	-	2.5	0.8	-	1.5	3.0	-
Heleidae		-	-	-	-	-	-	-	0.8	-	-	-	-	-	-	-
Unid. pupae		1.6	0.8	-	-	-	1.5	3.0	-	2.5	-	-	-	1.5	5.8	1.5

Group	Site	119	120	121	122	123	124	125	126	127	128	129	130	132	133	134
Tipulidae		0.8	2.5	15.0	0.8	0.6	1.6	5.6	-	6.5	0.8	1.6	0.8	-	1.6	-
Blepharoceridae		0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tabanidae		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Simuliidae		0.8	2.5	1.0	0.8	5.0	1.6	-	77.5	1.6	0.8	-	1.6	1.6	5.0	1.6
Empididae		-	-	-	-	-	-	-	5.0	1.6	-	-	-	-	-	8.0
Ephydriidae		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heleidae		-	-	-	-	-	-	-	0.8	-	-	-	-	-	-	-
Unid. pupae		0.8	2.5	-	2.5	2.5	-	1.2	0.8	0.8	1.6	-	1.6	5.0	-	-

usually made up less than 2% of the total number of invertebrates present (Table 37). Only Ross Lake had tipulid larvae in dredge samples while 3 lakes (Wapta, Emerald, and Sherbrooke) had them in shoreline samples (Table 35 and 36).

Blepharoceridae (net-winged midges).

The adults of this group of midges are mosquito-like insects of moderate size, with long legs and broad wings. The aquatic larvae are quite unique in shape being flattened and composed of seven divisions; the first consists of the fused head, thorax, and first abdominal segment; the next five are abdominal segments two to six; the last and smallest division includes three abdominal segments. Each of the first six divisions has a median ventral sucker by which the larvae attaches itself to rocks in streams. They frequent the borders of streams where they are thought to feed on smaller insects (Pennak 1953) or algae (Wirth and Stone 1963).

In the Park the net-winged midges are represented by the genus Bibliocephala which was collected at 9 stream sites (Table 37). Usually only one or two individuals were collected in each kick sample. All of the sites where they were collected are of generally low elevation with the highest being Otto Creek at 1459 m.

Culicidae.

The Family Culicidae comprise a large group of Diptera

which is commonly divided into two Subfamilies, the Culicinae and the Chaoborinae, the former including the true mosquitoes, the latter the phantom midges. The aquatic larvae of mosquitoes feed on algae, protozoa and bits of organic debris by means of the filtering action of small mouth brushes. A few species have been observed gnawing on submerged surfaces or scraping the periphyton from such objects.

The aquatic larvae of Chaoborinae are called phantom larvae because of their transparency (see Plate 5). In a series of laboratory experiments and field observations, Anderson and Raasveldt (1974) found that Chaoborus commonly preyed upon adults of small species of Diaptomus and the larval instars of larger species of Diaptomus. They indicated the predatory habits of Chaoborus may have an effect on the distribution and abundance of prey species.

Aquatic mosquito larvae were collected at only two sites: Mary Lake and Summit Lake (Table 36). In the timed shoreline collections at Mary Lake a total of 50 Aedes of two species were collected. At Summit Lake a single Aedes hexodontus was collected in the shoreline survey.

Chaoborus brunskilli was collected only at Lower Opabin Pond (site 13). In dredge samples from a depth of 1.2 m, C. brunskilli were found to number about 21.5 m^{-2} and a total of 13 were collected in the 30 minute shoreline survey (Tables 35 and 36).

Simuliidae (blackflies).

The Simuliidae are a small family of world-wide distribution and includes those Diptera commonly called "blackflies" or "buffalo gnats". Blackfly larvae are found in the shallows of streams where the current is especially swift. The caudal third of the larvae is distinctly enlarged making them unique and easily identified (Pennak 1953). By means of a posterior sucker, they attach to rocks with their heads pointed downstream, and they strain the water for food particles using a pair of large mouth brushes (Wirth and Stone 1963). Plankton and organic debris make up the majority of their diet (Pennak 1953).

Simuliidae were collected at 18 stream sites (Table 37). At most sites simuliids averaged less than 2.5 m^{-2} and were most numerous at lower Cataract Brook (site 126) with 77.5 m^{-2} . Simuliids were absent from all Kicking Horse River sites but were present in most of its tributaries.

Heleidae (biting midges).

The Family Heleidae or biting midges (often called "no-see-ums") are blood sucking or predaceous relatives of the true midges. The immature stages of Heleidae are mostly aquatic, their habitats ranging from fresh to salt water. The larvae of most genera are elongate, eel-like, legless, and live as predators and scavengers in sand or mud. In the Park this family is represented by the genus Alluaudomyia which was collected in both lakes and streams. Dredge samples from 5 lakes (Table 35) produced moderate numbers of Alluaudomyia and it was found in

the shoreline collections of one additional lake (Table 36). All of the lakes where this species was found were of a relatively eutrophic nature. Two stream sites (Otterhead River and lower Cataract Brook) each produced only a single Alluaudomyia in kick samples (Table 37).

Empididae (dance flies).

Adult empidids or dance flies frequent moist habitats and are predaceous on smaller insects. The wormlike larvae of this family are found in streams where they prey upon other invertebrates. In the Park, empidid larvae were found at 7 stream sites and were usually in very low numbers (Table 37). Empidid larvae were not collected at any of the Kicking Horse, Amiskwi, or Yoho River sites but were present in most other tributaries. A single specimen was also collected in trawl samples along the shoreline of Wapta Lake (Table 36).

Ephydriidae (shore flies).

Adult Ephydriidae, or "shore flies", inhabit moist environments where they are commonly seen walking about on the surface of the mud or water, lapping up or scraping off minute particles of algae or diatoms which make up much of their food. Most of the larvae are aquatic or semi-aquatic, and some of them live in or on the leaves and stems of aquatic plants (Wirth and Stone 1963). The aquatic larvae are wormlike and in most cases lack prolegs or other distinguishing structures (Johannsen 1935). In the Park Ephydriidae were collected at 7 stream sites (Table 37). Site 108 at the lower Ottertail River produced the most

specimens with an average of 13 m^{-2} . The other sites produced only very low numbers of Ephydriidae.

Tabanidae (horseflies).

The horseflies are a large family of world-wide distribution. The females of some species bite severely, and many species are serious pests. The wormlike aquatic larvae are all predaceous on soft-bodied invertebrates in the streams or ponds where they live. Tabanid larvae (probably Tabanas sp.) were collected at three stream sites (lower Beaverfoot River, Otto Creek, and upper Amiskwi River) where they were found in low numbers (Table 37). The species present in the Park is quite easily distinguished from other larval Diptera by the presence of elongate pseudopods used for walking.

Hemiptera (true bugs).

The Hemiptera or "true bugs" comprise a number of Families, three of which were represented in the Park.

Water striders, Family Gerridae, are semi-aquatic long-legged hemipterans which may be found skating or leaping about on the surface film of ponds and streams. Water striders feed upon a variety of crustacea and aquatic insects which they catch just below the surface (Pennak 1953). Gerrids are very agile and move rapidly on the surface using the middle legs for propulsion while the front and hind legs act as balancers (Brooks and Kelton 1967). Their agility does not permit easy capture with the collection methods employed during the present study.

Gerris comatus was the only member of this family collected in the park and was found only at South Narao Lake (Table 38). Very likely this species is more widespread than the collections would indicate, but more suitable methods of collections are required to define its distribution.

Water treaders, Family Mesovelidae, live on the surface of water in ponds and lakes. They are very agile, foraging on floating leaves and other vegetation, and are able to run over the surface film (Brooks and Kelton 1967). Two specimens of Mesovela sp. were collected in the slow moving lower reaches of the Beaverfoot River (Table 38). As with the Gerridae these Hemiptera are difficult to collect with the methods employed and their distribution may include other areas of the Park.

Water boatmen, Family Corixidae, are medium to small bugs, usually less than 12 mm long. Corixids occur in the shallows of ponds, lakes, and streams where they spend most of their time on the bottom. Most water boatmen are strong fliers and take off easily from the surface of the water. The food of corixids consists of debris and a great variety of algae, Protozoa, and small metazoa (Pennak 1953). They may also feed on small crustacea (Anderson 1970a, 1970b). A single specimen of Sigara (Vermicorixa) alternata was collected in trawl samples from Summit Lake and four specimens of Arctocorixa sutillis were collected in trawl samples from Duchesnay Lake (Table 38).

Coleoptera (beetles).

The Coleoptera, or "beetles", form the largest group of insects

Table 38. Summary of the distribution of Hemiptera in Yoho National Park

Species	Site Sample type	104 K	18 S	42 T	49 T
<u>Sigara (vermicorixa) alternata</u>		-	-	-	1
<u>Arctocorisa subtilis</u>		-	-	4	-
<u>Gerris comatus</u>		-	3	-	-
<u>Mesovelia</u> sp.		2	-	-	-

Table 39. Summary of the distribution of Coleoptera in lakes of Yoho National Park.

Species	Site No. Sample type	7*		9 S	10		13 S	14		15 S	18		19 D	23 S	42			47 S	48	
		S	T		S	T		S	T		S	T			D	S	T		S	T
Agabus tristus		2	-	0.5	-	-	1	6	-	-	0.5	-	-	-	-	-	-	0.5	-	-
Hydroporus occidentalis		-	-	-	1	+	2	27	+	-	-	-	-	-	-	-	-	-	-	-
Hydroporus compertus		-	+	1	-	-	1	-	-	-	-	-	-	3	-	-	-	-	-	-
Hydroporus griseostriatus		-	-	-	-	-	-	1	-	-	-	-	-	-	10	-	+	-	2	+
Haliphus sp.		-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	1	-
Dyticid larvae		-	-	0.5	-	-	-	-	-	1	-	+	-	-	-	2	-	-	-	-
Unidentified		-	-	-	-	-	1	-	-	-	-	-	5.3	-	-	-	-	-	-	-

*D= dredge sample, numbers m⁻²

S= shoreline sample, numbers collected in 30 minutes

T= trawl sample, (+) indicates species present

with about 270,000 species including many aquatic ones. Several species representing two families of Coleoptera (Halipidae and Dytiscidae) were collected in the Park (Table 39).

Halipus sp. (Halipidae) was collected in shoreline samples from Summit Lake and in trawl samples from South Narao Lake. The Family Halipidae is characterized by having legs unmodified for swimming. As a result swimming is feeble and consists of alternate movements of the legs. Adult halipeds are usually found crawling about on and among masses of filamentous algae and other submerged vegetation in the shallows. Apparently they feed chiefly on vegetation, although some investigators have observed them eating animal material (Pennak 1953).

The remaining species of Coleoptera were all in the Family Dytiscidae or "predaceous diving beetles". Dytiscids usually occur in shallow protected bays and small inlets of lakes and ponds. The group is exclusively carnivorous and feed on all types of aquatic metazoa, the larger species commonly attacking dragon fly nymphs, tadpoles, and small fish.

Ten lakes and ponds in the park were found to have one or more dytiscid species (Table 39). The most common species was Agabus tristus which was found in 6 lakes. Most of the lakes in which dytiscids were found were of a relatively oligotrophic nature. The lower Opabin Ponds (sites 13 and 14), for example, had three species each.

Odonata (dragonflies and damselflies).

Adult Odonata are frequently seen flying along the shores and over the waters of marshes, ponds, rivers, and lakes. Dragonflies and damselflies differ in several important ways. Damselflies are smaller, more slender and delicate, and slower and more uncertain in flight. It is only the series of nymphal stages, or naiads, which are aquatic in both groups. The nymphs of damselflies differ from those of dragonflies in having caudal tracheal gills. All Odonata nymphs are carnivorous and feed chiefly on other aquatic insects, annelids, small crustacea, and molluscs. Although large dragonfly nymphs may be induced to feed on small fish in the laboratory when normal food is absent, it is doubtful whether they ever attack fish in the normal environment (Pennak 1953).

Odonata nymphs are commonly found in association with aquatic plants and the five lakes in the Park which had Odonata also had at least some shoreline macrophytes (Table 40). Dragonfly nymphs (Sympetrum sp., Aeshna interrupta, A. palmata) were present in five lakes while damselfly nymphs (Ischnura perparva, Enallagma boreale) were present in three. In all cases only a small number of these large insects were collected in shoreline surveys with the largest number being found among the macrophytes of Emerald Lake (Table 40).

Acarina (water mites).

The Order Acarina includes those eight-legged arthropods usually termed "water mites". Although the water mites are found in almost all types of freshwater habitats, they are most abundant and characteristic of ponds and the littoral

Table 40. Summary of mean numbers of Odonata collected
in 30 minute shoreline samples from lakes
in Yoho National Park.

Species	Site	18	19	26	48	49
<u>Sympetrum</u> sp.		1.0	-	-	-	1.0
<u>Aeshna interrupta</u>		0.5	-	4.0	-	-
<u>Aeshna palmata</u>		-	1.0	1.6	0.5	-
<u>Ischnura perparva</u>		+	-	-	-	1.0
<u>Enallagma boreale</u>		-	-	-	2.5	-

+ = present in trawl sample

region of lakes, especially where there are quantities of rooted aquatic vegetation. The great majority of water mites are carnivorous or parasitic, their food consisting chiefly of entomostraca, small insects, various kinds of worms, or host tissues (Pennak 1953).

Species representing at least nine different genera were collected in streams and lakes of the Park. The most common water mite in lakes was Lebertia sp. which was collected in benthic samples from 6 lakes and in shoreline samples from 11 lakes (Table 41 and 42). This species reached 172 m^{-2} in dredge samples from South Narao Lake while at the other lakes it numbered between 4.3 and 21.5 m^{-2} . Other water mites common in lakes included Arrenurus sp. and Limnesia sp. None were collected from deep, high altitude lakes such as McArthur, Upper Opabin, and Oesa.

The dominant species in streams was Sperchon sp. which was collected at 9 sites while Lebertia sp. Limnesia sp., Hygrobates sp., Hydrodroma sp., and an unidentified species of the Family Orbatei were all collected in 3 or fewer sites. Maximum numbers of Sperchon sp. were at upper Amiskwi River where 15 m^{-2} were collected (Table 43).

Pelecypoda.

The Pelecypoda are a group of bivalve molluscs which live in many types of aquatic habitats. The most common small freshwater clams are in the Family Sphaeriidae which are often found in great abundance on some lake bottoms more than 30 meters below

Table 41. Summary of mean numbers m⁻² of Acarina in benthic samples from lakes in Yoho National Park.

Species	Site	6	9	10	18	19	42	48	49
Lebertia sp.	21.5	-	6.4	172	10.5	-	10.3	4.3	
Arrenurus sp.	-	-	-	10.5	64.5	10.5	-	-	
Limnesia sp.	43.0	-	-	21.5	21.5	-	-	-	
Hygrobates sp.	-	-	-	-	-	10.5	-	-	
Plonidae	-	3.0	6.4	-	-	-	10.3	-	
Unidentified	21.5	-	-	10.5	-	-	21.5	-	

Table 42. Summary of mean numbers of Acarina collected in 30 minute shoreline samples from lakes in Yoho National Park.

[illegible]

Table 43. Summary of mean numbers m^{-2} of Acarina collected in stream samples from Yoho National Park.

Species	Site	110	111	116	117	118	121	125	127	128	129	130
Lebertia sp.		1.5	-	-	-	0.8	-	0.6	-	-	-	-
Limnesia sp.		-	-	-	-	-	-	-	-	-	-	2.5
Hygrobates sp		-	-	-	-	-	-	-	-	-	-	2.5
Hydrodroma sp.		-	-	-	-	-	-	-	-	-	-	0.8
Sperchon sp.		-	0.8	2.5	15.0	0.8	1.0	-	6.6	3.3	11.5	4.1

the surface.

Six species of the sphaerid genus Pisidium were collected from 10 lakes and 1 stream site in the Park (Table 44). Due to the difficulty of distinguishing live from dead individuals the data on Pisidium spp. presented in Table 44 is not quantitative. Pisidium conventus, P. ventricosum, and P. lilljeborgi were the most widespread of the species found.

Gastropoda.

The gastropods (snails) are molluscs with only a single shell and are commonly found along the shoreline of lakes and ponds. Three species were collected in the Park from 6 lakes and 1 stream site (Table 44). The gastropods collected very often made up the largest fraction of the biomass in shoreline collections.

Table 44. Summary of pelecypod and gastropod distribution in Yoho National Park.

Pelecypoda

Species	Site	8*	9	10	17	18	19	20	42	47	49	126
<i>Pisidium conventus</i>		+	+	-	-	+	+	+	-	-	+	+
<i>Pisidium ventricosum</i>		-	+	+	-	+	+	-	+	-	+	-
<i>Pisidium lilljeborgi</i>		-	+	-	+	+	-	-	+	+	-	-
<i>Pisidium casternatum</i>		-	-	-	-	-	+	-	+	-	+	-
<i>Pisidium subtruncatum</i>		-	-	-	-	-	-	-	-	-	+	-
<i>Pisidium nitidium</i>		-	-	-	-	-	-	+	-	-	-	-

* (+) indicates species is present

Gastropoda

Species	Site No. Sample type	17*	19		26	42		48	49		126
		S	S	D	S	S	D	S	S	D	K
<i>Lymnaea arctica</i>		-	15	231	25	3	-	-	1	42	3.3
<i>Gyrulus parvus</i>		20	-	42	-	-	10.7	-	-	-	-
<i>Physa gyrina</i>		-	-	-	2	-	-	4	-	-	-

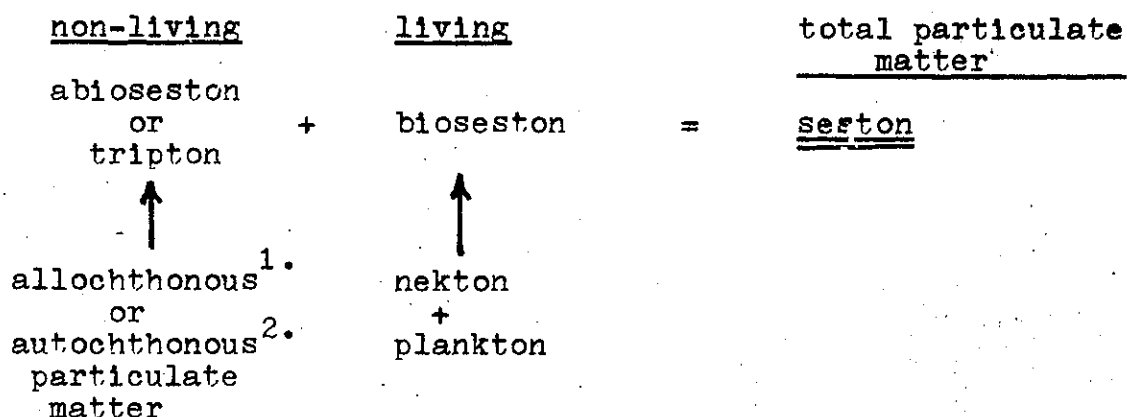
* D= dredge sample, numbers m⁻²

S= shoreline sample, numbers collected in 30 minutes

ZOOPLANKTON

Introduction

"Plankton" and related terms do not always convey clear meanings because, like many other general terms in science, they have been defined in different ways by different workers. Hutchinson (1967) has provided what have been accepted widely in North America as satisfactory definitions. The original definition of plankton included "all particulate organogenic material, living or dead" which drifts passively in the water. Seston is the term usually used now to describe this total material, according to the following scheme:



In the strict sense, the plankton includes only non-motile forms, but in the general sense includes all living forms not able to swim strongly enough to be independent of turbulent movements of the water. Forms completely independent of the waters turbulence are referred collectively as nekton. Also in the strict sense, plankton refers to the drifting forms in the open-water or limnetic zone of lakes (= the pelagic zone of the ocean, although this term is often used now for lakes as well). In practice, however, the

-
1. Arising outside the biotope (lake or pond, in this case) under consideration.
 2. Arising within the biotope (lake or pond, in this case) under consideration.

accidental migrants from benthic (bottom) communities or from littoral (inshore) communities are often included with the plankton. There are special terms for these other groups, but they need not be discussed here. Pond plankton, in theory, is not true plankton, but for the sake of simplicity in this study all forms collected with a plankton net will be referred to as plankton, the animal forms as zooplankton and the plant forms as phytoplankton. The phytoplankton will be further divided into two groups: the net phytoplankton (or microphytoplankton) as the small algae collected in the plankton net; the nanophytoplankton as the algae too small to be collected by the net (algae usually less than 0.06 mm in greatest dimension). The former group will be treated in this section; the latter group will be dealt with in more detail in a subsequent section. To be treated satisfactorily and in sufficient detail, the nanophytoplankton requires special preparation techniques and involves many difficult taxonomic problems. It is a group which has been given specialized treatment in the study area covered in this report partly because it is poorly known, and partly because the species involved are often important indicators of water quality.

Thirty-nine lakes and ponds were sampled a total of 93 times in this study; 10 samplings in 1974, 27 in 1973, 6 in 1972, 9 in 1971, 12 in 1970, 11 in 1969, 5 in 1968, and 13 in 1966. Altogether, 2 waters were studied 8 times, one 7 times, two 6 times, 2 waters were studied 4 times, 5 were

studied 3 times, 8 twice, and 19 only once. The latter group included some of the most remote alpine and subalpine lakes. In most lakes, plankton samples were collected from the upper and lower water layers near the lake centre at one or more locations, and additional samples were collected from inshore in most lakes. For inventory and check-list purposes, these samples will be treated collectively. Further treatment of some of the distributional data has been presented elsewhere in a general review of zooplankton communities in lakes in southwestern Alberta and southeastern British Columbia (Anderson 1974a).

In many earlier studies of this sort in western Canada, as well as elsewhere, species lists were drawn up with no indication of the relative or total abundance of each species present. Therefore, efforts have been made in this report to include maximum zooplankton counts per unit volume and relative abundances of species present. The relative abundance of organisms in the plankton net samples is indicated according to the following numerical scheme:

<u>Number used to indicate rela- tive abundance</u>	<u>Description of relative abundance</u>	<u>Approximate numbers of animals per litre</u>
1	- one to very few per sample	<0.1
2	- few	0.1 - 1.0
3	- several	1.0 - 10
4	- many	10 - 100
5	- very abundant	100 - 1000
6 (not encoun- tered in Yoho study)	- extremely abundant	>1000

Because numbers of small organisms vary a great deal spatially, seasonally, and from year to year, relative numbers are often just as useful as precise numbers. The principal fault with the scheme is that all samples do not represent the plankton-net-filtration of the same volume of water, and that clogging occurs to different degrees in different waters. Conversion of net samples to standard volumes was done according to methods described elsewhere (Anderson 1970e), but which assumes a general filtering efficiency of 20% for the type of net used in the study.

In general, the species composition of a zooplankton community reflects the presence or absence of predators, and the size and feeding habits of the predators when they are present (Anderson 1970f, 1972, Anderson and Raasveldt 1974; Brooks 1968; Brooks and Dodson 1965; Beavers and Stavn 1975; Dodson 1970, 1974; Galbraith 1967, 1975; Northcote and Clarotto 1975). In aquatic environments made more complex by the extensive presence of macrophytes, large littoral zones, long growing seasons and warm temperatures, and diverse and abundant predator species, the effects of predators on zooplankton diversity are not so easy to interpret. Most of the lakes and ponds in Yoho National Park are relatively cold, have fairly short growing seasons, and do not have distinctly different winter communities as opposed to summer communities. Therefore, the probable effects of predators on the zooplankton are somewhat easier to assess.

The standing crop of zooplankton has been used on occasion as an indicator of the potential fisheries productivity of lakes and ponds, whether or not the zooplankters present are fed on directly by the fish or not, the rationale being somewhat the same as that used by the farmer who declares that a field which produces a good crop of weeds ought also under suitable conditions to produce a good crop of grain. In order to get a complete and very accurate picture of zooplankton production and standing crop, more detailed studies than were done here must be carried out. For example, life cycles, generation times, wet-weight/dry-weight ratios, calorimetric evaluations, individual body size determinations and so on all require detailed work at frequent intervals over one or more seasons. Because such detailed investigations could not be included in a general study such as the Yoho National Park aquatic survey, results of studies conducted elsewhere have been applied to some of the Yoho results in order to make predictions about potential production. Although it is always risky to apply results from elsewhere indiscriminately, the Yoho lake communities were relatively uncomplicated, minimizing potential errors from the application of data from other studies.

Methods

Net plankton samples were collected with a 25-cm diameter conical plankton net (mean aperture dimension approx. 65-70 microns) towed approximately 0.5 metres/second. Multiple vertical tows were made from bottom to surface and from half maximum depth or 5 m (whichever was less) to surface at the deepest part of each lake (in larger lakes two or more sites were sometimes

sampled). Limnetic samples were supplemented with littoral (near-shore) samples collected with a hand net or a small plankton net tossed from shore. Identification was accomplished with the use of a Wild M-20 compound microscope. Principal keys used were those of Wilson, Brooks, Edmondson, and Yeatman (in Edmondson 1959). Enumeration was done with a Wild M4A dissecting microscope. In nearly all cases the entire samples were counted. Details of conversion factors for quantitative estimates of production are indicated in the productivity discussion of this section of the report.

Diversity and Frequency of Occurrence of Zooplankton Species

The zooplankton species occurring in the 39 Yoho National Park lakes and ponds of this study are summarized in Tables 45 and 46. In these tables, the frequency of occurrence of the species is also indicated as is a consideration of the frequency of occurrence of the same species in two other studies: i.e. Waterton Lakes National Park (Anderson et al. 1972) and 340 lakes in southwestern Alberta and southeastern British Columbia (Anderson 1974a). These tables do not take into account the fact that some species are much more abundant than others, and that many are extremely sparsely represented. Some of the more common species are pictured in Plates 1 to 5. The following annotated list includes some of the ecological and morphological features of the most commonly occurring species. There are discrepancies in some of the taxonomic categories used in various texts as they apply to the following groups

Table 45. Crustacean plankton species occurring in 39 Yoho National Park lakes, with comparisons to two other studies of lakes in Alberta and British Columbia.

	No. lakes (of 39) where species occurs, this study.	% of total where species occurs.	No. lakes (of 44) where species occurs, Waterton Park, (Anderson et al. 1972)	% of total where species occurs.	No. lakes (of 340) where species occurs, sw Alta. & se B.C., (Anderson 1974a).	% of total where species occurs.
<u>Diaptomus arcticus</u> Marsh 1920	16	41.0	8	18.2	124	36.5
<u>Diaptomus tyrrelli</u> Poppe 1888	7	17.9	5	11.4	68	20.0
<u>Orthocyclops modestus</u> (Herrick) 1883	3	7.7	0	0	14	4.1
<u>Macrocyclus albidus</u> (Jurine) 1820	6	15.4	10	22.7	43	12.6
<u>Eucyclops agilis</u> (Koch) 1838	9	23.1	17	38.6	55	16.2
<u>Acanthocyclops vernalis</u> Fischer 1853	19	48.7	28	63.6	179	52.6
<u>Diacyclops bicuspidatus thomasi</u> S.A. Forbes 1882	2	5.1	20	45.5	93	27.4
<u>Polypheumus pediculus</u> (Linné) 1761	4	10.3	3	6.8	49	14.4
<u>Sida crystallina</u> (O.F. Müller) 1776	3	7.7	1	2.3	7	2.1
<u>Holopedium gibberum</u> Zaddach 1855	1	2.6	5	11.4	20	5.9
<u>Eurycerus lamellatus</u> (O.F. Müller) 1785	2	5.1	2	4.6	13	3.8
<u>Acroperus harpae</u> Baird 1843	1	2.6	2	4.6	9	2.7
<u>Alona guttata</u> Sars 1862	2	5.1	13	29.6	37	10.9
<u>Alona affinis</u> (Leydig) 1860	1	2.6	4	9.1	16	4.7
<u>Alona rectangula</u> Sars 1861	2	5.1	2	4.6	13	3.8
<u>Alonella excisa</u> (Fischer) 1854	1	2.6	1	2.3	7	2.1
<u>Chydorus sphaericus</u> (O.F. Müller) 1785	19	48.7	23	52.3	174	51.2
<u>Daphnia middendorffiana</u> Fischer 1851	4	10.3	4	9.1	55	16.2
<u>Daphnia pulex</u> Leydig 1860, emend. Richard 1896	5	12.8	5	11.4	61	17.9
<u>Daphnia pulicaria</u> Forbes 1893, emend. Hrbáček 1959	1	2.6	1	2.3	19	5.6
<u>Daphnia catawba</u> Coker 1926	1	2.6	0	0	10	2.9
<u>Simocephalus vetulus</u> Schoedler 1858	2	5.1	9	20.5	28	8.2
<u>Simocephalus serrulatus</u> (Koch) 1841	1	2.6	1	2.3	1	0.3
<u>Scapholeberis kingi</u> Sars 1903	4	10.3	2	4.6	26	7.6
<u>Ceriodaphnia affinis</u> Lilljeborg 1900	4	10.3	10	22.7	26	7.6
<u>Bosmina longirostris</u> (O.F. Müller) 1785	1	2.6	17	38.6	80	23.5
Total no. lake occurrences, all crustacean plankton species	121	-	313	-	1227	-
Mean no. crustacean plankton species per lake (except phyllopods)	-	3.1	-	7.1	-	3.6
Total no. crustacean plankton species in study (except phyllopods)	26	-	42	-	82	-

Table 46. Planktonic rotifer species occurring in 39 Yoho National Park lakes, with comparisons to occurrences in Waterton Lakes National Park, Alberta.

	No. lakes (of 39) where species occurs, this study.	% of total where species occurs.	No. lakes (of 44) where species occurs, Waterton Lakes Park, (Anderson et al. 1972).	% of total where species occurs.
<u>Polyarthra vulgaris</u> Carlin 1943	12	30.8	27	61.4
<u>Filinia longiseta</u> (Ehrenberg) 1843	1	2.6	1	2.2
<u>Kellicottia longispina</u> (Kellicott 1879)	10	25.6	9	20.5
<u>Keratella cochlearis</u> (Gosse 1851)	13	33.3	22	50.0
<u>Keratella quadrata</u> (Müller 1786)	9	23.1	22	50.0
<u>Notholca acuminata</u> (Ehrenberg 1832)	4	10.3	5	11.4
<u>Asplanchna priodonta</u> Gosse 1850	1	2.6	15	34.1
<u>Brachionus</u> sp.	2	5.1	8	18.2
<u>Lepadella ovalis</u> (Müller 1786)	3	7.7	5	11.4
<u>Lecane elasma</u> (?) Harring & Myers 1926	1	2.6	0	0
<u>Monostyla lunaris</u> (Ehrenberg 1832)	1	2.6	6	13.6
<u>Synchaeta oblonga</u> Ehrenberg 1832	4	10.3	18	40.9
Total no. lake occurrences, all rotifer species	61	-	185	-
Mean no. rotifer species per lake	-	1.6	-	4.2
Total no. rotifer species occurring in the study	12	-	28	-

(e.g. Copepoda as an Order in some, as a Subclass in others).

Here, the system in Edmondson (1959) is used.

NET ZOOPLANKTON: Annotated List

Phylum Arthropoda (the arthropods = joint-footed animals)

Class Crustacea (the crustaceans)

Order Copepoda (the copepods)

Suborder Calanoida (the calanoid copepods)

Diaptomus arcticus - The largest of the copepods in the study area (up to 3 mm); dark red. Occurs in ponds and lakes, but uncommon when fish present, unless lake deep or water silty. A voracious predator on smaller crustacean plankters, rotifers, and its own young, but can subsist on periphyton and other algae. Normally one generation per year (Apr. to Nov.); usually one clutch of eggs per female; males to females approx. 1:1; overwinter in egg stage.

Diaptomus tyrrelli - Small, red copepod (usually <1.5 mm). Occurs in ponds and lakes, but uncommon with predaceous Diaptomus arcticus unless the latter species sparse, and uncommon when predaceous cyclopoid copepods very abundant. Too small for most "trout" species to feed on. A filter feeder (or "grazer"), or feeds on periphyton. Usually one generation per year (Apr. to Nov.); usually one clutch eggs per female; males to females approx 1:1; overwinters in egg stage.

Suborder Cyclopoida (the cyclopoid copepods)

Orthocyclops modestus - Moderately-sized cyclopoid (up to 1.5 mm); usually colorless. Often confined to deep waters of larger lakes and possibly missed in some routine sampling programs. Probably predaceous. Little known of life history (see also Morry 1973).

Macrocyclus albidus - Largest of the cyclopoids in the study area (about 2 mm); usually light grey to dull pink in color. Most common in shallow, weedy lakes; less abundant when fish present. Voracious predator on smaller crustaceans. Probably 2 or 3 generations per year in warmer lakes of study area; several clutches per female; females usually more common than males; overwinters as encysted sub-adult.

Eucyclops agilis - Moderately large cyclopoid (up to 1.5 mm); usually rather dark in color. Common to shallow and/or weedy lakes and ponds or inshore regions of larger lakes. A "grazer"; probably feeds largely on periphyton. Reproduction and overwintering much as in M. albidus.

Acanthocyclops vernalis - Moderately large cyclopoid (up to 1.7 mm); usually colorless or pink in color. Common in temporary ponds or cold lakes, sometimes as a winter species. Uncommon if large predaceous Diaptomus species present or large numbers of Diacyclops bicuspidatus thomasi. Generally predaceous, but not so voracious as D.b.thomasi. One to three generations per year in these lakes; males to females usually 1:1; possibly several egg clutches per female; encysts as sub-adult.

Diacyclops bicuspidatus thomasi - Smallest cyclopoid species of the study area (up to 1.2 mm); usually colorless, but can be pink if certain prey species present. Common to larger lakes, especially those with fish, but not widespread in Yoho area. Uncommon if large predaceous Diaptomus spp. established in lake. Intermediate host for Triaenophorus (parasites of fish). Voracious predators capable of eating prey larger than themselves. One or two generations per year in cold lakes; possibly two or more clutches per female; males often less abundant than females; encyst as sub-adults, although encystment not obligatory in lakes.

Order Cladocera (the water fleas)

Polyphemus pediculus - Small cladoceran characterized by unusually large, red compound eye; body colorless. Most common in small, warm, weedy ponds and shallow lakes. Purported to be a predator. Often several generations per year; females retain eggs in brood pouch (as do most cladocerans to follow); females usually much more abundant than males.

Holopedium gibberum - Moderate-sized cladoceran, usually limnetic in larger lakes, although found in a pond in this study; animal enclosed in a transparent, sphaerical gelatinous case; swims on its "back"; embryos retained in brood pouch.

Alona spp. and Alonella sp. - Very small cladoceran species; not usually very abundant in lakes of the study area and more often found in weedy ponds or littoral (in-shore) regions.

Chydorus sphaericus - A cosmopolitan species found everywhere, although infrequently in large numbers; rather sphaerical in shape and up to 0.5 mm in diameter; usually light yellow; rarely abundant in limnetic (open-water) zone, but frequently occurs there in small numbers; most common in small lakes and ponds.

Daphnia middendorffiana - A large daphnid or "water flea" (up to 3.5 mm) usually restricted to high altitude or high latitude (arctic) lakes; often darkly pigmented and therefore easily eradicated by fish. Usually one to three generations per year in cold water; females usually reproduce parthenogenetically (asexually); males extremely uncommon.

Daphnia pulex - Similar to D. middendorffiana, but no pigment and, therefore, often co-occur with fish species. Males not uncommon in warmer waters, but may occur only rarely in colder waters. Usually produce two or more broods parthenogenetically in the first part of the season, and produce resistant, over-wintering eggs (ephippia) sexually late in the season.

Daphnia pulicaria - General features similar to D. pulex, although often somewhat larger. General taxonomy of D. pulex, D. pulicaria, D. schoedleri, and possibly D. catawba and D. middendorffiana in a somewhat confused state. Difficult to breed in laboratory because of parthenogenetic reproduction, and morphologically confusing because of plasticity of the general group.

Daphnia catawba - Generally similar to D. pulex and D. pulicaria, but smaller; main taxonomic difference is in post-abdominal claw.

Simocephalus spp. - Large-bodied cladocerans (up to 3 mm); usually light yellow to colorless; poor swimmers; most common in weedy margins of lakes and in ponds; seldom abundant; the two species occurring in the general vicinity of the study area (S. vetulus and S. serrulatus) not uncommonly co-occur.

Scapholeberis kingi - Small (< 1 mm); usually dark (often black) in color; most commonly occurring in littoral (inshore) regions of lakes or in ponds, usually near surface.

Ceriodaphnia affinis - Usually small (< 1 mm); colorless; may occur in small lakes and permanent ponds; uncommonly abundant when large cladoceran competitors or predaceous Diaptomus spp. present; each female may produce several small broods; possibly several generations per year.

Bosmina longirostris - One of the smallest planktonic cladocerans (usually < 0.35 mm); colorless; usually restricted to larger lakes; not commonly abundant in presence of larger cladocerans or predaceous copepods, but often very abundant in presence of fish; each female may produce several small broods, and there may be several generations per year, depending on the temperature of the lake.

Order Ostracoda (the ostracodes)

Small, bivalved crustaceans outwardly resembling very small clams. Not usually present in plankton, but may swim near bottom. Infrequently encountered in this study. Two records and identifications follow:
Cyclocypris laevis (Müller) 1776. Duchesnay L., 12-VIII-70 (sample no. 70165).
Cyclocypris globosa (Sars) 1863. South Narao L., 9-VII-70 (sample no. 70116).

Subclass Malacostraca (of Class Crustacea)

Order Mysidaceae

Mysis relicta Lovén - "Opposum shrimp"; usually regarded as the most "primitive" (evolutionary-wise) of the orders of Malacostraca. Adult female characterized by development of brood pouch (or marsupium) where young are retained until fairly well developed - hence, the name opposum shrimp. Usually restricted to deep, cold, oligotrophic, pro-glacial lakes, and commonly considered a glacial "relict". Remains near bottom during the day, but becomes planktonic at night when it may feed extensively on zooplankton. Frequently introduced into potentially suitable lakes as a forage organism for fish, although the ecological impact of such transplants was inadequately studied before such transplants had become fairly common.

Order Amphipoda (the amphipods)

Gammarus lacustris Sars. Common amphipod or scud; often one of many species simply referred to as "freshwater shrimp". Very common in shallow, weedy lakes in many parts of the world, and not uncommon in margins of many lakes; occasionally occurs at considerable depths. Not

usually planktonic, but may occur commonly in plankton when fish absent. Although commonly referred to as detritivores or omnivores, appear to be important as predators in certain lakes (Anderson and Raasveldt 1974). When abundant, Gammarus may exhibit a considerable controlling influence over the abundance and diversity of other planktonic Crustacea.

Class Insecta (of Phylum Arthropoda) - the insects.

Order Diptera (two-winged insects)

Family Culicidae (the mosquitos and their relatives)

Chaoborus brunskilli Saether - The larval stage of this non-biting mosquito is usually called a "phantom midge" because it is essentially transparent in the water. More common in eutrophic lakes and ponds, but not restricted to them. May be reduced in numbers by Gammarus or fish predation. Usually benthic by day and planktonic by night, but like Gammarus may remain planktonic by day if no fish present. Voracious predators on smaller zooplankters and may have a considerable effect on the constitution of the zooplankton community (Anderson and Raasveldt 1974). Apparently not predaceous on Holopedium gibberum, possibly because of the gelatinous case. The only occurrence of Chaoborus of consequence in this study was in Opabin Pond 4 (lake no. 11) with Holopedium gibberum.

Phylum Platyhelminthes (the flatworms)

Class Turbellaria

Order Tricladida

Polycelis coronata (?) (Girard) - A small triclad (often called a "planarian") most common in clear streams in the study area, but can occur on rocky shoreline areas of mountain lakes. Not normally planktonic, but occasionally occurs in plankton samples as do somewhat distantly related flatworms, such as Mesostoma ehrenbergii and M. arcticum. Specific identification of this group is virtually impossible without detailed serial sectioned preparations of embedded, sexually mature specimens. Probably feeds of damaged insect larvae and damaged copepods. The only lake in which Polycelis found in this study was Indigo Lake (no. 61).

Phylum Protozoa (one-celled animals)

Class Sarcodina

Order Testacealobosa (Testicida)

Diffugia spp. - The "shelled" amoebae. Like a common Amoeba, but with a vase-shaped "shell" composed of mineral particles secreted by the cell. Eats small organic particles and possibly small organisms by ingestion. Not truly planktonic, but may occur in plankton of some lakes at time of spring or fall overturn. Found in Indigo Lake (no. 61).

Phylum Rotifera - the rotifers, or "wheel animalcules", so-called because of the ciliated trochal disc in the "head" used for locomotion and food gathering. Viewed under the microscope, the beating cilia resemble small wheels rotating. Mostly microscopic (48

microns to 2 mm); wormlike in basic structure consisting usually of head, trunk, and 'foot'; lacking a true body cavity; most tissues lack distinct cells (syncytial tissues); males usually dwarf and quite different from females; some species colonial but most true planktonic species solitary. Most species are filter feeders adapted to taking in very small particles in the size range of bacteria and very small nanophytoplankton; a few predaceous species; color closely associated with food. Life span usually 10 to 15 days, but may be longer in cold waters. Reproduction by eggs or living young; depending on species and time of life cycle, diploid (asexual) or haploid (sexual) eggs produced; both summer and overwintering (resting or dormant) eggs may be produced. Many species rather cosmopolitan in occurrence.

Order Pliota

Polyarthra vulgaris - Planktonic; characterized by long, "feathered" paddle-like appendages for swimming; lacking the "foot"; usually restricted to well-oxygenated waters.

Kellicottia longispina - Loricata; lorica with one long caudal spine and 6 long to short anterior spines; spines usually longer in colder water; more common in large oligotrophic lakes. Foot absent.

Keratella cochlearis - Strongly loricate; 6 anterior spines and 1 posterior (caudal) spine; foot absent; common to but not restricted to stagnant waters; caudal spine usually longer and development much slower in cold waters.

Keratella quadrata - Similar to K. cochlearis, but with two caudal spines; usually in permanent lakes, and often more common in deeper water layers in lakes of this study area; usually restricted to oligotrophic lakes.

Asplanchna priodonta - Illoricate, sac-like, and transparent; foot absent; largest of rotifers in study area; usually perennial in open waters of lakes and ponds; probably predaceous on smaller rotifer species and may feed as well on early instars of crustaceans; great variation in abundance in general study area from one year to another.

Synchaeta oblonga - Illoricate, sac-like; reduced foot; may be predaceous on very small forms; males rare; mainly pelagic in epilimnion (upper layers of open water) of permanent lakes.

Order Flosculariacea

Filinia longiseta - Illoricate; two anterior and one posterior "bristles"; foot absent; usually pelagic in epilimnion of permanent lakes; sometimes in brackish waters.

NET PHYTOPLANKTON

Division Pyrrophyta

Class Dinophyceae - the armored dinoflagellates

Order Peridiniales

Ceratium hirundinella - One of the largest dinoflagellates, usually 100 to 400 microns (about the size of small

rotifers); plates extended into long, horn-like processes (usually 3 posterior and one anterior); especially common in hardwater lakes, but may also be temperature dependent; capable of forming dense blooms if nutrient conditions suitable.

Division Chlorophyta

Class Chlorophyceae

Order Volvocales

Volvox spp. - Sphaerical, free-swimming colonies of 500 to several thousand cells; cells arranged in periphery of mucilaginous globe; "daughter" colonies form inside parent colony. Not uncommon in plankton of hardwater lakes and ponds, but often restricted to warm waters with fairly high nitrate concentrations; can form blooms.

Ceratium and Volvox are actually large, motile, net phytoplankters. Their occurrences were often sporadic in this area; they may occur once out of several years in mountain lakes (see Table 51). Although large by comparison to nanophytoplankton, in terms of biomass they are small compared to the crustaceans, or even the rotifers. Consequently, they are not considered in any more detail in this section.

In Table 47, a general comparison of diversity of Yoho National Park zooplankton to that of other areas and all of North America is given. The most comparable study cited is that of Waterton Lakes National Park (Anderson et al. 1972) where 44 lakes and ponds were studied. The greater altitudinal and size differences in the lakes of Waterton Lakes National Park are probably the main factors responsible for the greater zooplankton diversity in that park. Perhaps one of the more striking differences between the Yoho study and others in the general vicinity is the total absence of phyllopods (especially Anostraca, or fairy shrimps—see Plates 1 to 5) in Yoho waters. Although they may yet turn up in samples from some of the ponds or smaller lakes, it may be that waters suitably free of potential predators are too cold and growing seasons too short for them to

Table 47. Comparison of species diversity of Yoho National Park zooplankton to species diversity in nearby study areas and elsewhere in North America.

	Total no. crustacean plankton species	No. free-living copepod species (calanoid, cyclopoid, & harpacticoid)	No. calanoid copepod species	No. cyclopoid copepod species	No. cladoceran species	No. phyllopod ^a . species	No. anostracan ^a . species
39 lakes and ponds, Yoho National Park (this study)	26	7	2	5	19	0	0
44 lakes and ponds, Waterton Lakes National Park (Anderson <u>et al.</u> 1972)	60	20	11	7	32	5	3
340 lakes and ponds in southern Alberta and southeastern British Columbia (Anderson 1974a)	94	32	21	9	50	12	9
Known Alberta species of Anostraca (Hartland-Rowe 1965, and personal communication)	-	-	-	-	-	-	14
Known Saskatchewan species of calanoid copepods (Wilson 1958; Anderson 1970d, 1971b)	-	-	25	-	-	-	-
Known Ontario species of Cladocera (1972 - C.H. Fernando, personal communication)	-	-	-	-	80	-	-
Listed species of planktonic ^c crustaceans for North America (various keys, Edmondson 1959)	413	218 ^b	80	56	130	65	31

a. Phyllopods include the Anostraca (fairy shrimps), Notostraca (tadpole shrimps), and Conchostraca (clam shrimps), all most frequently characteristic of temporary or astatic waters.

b. Includes 82 harpacticoid species, most of which are not truly planktonic.

c. In the sense of occurring frequently or sporadically in plankton net samples.

survive. Fairy shrimps are unable to withstand predation from fish or predaceous amphipods. Harpacticoid copepods were also missing from the Yoho samples; however, they are very small, bottom-dwelling species and they may have been missed easily, especially if they are only sparsely represented.

Of the crustacean plankton species known to occur within about 200 to 300 km of Yoho National Park (Anderson 1974a), only slightly more than $\frac{1}{4}$ of them occur in Yoho. All of the Yoho species except Simocephalus serrulatus were among the most common species in the 340-lake study. In addition to the missing Anostraca (fairy shrimps), eight other most-common species in the larger study were absent from Yoho, although some may turn up in small numbers in future studies:

<u>Diaptomus shoshone</u>	<u>Alonella nana</u>
<u>Diaptomus leptopus</u>	<u>Daphnia rosea</u>
<u>Diaptomus sicilis</u>	<u>Daphnia schoedleri</u>
<u>Diaptomus nudus</u>	<u>Ceriodaphnia quadrangula</u>

1.

Of the 121 species occurrences for crustacean plankton species, only 32 were at an abundance level of 3 or 4 (e.i. one to 100 individ./litre, see Introduction of this section) and there were no 5's or 6's (i.e. more than 100/litre). Of the 61 lake occurrences for rotifer species, only 8 were at an abundance level of 4 or 5 (i.e. ten to 1000 individ./litre, relatively less abundant than crustaceans, taken on a biomass basis). So, it can be seen that the diversity of zooplankton forms is not only impoverished in Yoho National Park waters, but that many of the species that do occur are rather rare. The mean number

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1. "Species occurrence" = one lake where a species occurs. Therefore, 3 different species occurring in each of 6 different lakes would be 18 species occurrences.

Table 48. Breakdown of zooplankton species diversity in 39 lakes of Yoho National Park, and mean numbers of certain groups per lake.

Lake number	Lake name	No. rotiferan species	No. crustacean species	No. calanoid copepod species	No. cyclopoid copepod species	No. cladoceran species	Total no. zooplankton species
50	Fairy	2	3	1	0	2	5
37	Kiwetinok	1	2	1	0	1	3
55	Amiskwi	1	2	1	0	1	3
61	Indigo	0	1	1	0	0	1
35	Otto	0	1	1	0	0	1
29	Crystal	0	1	1	0	0	1
38	Hamilton	0	3	1	1	1	3
16	Oesa	2	2	1	1	0	4
14	Opabin 2	0	3	1	0	2	3
15	Opabin 1	0	2	1	0	1	2
15A	Opabin 5	0	1	1	0	0	1
31	Little Gem	0	2	1	1	0	2
44B	Hidden P.	0	5	1	2	2	5
20	Wapta	6	3	1	1	1	9
9	O'Hara	3	4	1	2	1	7
8	McArthur	3	3	1	1	1	6
41	Celeste	1	2	1	0	1	3
42	Duchesnay	3	5	1	1	3	8
49	Summit	1	13	1	3	9	14
48	Sink	1	8	1	2	5	9
26	Emerald	7	4	1	2	1	11
7	Schaffer	4	3	1	1?	1	7

Lake number	Lake name	No. rotiferan species	No. crustacean species	No. calanoid species	No. cyclopoid species	No. cladoceran species	Total no. zooplankton species
43	Yoho	3	1	0	1	0	4
44	Hidden L.	0	2	0	1	1	2
47	Sherbrooke	4	4	0	2	2	8
17	Ross	4	3	0	1	2	7
19	No. Narao	2	8	0	2	6	10
18	So. Narao	3	8	0	3	5	11
10	Mary	2	6	0	3	3	8
13	Opabin 3	2	2	0	1	1	4
11	Opabin 4	1	3	0	1	2	4
23	Up. Morning						
	Glory	1	2	0	1	1	3
6	Ottertail	0	4	0	2	2	4
51	Waves P.	0	0	0	0	0	0
41A	nr Celeste	0	0	0	0	0	0
28	Ptarmigan P.	1	0	0	0	0	1
22	mid Morning						
	Glory	1	1	1?	0	0	2
24	Linda	2	3	0	2?	1	5
12	Victoria	0	1	0	1?	0	1
52	Marpole						
Mean no./lake		1.6	3.1	0.6	1	1.5	4.7

? = questionable very low density occurrences.

Table 49. Frequency of various aspects of zooplankton diversity in the 39 lakes of the Yoho National Park study.

No. species in various groups per lake	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Rotifers	0	0	0	0	0	0	0	1	1	0	3	5	6	9	14
All crustaceans	0	1	0	0	0	0	3	0	1	2	4	9	9	7	3
Calanoid copepods	0	0	0	0	0	0	0	0	0	0	0	0	0	23	16
Cyclopoid copepods	0	0	0	0	0	0	0	0	0	0	0	3	8	14	14
Cladocerans	0	0	0	0	0	1	0	0	1	2	0	2	7	14	12
All Zooplankton	1	0	0	2	1	2	3	3	1	3	5	6	4	6	2

of crustacean plankton species in the 39 lakes is only 3.1 per lake, and for rotifer species only 1.6 per lake, or for all zooplankton species only 4.7 per lake (Table 48), comparable to truly alpine² lakes in the Rocky Mountains of Alberta and British Columbia (Anderson 1971a) and much lower than would be found in montane or colline³ lakes and ponds in many nearby areas. From Table 49, it can be seen that the number of lakes containing very diverse faunas (10 or more species) is very small (4 of 39 lakes); over half contain less than 4 species including rotifers and, indeed, two contain no zooplankters at all. It is also evident at this stage that there is little unique about the plankton fauna of Yoho National Park waters.

Community Composition and Predator-Prey Relationships

In the previously noted study of 340 lakes and ponds in southwestern Alberta and southeastern British Columbia (Anderson 1974a), the crustacean plankton communities fell rather logically into seven groups based largely on the presence of certain copepod species. The Yoho lakes and ponds of this study represented only four of these groups. One of these subdivided into three subgroups was represented by only two subgroups in Yoho. A comparison of the present study with the larger study follows:

-
2. "Alpine" in the sense of above treeline.
 3. "Colline" = foothills or piedmont.

<u>Table</u>	<u>Group</u>		<u>340 lakes</u>	<u>39 Yoho lakes</u>
2	I	one or both <u>Diaptomus shoshone</u> and <u>D. arapahoensis</u> , + <u>Leptodiaptomus</u> spp.	(37)	-
3	IIA:	<u>D. arcticus</u> the only copepod	(55)	11
4	IIB:	<u>D. arcticus</u> + <u>Leptodiaptomus</u> spp. + cyclopoids	(24)	-
	IIC:	<u>D. arcticus</u> + cyclopoid spp.	(24)	5
	III:	prairie <u>D. arcticus</u> or other <u>Hesperodiaptomus</u> spp.	(10)	-
5	IV:	<u>Acanthodiaptomus denticornis</u> , <u>D. leptopus</u> , <u>D. forbesi</u>	(57)	-
6	V:	<u>D. tyrrelli</u> , <u>D. ashlandi</u> , <u>D. sicilis</u> , <u>D. nudus</u> , <u>D. oregonensis</u> , <u>D. franciscanus</u> or <u>D. connexus</u> the only diaptomid	(62)	6
7	VI:	cyclopoids only, except two very sparse diaptomid occurrences	(53)	11
8	VII:	no copepods except very sparse cyclopoid nauplii	(18)	6

It can be seen that the Yoho lakes represent more than a proportional share of the simplest or least diverse communities (i.e. groups IIA, VI and VII, the latter including lakes with extremely sparse or no zooplankton at all).

A summary of the species by lakes including an indication of abundance and indicating grouping is given in Tables 50 and 51. As can be seen in Table 51, the rotiferan fauna is very sparse, about 1/3 of the lakes yielding no rotifers at all in plankton samples, and only 6 containing populations at a density estimated at from 75 to 125 per litre - very sparse for rotifers. The most diverse rotifer community in the 39 lakes (Emerald Lake at 7 species) seems to have changed drastically in the last two years, a point to be discussed in more detail below.

From Table 50, it can be seen that nearly half of the species occurrences are at extremely low densities (i.e.

less than 0.1 per litre, and often no more than one zooplankter for every one or two cubic metres!). The composition of the communities in group IIA indicate the ability of the predaceous Diaptomus arcticus to effectively eliminate all small zooplankters and rotifers. In group IIB, this predator still limits the existence of other species, but less effectively as a result of some control over its own numbers by fish (McArthur Lake and O'Hara Lake), rapid water renewal rates (Wapta Lake), and the controlling effects of a temporary pond freezing solid in winter (Hidden Pond). Such controlling effects on D. arcticus in lake group V permit the occurrence of the smaller, non-predaceous Diaptomus tyrrelli, a species rather more common in alpine and subalpine lakes and ponds elsewhere in the mountain national parks. The lakes in lake group VII are apparently too cold, too nutrient poor, or too lacking in permanence to permit the development of much of any type of community.

The role of Gammarus as an effective predator having a potential controlling influence on the composition and abundance of certain zooplankton communities in Yoho lakes (see Anderson and Raasveldt 1974) is probably greatly reduced compared to some other lakes because of the low numbers of Gammarus present in Yoho lakes. Up to 20 or 30 per sq. metre* may occur in O'Hara and Sink lakes, and much smaller numbers in Linda, Sherbrooke, Wapta, and Ross lakes. These numbers are very small compared to previously estimated highs of 1000/m² for Linnet Lake in Waterton Park and current estimates which suggest numbers as high as

*Nos. based on dredge, shoreline, and trawl samples. Moderate numbers of Gammarus were found in fish stomachs from O'Hara and Wapta lakes, and smaller numbers in fish from Sink and Ross lakes. No Gammarus appeared in stomachs of fish from other lakes.

8000/m² for the same lake. Even at very low numbers (as low as 5/m²), it is believed that Gammarus could effectively control Anostraca (fairy shrimp) numbers in very cold lakes where growth rates are low.

Plankton Stability

A great deal has been written about the stability (or lack of stability) of the zooplankton from year to year, and the need to sample fairly frequently in all seasons over a period of several years in order to get a true picture of the zooplankton community of a lake. The Yoho samples, collected over a period of 9 years and including at least a few winter and spring samples as well as frequent summer and autumn samples, indicate (1) that major changes are unlikely in the normal course of events, (2) that additional species found as a result of multiple sampling are likely to represent very sparse populations having very little ecological impact on the community, and (3) that distinctly different seasonal communities are not likely to occur other than that in winter there is often no community at all or merely the sparse remnants of the summer community.

Changes in species lists as a result of multiple sampling of lakes and ponds were frequent with regard to rotifers (16 of 20), a feature more to be expected among rotifers than among crustacean plankton species (e.g. Pennak 1955) although even with rotifers in this study the changes most frequently involved new occurrences of very sparsely represented species. Major changes occurred in Emerald Lake rotifers, a situation to be dealt with below.

Multiple sampling provided changes in 18 of 20 species lists for the crustacean plankton, most of which also involved sparsely represented species which may always be present at very low numbers. The only very great differences were in shallow, often temporary ponds where large changes are a constant and natural phenomenon. The major changes in waters other than temporary ponds can usually be attributed to three principal causes:

- i. Large seasonal variations in mean air temperatures, mean precipitation, length of open-water season, and snow cover over ice in winter.
- ii. Natural fluctuations in certain predator species such as Chaoborus spp. larvae.
- iii. Intentional manipulations or introductions by man, such as:
 - a) water level changes or diversions.
 - b) introduction of fish, resulting in the reduction or elimination of certain large invertebrate predators and possible increases in numbers of rather small species.
 - c) introduction of certain invertebrates as food organisms for fish, such as the introduction of Mysis relicta into Emerald Lake.

Conversely, if the fish populations artificially maintained in a lake are allowed to disappear, it might be expected that the plankton community would revert to its original type.¹ Such may not be the case if a smaller, efficient predator becomes firmly established in large numbers. In such a case, the smaller predator may effectively prevent recurrence of the larger by controlling the abundance of the offspring of the larger species (Anderson 1972). This may be the reason why some fishless lakes where D. arcticus might be expected does not occur.

1. There is some evidence to indicate that this may be occurring in McArthur Lake. It would be useful to monitor this lake about every 2 years for 6 or 8 years to assess this possibility, assuming that no further fish stocking occurs in the lake.

Changes in Emerald Lake Zooplankton

In September, 1967, 60,000 Mysis relicta from Upper Waterton Lake were introduced into Emerald Lake in an attempt to increase the food organisms available to the sport fish in the lake. As a relatively cold, glacier-fed lake, Emerald Lake has never held much promise of being very productive: for example, see Schultz (1953) for comments on 1952-53 investigations and a résumé of previous studies. During the 1953 investigations, deep-water benthic samples produced no fauna, and bottom fauna was generally sparse over all the lake. Superficially at least, there seemed to be an unoccupied niche in or on the sediment substrate. In the present study, examination of bottom sediments indicated the accumulation of extremely little organic matter in these sediments (see Table 13).

Part of the rationale behind the introduction of Mysis relicta into a number of large oligotrophic lakes in both North America and Scandinavia has been that Mysis was probably missing from many of the lakes by accident of glaciation and that the species could occupy a hitherto unoccupied ecological niche in such lakes, thereby enhancing total productivity. Subsequent studies and events in both Sweden and North America have shown that the dimensions of the ecological niche for Mysis were poorly known and that changes that have occurred are not necessarily wholly beneficial. To summarize:

1. Some studies have shown (or authorities stated) that Mysis has become an important food organism in the diets of fish in lakes where Mysis was newly introduced (Larkin 1948; Rawson 1961; Threinen 1962; and many others).

- ii. Some studies seem to show (not prove) that the improved growth of Kokanee in some lakes may be linked to the introduction of Mysis (Sparrow et al. 1964).
- iii. Studies before 1971 in Lake Tahoe, California, (Cordone, et al. 1971) indicated that Daphnia was the main food of Kokanee, and that a "recently established" population of Mysis relicta might "insert a previously unavailable energy source into the Kokanee food chain". Instead, the Daphnia have disappeared, and the Kokanee do not seem to have been able to utilize Mysis (Richards, et al. 1975).
- iv. Quote from N.G. Hairston in Ecology (Hairston 1959). "It has frequently been claimed that empty niches must abound in view of the ability of certain introduced species to succeed in establishing themselves. Such introductions, however, result in a decrease in numbers of some previously established species, as is shown dramatically in the history of oceanic islands. The author knows of no adequate data contrary to the generalization that successful introductions reduce the population of one or more indigenous species. The implication that natural communities contain no unoccupied niches is clear."
- v. Mysis relicta has been shown to be predaceous on zooplankton at least in some lakes (Lasenby and Langford 1973), and the sudden disappearance of certain crustacean plankton species has been noted in some lakes when Mysis was introduced (e.g. Lake Tahoe - Richards et al. 1975).
- vi. Because of unpredicted changes such as those in item "v.", it is now forbidden by law in Sweden to introduce Mysis relicta into lakes previously barren of Mysis without extensive prior investigation and the permission of the Fishery Board of Sweden (Magnus Furst, personal communication).

There is some evidence that the condition of Salvelinus fontinalis (brook trout) in Emerald Lake is slightly better since the introduction of Mysis, but there is also evidence that the plankton community is being depauperated. Fig. 43 summarizes the results of samples taken over the past 9 years. Although further checking is necessary to verify the possibility of

permanent changes in the plankton, it appears that rotifers may have been eliminated. None was found in Mysis stomachs from Emerald Lake. Diaptomus numbers were greatly diminished in both 1974 sample sets and one 1972 set. One puzzling irregularity in Fig. 43 is the greater copepod abundance in 1973. Studies currently underway indicate that Mysis has a two-year life cycle in Emerald Lake and Upper Waterton, and it is possible that the numbers of Mysis of a size capable of predation are occurring in even-numbered years in larger numbers than in odd-numbered years. This, too, requires verification. Additional treatment of the present Mysis data and additional studies are in preparation or are underway.

Zooplankton Standing Crop and Production

As noted earlier, it has been necessary in this part of the study to employ values and factors determined by others in order to make an assessment of production by zooplankton. Whenever possible, derived values for the same or closely related species from similar habitats were used, and for others, where closely related data were not readily available, adjustments for size differences or slower growth rates were made. Consequently, the final production values are estimates (as they would still be in very detailed studies, although precision would increase), but it is unlikely that present estimates are grossly in error. References used (and justification for selection, in the case of rotifers) are indicated in the tables of data.

Tables 52 and 53 include dimension data and biomass calculations for the rotifer and crustacean species of the

Table 52. Dimension and biomass calculations for crustacean plankton species of this study.

Species ^c .	a. Factor for converting wet wt. to dry wt.	Body length, mm	Approx. adult biomass wet wt. (frwt), mg	Dry wt./individual mg	b. Caloric value estimate cal/mg	Estimated calories per individual	Expected no. generations per year	Estimated annual ^{d,e} P/B ratio
<u>Diaptomus arcticus</u>	.12	2.2	.512	.060	5.6	.336	1	1.3
" " (O'Hara)		2.6	.751	.088		.493		1.5
<u>Diaptomus tyrrelli</u>	.12	1.4	.120	.021	5.6	.118	1	1.5
<u>Orthocyclops modestus</u>	.12	1.2	.090	.011	5.8	.064	1	2.0
<u>Macrocyclus albidus</u>	.12	2.0	.370	.044	5.8	.255	1(2)*	2.0(3.0)*
<u>Eucyclops agilis</u>	.12	1.3	.110	.013	5.8	.075	1(2)*	1.5(2.5)*
<u>Acanthocyclops vernalis</u>	.12	1.5	.150	.018	5.8	.104	1(2)*	1.5(2.5)*
<u>Diacyclops bicuspidatus</u>	.12	1.1	.070	.008	5.8	.046	1(2)*	2.0(3.0)*
<u>thomasi</u>								
<u>Polyphemus pediculus</u>	.1	1.0	.070	.007	5.0	.035	2	3.0
<u>Sida crystallina</u>	.1	2.4	1.000	.100	5.0	.500	2	3.0
<u>Holopedium gibberum</u>	.1	1.5	.150	.015	5.0	.075	2-3	2.5
<u>Eurycercus lamellatus</u>	.1	2.6	1.200	.120	5.0	.600	2-3	2.5
<u>Acroperus harpae</u>	.1	0.7	.040	.004	5.0	.020	2-3	2.5
<u>Alona guttata</u>	.1	0.35	.010	.001	5.0	.005	2	2.0
<u>Alona affinis</u>	.1	0.9	.060	.006	5.0	.030	2	2.0
<u>Alona rectangula</u>	.1	0.3	.010	.001	5.0	.005	2	2.0
<u>Alonella excisa</u>	.1	0.4	.020	.002	5.0	.010	2	2.0
<u>Chydorus sphaericus</u>	.1	0.45	.040	.004	5.0	.020	2	2.0
<u>Daphnia middendorffiana</u>	.1	3.0	1.100	.110	5.0	.550	2	2.0
<u>Daphnia pulex</u>	.1	2.4	.580	.058	5.0	.290	3	3.0
<u>Daphnia pulicaria</u>	.1	2.5	.650	.065	5.0	.325	3	3.0
<u>Daphnia catawba</u>	.1	2.1	.380	.038	5.0	.190	3	3.0
<u>Simocephalus vetulus</u>	.1	2.4	.950	.095	5.0	.475	3	3.0
<u>Simocephalus serrulatus</u>	.1	2.4	.950	.095	5.0	.475	3	3.0
<u>Scapholeberis kingi</u>	.1	0.9	.080	.008	5.0	.040	2-3	2.5
<u>Ceriodaphnia affinis</u>	.1	0.8	.060	.006	5.0	.030	2-3	2.5
<u>Bosmina longirostris</u>	.1	0.45	.020	.002	5.0	.010	2-3	2.5

a. Based on data from Burgis (1975), Dumont (Ms 1975), Herzig (1974), Klekowski & Shushkina (1966), Nauwerck (1963), and Anderson (1968a).

b. Approx. values from Schindler (1970) and Cummins & Wuycheck (1971).

c. Data apply to adults: Cladocera (♀ no eggs); Copepoda (approx. mean of males and females without eggs).

d. Based on no. generations per year & generation time, & other estimates (Alimov & Winberg 1972; Anderson 1974c; Schindler 1970; Winberg 1971)

e. P/B ratio used in this table to reflect attempt to reconcile general species characteristics with particular locations in Yoho Nat. Park.

* Higher numbers in parentheses apply to warmer lakes only.

Table 53. Dimension and biomass calculations for rotifers of this study.

	Factor converting ^{b.} wet wt. to dry wt.	Vol. in μ^3 (max.) ^{a.} (Nauwerck 1963)	Dry wt. μg (max.) (from: Dumont et al. Ms submitted, 1975)	Est. calories ^{e.} per individual (based on Dumont et al.)	Est. calories per individual (based on Nauwerck and on factors in col. 1)	Comparison of ests. Dumont/Nauwerck	Comparable values from Winberg (1971)
<u>Polyarthra vulgaris</u>	.15	5.5×10^5	0.74^d	.0036	.00040	9	-
<u>Filinia longiseta</u>	.15	1.0×10^{5d}	0.42	.0021	.00007	30	.0001
<u>Kellicottia longispina</u>	.2	1.0×10^5	0.50^c	.0025	.00010	25	-
<u>Keratella cochlearis</u>	.2	5.0×10^4	0.11	.0005	.00005	10	.0001
<u>Keratella quadrata</u>	.2	1.0×10^5	0.35	.0017	.00010	17	-
<u>Notholca acuminata</u>	.2	1.0×10^5	0.35^c	.0017	.00010	17	-
<u>Asplanchna priodonta</u>	.1	3.0×10^7	1.00^d	.0049	.01470	0.3	-
<u>Brachionus</u> sp.	.15	5.0×10^{4c}	0.20^d	.0010	.00004	25	$.0008^d$
<u>Lepadella ovalis</u>	.2	5.0×10^{5c}	0.31	.0015	.00049	3.1	-
<u>Lecane elasma</u>	.2	2.0×10^{5d}	0.60^c	.0029	.00020	14.5	-
<u>Monostyla lunaris</u>	.2	2.0×10^{5c}	0.60^c	.0029	.00020	14.5	-
<u>Synchaeta oblonga</u>	.1	1.0×10^6	0.27^d	.0013	.00049	2.7	-

a. Volume in μ^3 converts to grams by multiplying by 10^{-12} .

b. Factor based on presence/absence of lorica, lorica type, setae, & other hard parts, etc.

c. Estimated values; specific data unavailable.

d. Species different, but dimensions essentially the same.

e. Estimated calories per gram dry wt. = 4900 (Schindler 1970).

zooplankton. Many are not used in detailed considerations because the species involved were too rare to warrant detailed calculations. These calculations were made in a few cases and compared to lumped data (i.e. where rare species were treated as the nearest-sized dominant) and differences were too small to justify the detailed calculations.

Production of dominant or subdominant species (here taken to be any species constituting 5% or more of the total numbers of crustaceans in a given lake) was derived from estimates of survival, generation time, feeding efficiency, number of generations per year, and adult biomass and calorific values. The adult biomass rather than the mean annual biomass for a species was used in estimating the P/B ratio (here: total-annual-net-production/maximum-biomass) because most consistent sampling was done in the late summer and early autumn, and because maximum standing crop biomass appears to occur commonly at this time of year in most of the lakes of the type studied here (Anderson 1974c). The general procedure used for estimating production potentials follows the pattern used in a study of an alpine lake and a subalpine pond for the purpose of estimating sport-fish production potential as it relates to management recommendations (Anderson 1974c).

Estimates of total annual production by zooplankton for the 39 lakes and ponds of Yoho National Park are summarized in Table 54. These estimates range from a low of zero (0) - no zooplankton - to a high of 53,463 cal/m³ (Sink Lake, no. 48). To convert these values to other terms, the total energy

Table 54. Crustacean plankton production estimates for 39 Yoho National Park lakes.

Lake No.	Name	Maximum nos./litre	Estimated annual production in calories per m ²	Mean depth of lake, m	Estimated mean annual zoo-plankton production in calories per m ²	"Available" production ^f converted to approx. equivalent fish biomass, kg/ha	"Available" production ^f as approx. equivalent of fish biomass, kg/lake
50	Fairy	0.7	306	8 ^e	2448	0.6	7.0
37	Kiwetinok	1.2	524	7 ^e	3669	0.9	5.4
55	Amiskwi	2.1	917	4.5 ^e	4126	1.0	6.0
61	Indigo	0.9	393	18 ^e	7074	1.8	6.9
35	Otto	0.6	262	3.5 ^e	917	0.2	0.2
29	Crystal	7.5	3276	1.3 ^e	4259	1.0	1.2
38	Hamilton	0.6	262	7 ^e	1835	0.5	2.3
16	Oesa	2.7	1179	13.6	16039	3.9	64.0
14	Opabin 2	4.6	2009	1.0 ^e	2009	0.5	0.9
15	Opabin 1	4.4	1922	4.0	7688	1.9	6.1
15A	Opabin 5	0.1	44	.7 ^e	31	<0.1	<0.1
31	Little Gem	0.4	175	10 ^e	1747	0.4	3.9
44B	Hidden P.	12.0	5242	1 ^e	5242	1.3	0.1
20	Wapta a.	<0.1	<15	4.2	<65	<0.1	<0.1
9	O'Hara	3.6	2662	19.1	50848	18.1	546.0
8	McArthur	2.6	1136	25.6	29073	7.2	551.1
41	Celeste ^b	11.1	4041	3.0 ^e	12123	7.1	14.2
42	Duchesnay ^b	87.3	27552	0.7	19286	10.6	37.1
49	Summit ^b	23.3	12198	1.0 ^e	12198	7.9	15.9
48	Sink ^b	142.0	53463	1.5 ^e	80195	46.9	234.9
26	Emerald	9.0	1593	17.0	27081	9.6	1116.9
7	Schaffer	3.7	655	1.2	786	0.3	0.1
43	Yoho	6.2	1612	5.0 ^e	8060	5.2	17.0
44	Hidden L.	47.2	7363	3 ^e	22090	7.9	3.9
47	Sherbrooke	2.0	312	6.0	1872	0.7	23.3
17	Ross ^c	31.1	2239	8.0	17914	11.5	68.8
19	No. Narao ^d	2.2	413	0.7	289	0.2	0.6
18	So. Narao ^d	48.1	5832	3.0	17496	11.2	7.8
10	Mary	21.0	11970	3.0	35910	25.5	166.0
13	Opabin 3 ^b	25.0	3900	1.0 ^e	3900	1.4	0.4
11	Opabin 4 ^b	50.0	8981	1.0 ^e	8981	5.2	1.6
23	Up. Morning Glory	1.3	203	2.0	406	0.1	0.2
6	Ottertail	1.2	225	1.0	225	0.1	0.9
51	Waves P.	0	-	1.5	-	-	-
41A	nr Celeste	0	-	1 ^e	-	-	-
28	Ptarmigan P.	0	-	1 ^e	-	-	-
22	mid Morning Glory	0	-	1.5	-	-	-
24	Linda	0.1	19	6.0	113	0.1	0.3
12	Victoria	0	-	2 ^e	-	-	-
52	Marpole						

a. Daphnia regularly <10% of Diaptomus numbers; single exception, 5-IX-69.

b. Two co-dominants.

c. Bosmina usually about 4x cyclopoid numbers.

d. Ceriodaphnia usually about 3x cyclopoid numbers.

e. Estimated on basis of general morphometry and known maximum depth.

f. "Available" production = P - B; conversion assumes 16% ecological efficiency at 1500 calories per gram frwt., and assumes that production would in fact be available (see text discussion).

accumulated by the zooplankton of Sink Lake in one season would be about enough to raise the temperature of the water in the lake by about $1/20$ of 1 degree Celsius.

The total production cannot be utilized by other organisms (such as fish) for two main reasons:

- i. Total utilization would result in elimination of the potential food organism.
- ii. Many of the potential food organisms are in reality too small to be utilized by the fish.

Ignoring the second reason for a moment, we can get an estimate of the available production by the various species of zooplankton by looking at the P/B ratio. Assuming that the populations of these organisms that exist in many of these lakes are living close to subsistence levels ecologically (probably true for many of the Yoho lakes), it appears that the populations are reproducing at the minimum level necessary to maintain the numbers from year to year: egg numbers are very low; predation rates on the species are often very low; mortality rates appear to be very low (Anderson 1968a, 1974c). Therefore, the production in excess of that required to maintain the species (i.e. that production "available" to secondary consumers such as fish) is P-B, or approximately that portion of total production greater than the adult biomass. Conversion of this "available production" to the equivalent of fish biomass¹ as freshweight indicates that the potential sustainable production of sport fish per hectare².

-
1. Assuming an ecological efficiency of 16% based on calories, probably a rather conservative estimate, and assuming a calorimetric value of 1500 cal/gram frwt. of fish biomass.
 2. One hectare is approximately equal to 2.5 acres.

on the basis of zooplankton production is rather meagre for even the most productive of the 39 Yoho lakes. Sink Lake would be potentially capable of producing about 47 kg frwt. fish per hectare per year (or something less than 1000 half-pound fish for the entire lake), if all the "available" zooplankton production could be utilized. The fact that many of the organisms are too small to be profitably utilized as food by the fish substantially reduces this estimate. The maximum production estimate of fish biomass per hectare is only about 15% of maximum yields obtained in some prairie potholes (Lawler et al. 1974).

There were only 6 lakes where rotifers were abundant enough to warrant making theoretical calculations concerning production (Table 55). Only two of these (Ross and Yoho lakes) indicated significant rotifer biomass. If rotifers were available directly to fish as food (which they are not), then they would add a potential of about 2 half-pound trout to the sport fish production of Yoho Lake and about 48 half-pound trout to the Ross Lake production.

It is clear from the results and discussion in this section that the introduction of fish into many of the small lakes containing large (especially dark-colored) zooplankton species, where the lakes offer little cover and no refuge for the zooplankters, would result in rapid decimation or possibly elimination of the zooplankton species.¹ It is evident also,

1. Even in lakes with some cover, it becomes obvious that excessive numbers of fish can soon reduce numbers of large, slow-growing, cold-water invertebrates below the level at which they can sustain populations at near natural abundances.

Table 55. Rotifer production in six Yoho National Park lakes^a, expressed as percentages of crustacean plankton production and as percentages of equivalent fish biomass^b.

Fish present = F	P/B ^c	calories per individ.	number per litre	est. calories per m ³ biomass	% crust. plankton biomass	"available" production as fish biomass ^b . kg frwt./ha	"available" rotifer production as % "available" crustacean production
Duchesnay -	10	.00005	75	37.5	0.1	.02	<0.1
Yoho F	5	.0004	125	250.0	15.5	1.06	20.0
Ross F	5	.00049	125	306.0	13.7	2.08	18.0
Mary F	5	.0004	125	250.0	2.1	.64	2.5
Opabin 3 -	4	.00005	125	25.0	0.6	.02	1.4
Opabin 4 -	5	.00005	125	31.3	0.3	.02	0.4

a. Only 6 of 39 lakes having significant numbers of rotifers. Three are fishless, so considerations of significance to fisheries are theoretical.

b. Conversion to equivalent fish biomass assumes 16% ecological efficiency (based on caloric content of biomass), 1500 calories/gram frwt. for fish, and treats rotifer production as theoretically available to fish (untrue in reality, due to very small rotifer body size). P - B taken as a measure of "available" production, assuming that the adult population reaching maturity is necessary to maintain zooplankton species at the low reproductive levels apparently characteristic for the species in these lakes. B = adult biomass estimate for crustacean species.

c. P/B based on mean summer biomass estimates for rotifers.

on the basis of documented cases and other evidence, that the large invertebrate species might be replaced, if they were at all, by smaller species which would be too small for the fish to eat (i.e. usually smaller than 1.5 mm; Anderson 1972). Many lakes which seem to have abundant plankton forms do not provide the fish populations with much food from the plankton except possibly in cases where fingerlings can utilize the very small zooplankters. In many clear alpine, subalpine, and montane lakes where food organisms are relatively scarce, the small fish cannot venture into the limnetic zone (open-water regions) to capitalize on small zooplankters because the small fish themselves become the prey of larger fish.

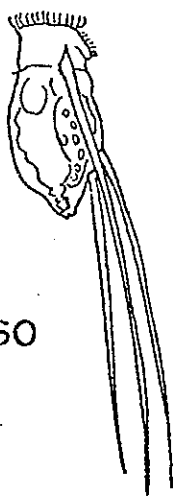
The introduction of exotic forage species, whether relicts or not, and whether vertebrates or invertebrates, can produce unexpected and sometimes unpredictable results. In Emerald Lake, the introduction of Mysis relicta may be the reason for the decline in numbers of rotifers and copepods. Although these plankters are too small for the fish to utilize effectively, the conversion of their rather meagre biomass into larger biomass units as Mysis is only accomplished at the sacrifice of much of the energy involved. The ecological efficiency from one trophic level to another is usually about 10% (a 90% energy loss). The longer the life span of an organism, the lower its efficiency in most cases, and Mysis appears to have a two-year life cycle in Emerald Lake. Consequently, any advantage gained is likely to be small and short-lived, and possibly at the expense of the destruction of a natural community.

Plates 1 - 5. Diagrams of some of the common species discussed in the zooplankton section. The fairy shrimp Branchinecta sp. (Crustacea: Anostraca) is also shown even though no fairy shrimps were collected in the present study.

ROTIFERA or ROTATORIA

F-39

— the rotifers or wheel animalcules



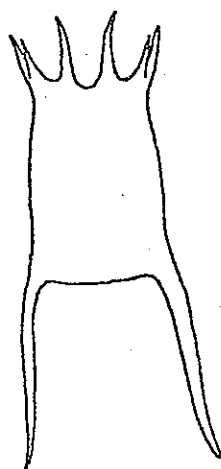
x160

Filinia sp.



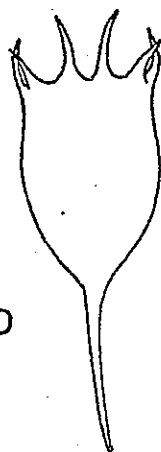
x90

Kellicottia sp.

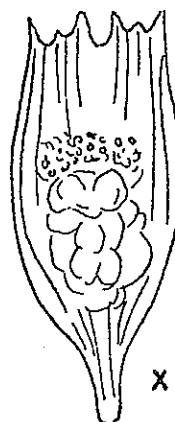


x200

Keratella quadrata

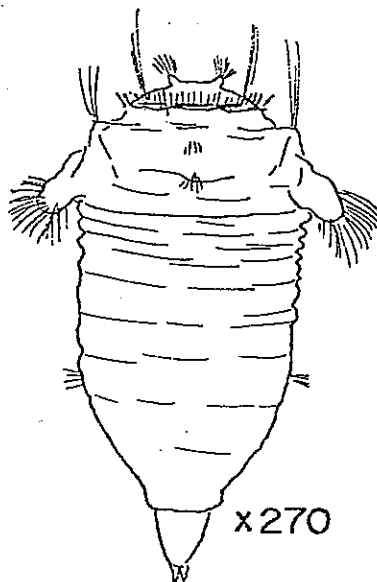


Keratella
cochlearis



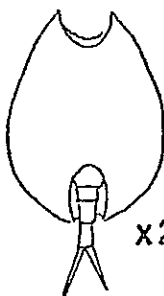
x250

Notholca sp.



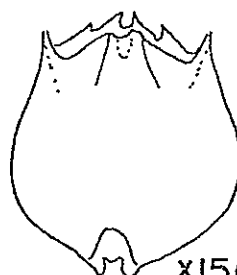
x270

Synchaeta sp.



x250

Lepodella sp.



x150

Brachionus sp.



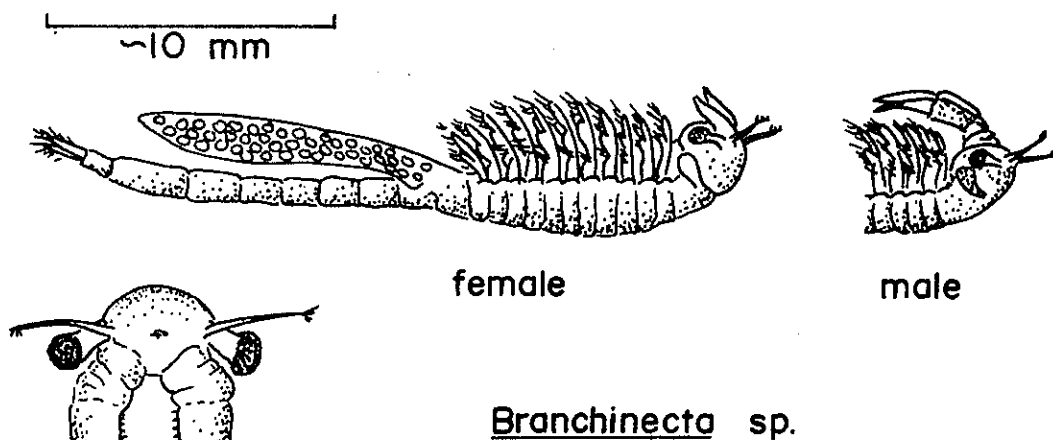
x100

Asplanchna sp.

CLASS CRUSTACEA

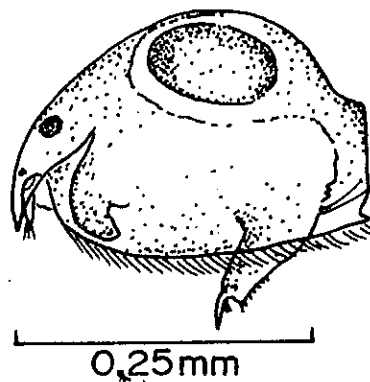
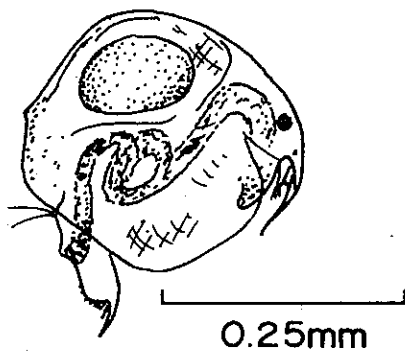
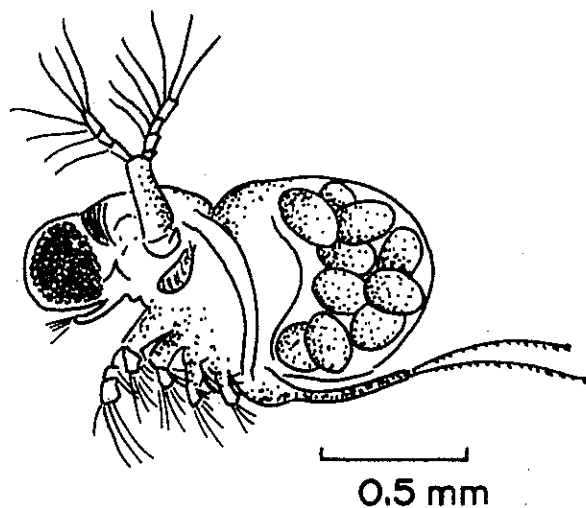
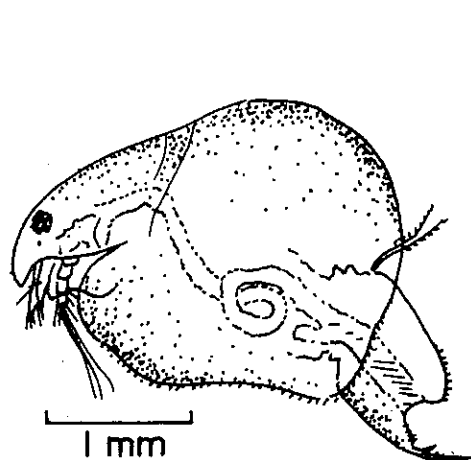
F-40

ORDER ANOSTRACA — the fairy shrimps



ORDER CLADOCERA

— the water fleas



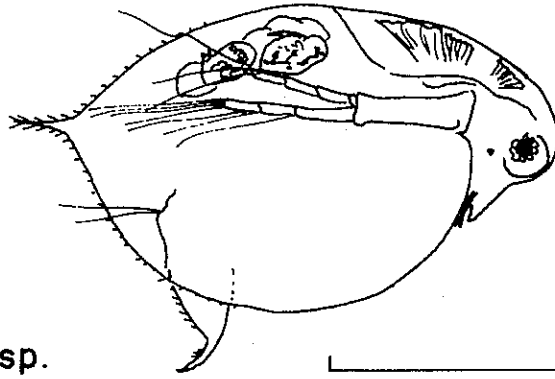
ORDER CLADOCERA

— the water fleas



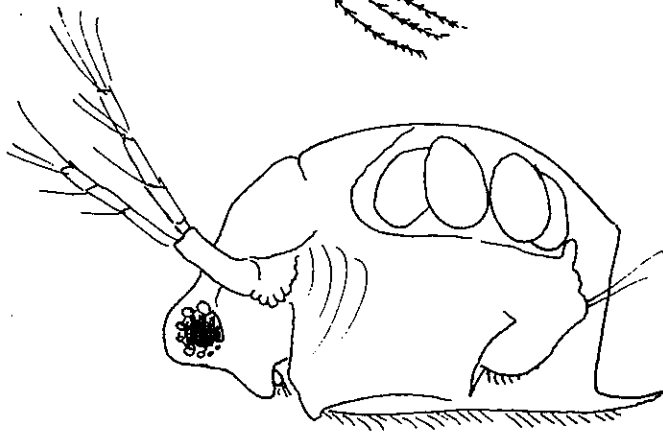
0.5 mm

Holopedium sp.



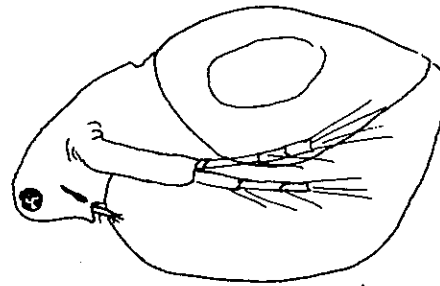
1 mm

Daphnia sp.



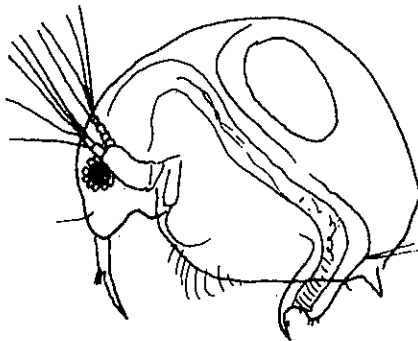
0.5 mm

Scapholeberis sp.



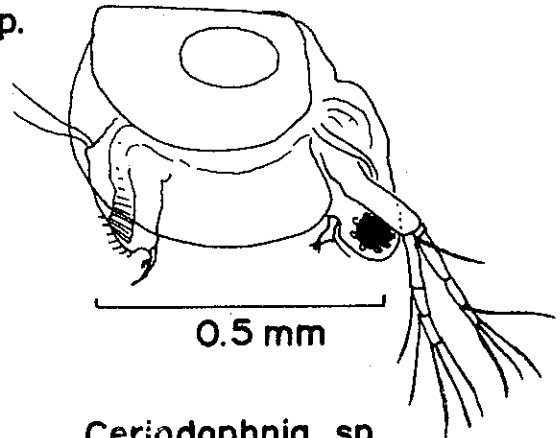
1 mm

Simocephalus sp.



0.5 mm

Bosmina sp.



0.5 mm

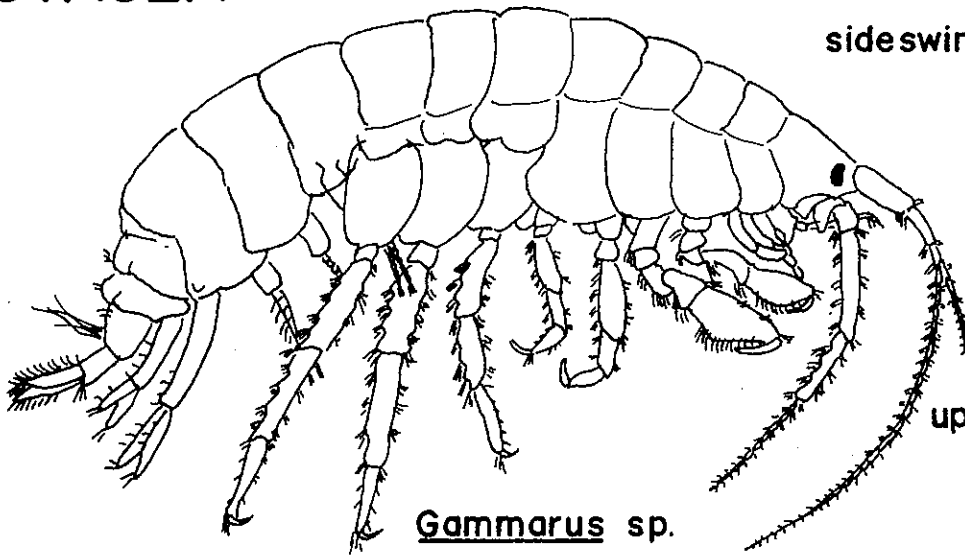
Ceriodaphnia sp.

**CLASS
CRUSTACEA**

ORDER AMPHIPODA

F-42

— amphipods, scuds,
sideswimmers, shrimps

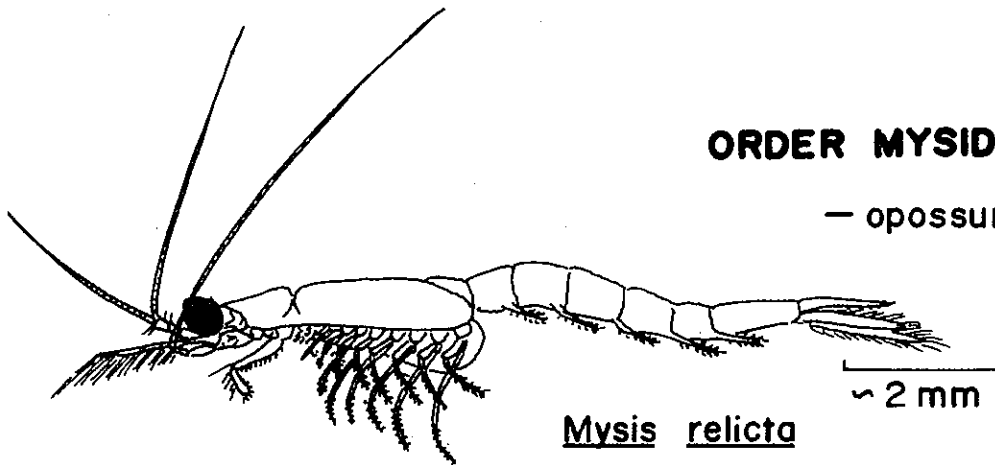


up to 25 mm long

Gammarus sp.

ORDER MYSIDACEA

— opossum shrimps

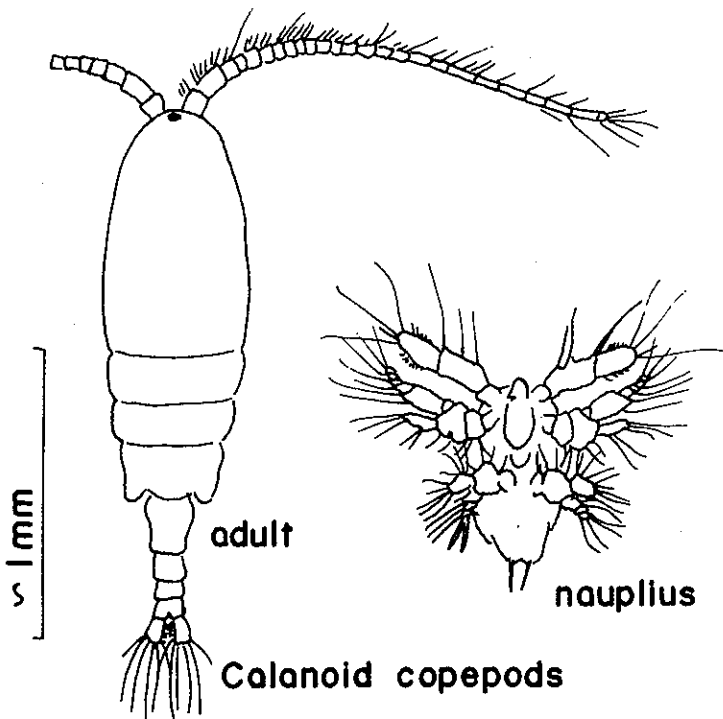


~ 2 mm

Mysis relicta

ORDER CALANOIDA

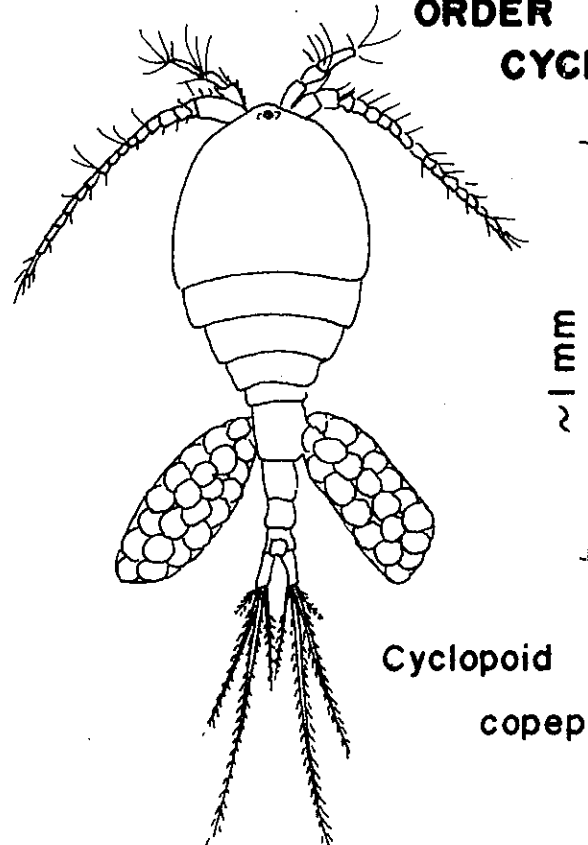
**ORDER
CYCLOPOIDA**



adult

nauplius

Calanoid copepods



~ 1 mm

Cyclopoid

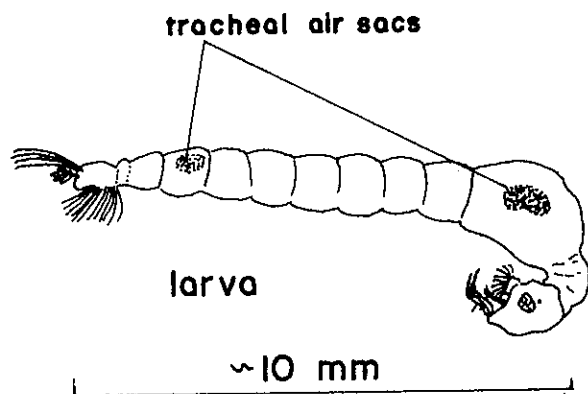
copepods

CLASS INSECTA

F-43

ORDER DIPTERA

— flies and mosquitoes

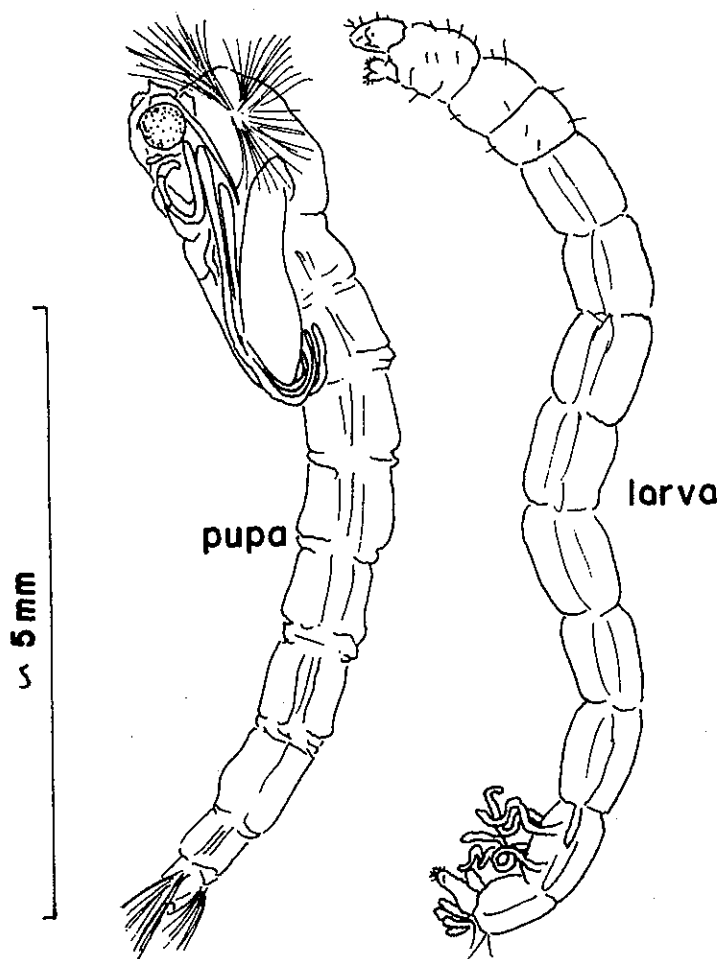


Chaoborids

Chaoborus americanus

Chironomids

Tendipes tentans



FISH

A total of 177 fish of 7 species were collected from 11 stream and 6 lake sites. A summary of the fish collections is given in Tables 56 & 57. Dolly Varden, pygmy whitefish, slimy sculpin, and cutthroat trout are native to the Park while brook, rainbow, and lake trout have been introduced. A discussion of each species is given below.

Dolly Varden char (Salvelinus malma).

Freshwater and anadromous populations of Dolly Varden char are found in western regions of North America. The biology of Salvelinus malma has been reviewed by Scott and Crossman (1973). In general, freshwater resident populations are somewhat slower growing than anadromous ones with a decrease in growth as one proceeds north. Like other chars, S. malma is a fall spawner. It spawns in different areas from September to early November (usually October). Sexual maturity is reached in years 3 to 6 and some fish may spawn every year from year 6 to year 10 or 11. Ten to twelve years appears to be the usual maximum age. Although S. malma can grow quite large, inland, high altitude and northern populations are often stunted and do not exceed 12 inches (305 mm) in length (Scott and Crossman 1973).

A total of 28 S. malma were collected at 5 of the 14 stream sites examined in the Park (Table 56). Only S. malma were collected in Otto Creek and upper Amiskwi River. In the lower Amiskwi River a single S. malma was collected along with brook

Table 56. Summary of fish collected from streams in Yoho National Park.

Species	Site 106A*	107	108	111	114	114A*	116	117	118	119	119A*	126	134
<i>Salvelinus malma</i>	-	-	1	3	1	-	17	6	-	-	-	-	-
<i>Salvelinus fontinalis</i>	8	1	-	10	2	15	-	-	2	-	-	23	3
<i>Prosopium coulteri</i>	4	-	1	-	-	-	-	-	1	-	-	-	-
<i>Cottus cognatus</i>	3	-	9	-	3	-	-	-	2	-	-	-	-
Total	15	1	11	13	6	15	17	6	5	-	-	23	3

Table 57. Summary of fish collected from lakes in Yoho National Park.

Species	Site	9	17	20	26	48	49
<i>Salvelinus fontinalis</i>		-	9	-	9	-	-
<i>Salvelinus namaycush</i>		-	-	13	-	-	-
<i>Salmo clarki</i>		11	-	-	-	-	-
<i>Salmo gairdneri</i>		-	-	-	2	7	10
Total		11	9	13	11	7	10

trout and slimy sculpin. Dolly varden and brook trout were collected in the Otterhead River while whitefish and slimy sculpin were present along with Dolly Varden in the Ottertail River.

Dolly Varden were found to be most numerous at Otto Creek where 17 were collected by electrofishing less than 50 m of the stream. Upper Amiskwi River at site 117 produced fewer but larger fish in a 100 m section of stream. The remaining streams produced only small numbers of Dolly Varden in the 100 to 200 m sections which were electrofished (Table 56).

The size of fish in various age classes was found to be smallest for those fish from Otto Creek while specimens from Otterhead River and Amiskwi River were generally larger as shown in the following table:

Age (years)	Mean length of Dolly Varden (mm)				
	Otto	Amiskwi	Lwr Amiskwi	Otterhead	Ottertail
1	80	-	63	-	-
2	83	79	-	-	89
3	85	98	-	-	-
4	114	-	-	118	-
5	126	175	-	153	-
6	149	-	-	-	-
7	163	-	-	295	-
8	-	-	-	-	-
9	177	233	-	-	-

Seven-year-old fish from Otto Creek averaged about 160 mm (about 6 inches) in length while a fish of the same age from Otterhead River was 295 mm long.

Even though a wide range in the size of fish for a given

age was found at various stream sites, no difference was noted in the length-weight relations of the Dolly Varden collected. The formula describing the length-weight relationship for the combined S. malma samples is:

$$\begin{aligned}\text{Log}_{10}\text{Weight} &= -11.48 + 3.03(\text{Log}_{10}\text{Length}) \\ n &= 28 \\ r &= 0.99\end{aligned}$$

For a description of the significance and meaning of the length-weight formula see Varley et al. (1971).

Among Dolly Varden collected the older, larger fish were exclusively male with the largest female being 153 mm in length.

The growth rates of Dolly Varden in the Park are not strictly comparable with those presented by Scott and Crossman (1973) because of the variability of life histories in different areas. Their data illustrate the wide variation in growth rates with two-year-old fish, for example, ranging in length from 61 to 239 mm. In general, the Yoho National Park populations examined appear to be very slow growing.

The stomach contents of Dolly Varden collected included a variety of food items ranging from insects to mice. With the exception of a single Dolly Varden collected in the lower Amiskwi River, all of the Dolly Varden examined had some food in the stomach. An estimate of the percent fullness of the stomach for each individual was made and a summary of results is given in Table 58. Fish collected in Otto Creek had the fullest stomachs with an average of 64.7%. In addition to having the fullest stomachs, these fish also contained the greatest variety

Table 58. Summary of stomach contents analysis for fish collected in lakes and streams of Ioho National Park.

Species Site	Otterhead River			Dolly Varden			Upper Amiskwi R.			Ottertail River			Lake trout			Emerald Lake			Rainbow trout			Summit Lake		
	No. of fish	mean abundance	(%) abundance	No. of fish	mean abundance	(%) abundance	No. of fish	mean abundance	(%) abundance	No. of fish	mean abundance	(%) abundance	No. of fish	mean abundance	(%) abundance	No. of fish	mean abundance	(%) abundance	No. of fish	mean abundance	(%) abundance	No. of fish	mean abundance	(%) abundance
Item in stomach																								
Echinozoa	-	-	-	11	1.5	(64)	3	(50)	1.3	-	-	-	6	(46)	0.7	-	-	-	1	(14)	0.1	-	-	-
Plecoptera	-	-	-	15	2.1	(88)	4	(66)	1.3	-	-	-	3	(23)	0.3	-	-	-	1	(14)	0.1	-	-	-
Trichoptera	-	-	-	6	0.5	(35)	1	(16)	0.3	-	-	-	1	(7)	0.1	-	-	-	-	-	-	-	-	-
Coleoptera	-	-	-	14	0.4	(82)	1	(16)	0.1	1	(100)	1.0	2	(15)	0.1	-	-	-	-	-	-	-	-	-
Diptera: larva	-	-	-	1	1.4	(8)	-	-	-	1	(100)	1.0	2	(15)	0.2	1	(50)	0.5	3	(42)	0.5	4	(20)	0.2
Diptera: pupae	-	-	-	1	0.1	(5)	-	-	-	-	-	-	3	(23)	0.4	1	(50)	0.5	3	(42)	0.8	2	(20)	0.2
Diptera: adults	-	-	-	1	0.05	(5)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mollusca: Gastropoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mollusca: Pelecypoda	-	-	-	-	-	-	-	-	-	-	-	-	11	(84)	1.9	-	-	-	2	(28)	0.7	-	-	-
Arthropoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nyctis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Copepoda	-	-	-	9	0.8	(52)	5	(83)	2.0	1	(100)	2.0	1	(7)	0.1	-	-	-	-	-	-	-	-	-
Misc. Insecta	1	(33)	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ephemeroptera	-	-	-	9	1.0	(52)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ceratopoda	-	-	-	2	0.1	(11)	1	(16)	0.1	-	-	-	2	(15)	0.2	-	-	-	-	-	-	-	-	-
Acarina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cnidaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fish	-	-	-	3	0.1	(17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other	1	(33)	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	(57)	1.7	4	(40)	1.2
No. fish examined	3			17			6			1			13			2			7			10		
Mean % fullness	50			84			61			60			10			10			32			21		
Fish length: mean (mm)	188			126			123			89			342			163			162			176		
Fish length: range	118-295			80-177			71-233			89			217-458			159-168			140-180			86-238		
Fish weight: mean (g)	117			30			42			6.9			523			52			56			86		
Fish weight: range	19.0-297			5.9-77.5			4.1-150.5			6.9			118-1153			52-53			40-75			8.2-196		

* On a scale of 0-3: 0= absent
1= rare
2= frequent
3= abundant

Table 58. ---Cont'd.

Species Site	Cutthroat trout			Hoodoo Creek			Pyaw whitefish			Ottertail River			Hoodoo Creek			Slimy sculpin			Lower Amiskwi R.			Kicking Horse R.		
	No. of fish	mean abundance	(%)	No. of fish	mean abundance	(%)	No. of fish	mean abundance	(%)	No. of fish	mean abundance	(%)	No. of fish	mean abundance	(%)	No. of fish	mean abundance	(%)	No. of fish	mean abundance	(%)	No. of fish	mean abundance	(%)
Ephemeroptera	1	-	-	1	(25)	0.3	-	-	-	1	(100)	2.0	-	-	-	2	(22)	0.2	1	(33)	0.3	1	(50)	0.5
Plecoptera	3	(27)	0.5	1	(25)	0.3	-	-	-	1	(100)	3.0	-	-	-	2	(22)	0.6	1	(33)	0.3	1	(50)	1.0
Trichoptera	2	(18)	0.3	-	-	-	-	-	-	-	-	-	-	-	-	1	(11)	0.2	-	-	-	-	-	-
Coeloptera	5	(45)	0.5	4	(100)	3.0	1	(100)	3.0	1	(100)	2.0	2	(66)	0.6	4	(44)	1.2	2	(66)	2.0	2	(100)	2.0
Diptera larva	3	(27)	0.3	1	(25)	0.3	-	-	-	-	-	-	-	-	-	-	-	-	1	(33)	0.6	-	-	-
Pupae	1	(9)	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Adults	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mollusca, Gastropoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda	8	(72)	1.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Copepoda	3	(27)	0.8	-	-	-	-	-	-	-	-	-	1	(33)	0.3	4	(44)	0.8	-	-	-	-	-	-
Fysis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Insecta	1	(9)	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hyenoptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidoptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ostracoda	1	(9)	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	(33)	0.6	-	-	-
Acarina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Odonata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No. fish examined	11	-	-	4	-	-	1	-	-	1	-	-	3	-	-	1	(11)	0.2	-	-	-	-	-	-
Mean % fullness	60	-	-	42	-	-	40	-	-	60	-	-	46	-	-	9	-	-	3	-	68	15	-	
Fish length, mean (mm)	262	-	-	76	-	-	104	-	-	90	-	-	81	-	-	43	-	-	71	-	62	62	-	
Fish length, range	171-317	-	-	74-79	-	-	104	-	-	90	-	-	81-82	-	-	60-89	-	-	64-76	-	61-83	61-83	-	
Fish weight, mean	227	-	-	4.7	-	-	12.8	-	-	8.7	-	-	6.7	-	-	4.2	-	-	4.2	-	2.5	2.5	-	
Fish weight, range	42-391	-	-	4.1-5.2	-	-	12.8	-	-	8.7	-	-	6.3-7.5	-	-	2.5-7.0	-	-	3.0-5.3	-	2.0-3.0	2.0-3.0	-	

* On a scale of 0-3, 0= absent
1= rare
2= frequent
3= abundant

of food items. Eleven categories of food were found in fish from this site with the most important items being Plecoptera, Diptera larvae, Ephemeroptera, and Hymenoptera (Table 58).

Fish examined from upper Amiskwi River also had quite full stomachs (61.6%) but contained food items from only 6 categories (Table 58). Miscellaneous Insecta were the most frequently encountered food item and were found in 5 of the 6 fish (83.3%) from this site while Plecoptera were found in 4 fish (66.6%).

The stomach contents of Dolly Varden collected in Otterhead and Ottertail River differed considerably from those already discussed. Ephemeroptera and Plecoptera were not found in these fish and only 4 types of food items were found in stomachs from each site (Table 58). The most common item in the Otterhead River fish was Acarina while in the Ottertail River fish miscellaneous Insecta and Hymenoptera were abundant

Many factors undoubtedly contribute to the food types found in examination of stomach contents. These include: availability of food, selective predation, fish size, and seasonal as well as daily variations in feeding activity (McLeod 1971). In general the major items in the stomach contents of fish from Otto Creek do not differ significantly from the available food as indicated in analysis of kick samples from this site as shown below:

Composition in decreasing order of importance (data from Table 18 and 58)	
Kick sample	Stomach contents
Ephemeroptera	Plecoptera
Plecoptera	Chironomidae
Chironomidae	Ephemeroptera
Trichoptera	Miscellaneous Insecta
Miscellaneous Insecta	Hymenoptera
	Trichoptera

Ward (1974) does not list Dolly Varden from any of the lakes in the Park and none were collected from any of the lakes sampled during the present study. Schultz (1953) reported that Dolly Varden were planted in Emerald Lake as early as 1906. He collected 3 specimens from this lake in 1953 and these fish were considerably larger (200-550 mm) than any of the Dolly Varden collected in streams during the present study. Emerald Lake was poisoned with toxaphene in 1959 and, because of persistent toxicity, it was 1962 before it could be stocked again (Ward 1972). It is quite possible that some young Dolly Varden, which normally spend 3 to 4 years in streams before moving to a lake, may have survived the toxic period and may again be present in this lake.

Brook trout (*Salvelinus fontinalis*).

Brook trout (actually char) are the most common species of char in the Park. The life history of brook trout has been reviewed by Scott and Crossman (1973) and is similar to that already described for Dolly Varden. Spawning takes place in

late summer or autumn over gravel beds in headwater streams or in gravelly shallows of lakes. Brook trout are relatively short-lived, wild trout seldom living longer than 5 years, and almost never beyond 8 years. Introduced brook trout may live up to 15 years. Sexual maturity is usually attained at age 3, but some individuals may mature at age 2. Five year old fish attain lengths from 250-480 mm. Brook trout occur in clear, cold, well oxygenated streams and lakes where they feed on a wide range of organisms including aquatic insect larvae, worms, leeches, crustaceans, mollusks, and fish.

A total of 82 brook trout were examined from 3 lakes and 8 stream sites in the Park (Table 56). All of these populations represent brook trout which have been introduced to Park waters or are descendants of introduced individuals. Sixteen lakes or ponds in the Park have had brook trout introductions (Ward 1974, Table 59). At least 8 of these water bodies experience regular winterkill and some, such as Sink and Summit lakes, have had frequent introductions to offset the loss due to winterkill (Table 59). Only one stream, Hunter Creek, is listed in the stocking records as having introductions of brook trout although they were collected at most of the stream sites examined during the present study. The brook trout collected in streams probably represent breeding populations which have been established by individuals which migrated from the stocked lakes in the Park although some unrecorded or unofficial introductions may have been made.

Lake samples of brook trout included 9 fish each from Ross

Table 59. Summary of fish introductions in Yoho National Park between 1964 and 1973. Original data from official stocking records.

Lake No.	Winter-kill	Species present	Reproduction	No. times intro. 1964-1973	Mean No. intro. per stocking
6	yes	EBT	no	2	750
8	no	EBT	?	2	10000
10	yes	Cutt	?	1	5000
		RBT	?	1	250
17	no	EBT	poor	5	3600
18	?	EBT	?	5	680
		RBT	?	4	325
20	no	RBT	?	4	625
		EBT	?	11	2931
		SPL	?	1	5000
22	?	Cutt	?	3	3000
24	no	RBT	yes	2	1050
25	?	Cutt	yes	2	1500
26	no	RBT	yes	19	8463
		EBT	yes	9	8166
42	yes	EBT	no	2	4000
43	no	RBT	?	2	375
		EBT	?	4	1275
44	yes	RBT	no	3	1116
48	yes	EBT	no	14	1117
		RBT	no	6	383
49	yes	EBT	no	5	450
		RBT	no	2	375
52	no	RBT	yes	1	500
		Cutt	yes	1	1000
62	yes	EBT	no	3	483
		RBT	no	2	425

EBT= eastern brook trout
 RBT= rainbow trout
 Cutt= cutthroat trout
 SPL= splake

and Emerald and 1 from Summit Lake. The single individual from Summit Lake collected on August 9, 1973, likely originated from an introduction of 500 brook trout in June of the same year.

Brook trout from Ross Lake were found to be much shorter and lighter than fish of a similar age from Emerald Lake as shown in the following table:

Age (years)	Mean length (mm) and weight (g) of brook trout from lakes			
	Ross		Emerald	
	length	weight	length	weight
3	188	74.5	193	101.5
4	212	125.5	320	424
6	267	235	368	703
7	300	360	449	1310
11	284	262	-	-

Compared with some other lakes in the mountain National Parks Ross Lake appears to offer only minimal conditions for growth (Figure 44). Three-year-old fish from Ross Lake were comparable in size to the "stunted" brook trout populations from some Colorado beaver ponds described by Rabe (1970).

Brook trout from Emerald Lake were considerably larger in size than those of a similar age from Ross Lake. When compared with brook trout from other mountain National Park lakes for which data are available the fish from Emerald Lake appear to have growth rates which are about average (Figure 44).

The length-weight relationship of brook trout from Ross and Emerald lakes was quite similar. The formula describing the length-weight relationship for brook trout from Ross Lake is:

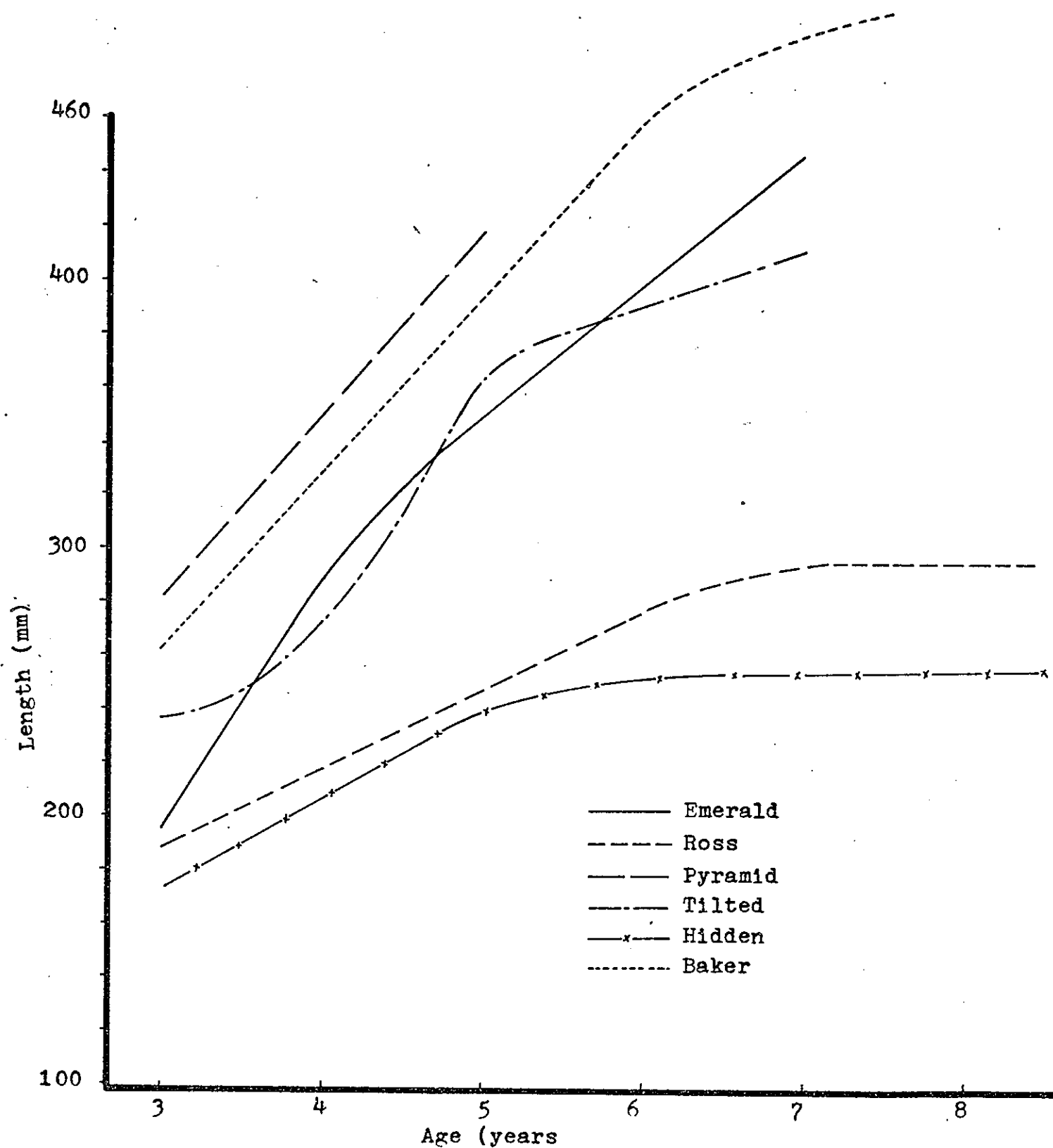


Figure 44. Age-length relationship for brook trout in Emerald and Ross lakes as compared with other areas (supplementary data from Rawson and Elsey 1950 and Smiley 1974).

$$\log W = 3.07 \log L - 5.11$$

$$\begin{aligned} \log_{10} \text{ weight} &= -11.76 + 3.07 (\log_{10} \text{ length}) \checkmark \\ n &= 9 \\ r &= 0.99 \end{aligned}$$

and for Emerald Lake is:

$$\begin{aligned} \log_{10} \text{ weight} &= -11.07 + 2.98 (\log_{10} \text{ length}) \\ n &= 9 \\ r &= 0.99 \end{aligned}$$

$$\log W = 2.98 \log L - 4.81$$

With the exception of two males from Ross Lake all of the brook trout collected in both lakes were gravid females.

Eight of 14 stream sites examined produced brook trout (Table 56). At four sites (Porcupine Creek, Emerald Creek, Cataract Brook, Ross Creek) only brook trout were collected. At the remaining sites, brook trout were collected along with other species as shown in Table 56.

Brook trout were most numerous at Emerald Creek and Cataract Brook where electrofishing of approximately 100 meters of stream produced 15 and 23 specimens, respectively. Ottertail River, lower Amiskwi River, and Ross Creek all produced fewer but larger specimens of brook trout. Hoodoo Creek and Kicking Horse River both produced a small number of small fish. As previously noted, there are no records of stream introductions of brook trout except for Hunter Creek (in 1954) from which no fish of any species was collected during the present study.

Growth rates of brook trout from Park streams are considerably below those of Emerald and Ross Lakes and are generally lower than growth rates from other streams (Red Deer River, Alberta; McCart and Jones 1974; Nelson and Hays River, Manitoba; Doan 1948, in Scott and Crossman 1973). Some variation was found in

the fish size in relation to age from the various streams, although a fairly uniform linear growth rate was determined for all sites. A comparison of the age-length statistics for the stream sites is given in the following table:

Age	Mean length (mm) of brook trout from streams							
	Lower Amiskwi	Hoodoo	Porcu- pine	Otter- head	Emerald	Kicking Horse	Cataract	Ross
1	-	55	-	93	68	-	63	-
2	118	100	-	112	92	85	93	108
3	-	168	142	134	146	-	119	-
4	-	-	-	176	-	-	143	194
5	219	-	-	-	-	-	-	-
6	-	-	-	245	-	-	-	-

The length-weight relationship for the combined stream samples of brook trout is described by the formula:

$$\begin{aligned}\text{Log}_{10} \text{ weight} &= -0.32 + 3.78(\text{Log}_{10} \text{ length}) \\ n &= 63 \\ r &= 0.99\end{aligned}$$

The specimens from Ross Creek were gravid and considerably heavier than most fish their length.

Many of the smaller specimens could not be sexed, although the larger specimens from Hoodoo, Porcupine, Otterhead, Emerald, and Cataract were predominantly male. The largest female collected was 200 mm long (from Ross Creek) while the largest male was 245 mm long (from Otterhead River).

Stomach contents of brook trout from Emerald, Ross, and Summit lakes differed considerably (Table 58). None of the stomachs examined were empty and the average fullness ranged from 38.4% in Ross to 75.5% in Emerald Lake. The single individual

from Summit Lake contained only chironomid larvae and adult Diptera. Rainbow trout from Summit Lake collected at the same time as the brook trout had 7 different categories of food items.

Brook trout from Emerald Lake had the fullest stomachs with an average of 75.5% but contained food items in only 5 categories (Table 58). Diptera pupae and Mysis were the most abundant food items and were found in 100% and 55% of the fish examined, respectively. As noted previously Mysis was introduced to Emerald Lake in 1967. Stomach contents of the fish examined during the present study indicate Mysis relicta has become one of the most important food items for brook trout in Emerald Lake.

A comparison of the potential food items from benthic and shoreline samples with those in the stomach contents is given in the following table:

Composition in decreasing order of importance (data from Tables 14, 16, and 58)		
Benthic sample	Shoreline sample	Stomach contents
	<u>Ross Lake</u>	
Chironomidae	Gastropoda	Diptera pupae
Pelecypoda	Pelecypoda	Chironomidae larvae
Oligochaeta	Oligochaeta	Trichoptera
Misc. Diptera	Trichoptera	Amphipoda
	Ephemeroptera	Plecoptera
	Plecoptera	Ephemeroptera
	Coleoptera	Copepoda
	Acarina	Acarina
	<u>Emerald Lake</u>	
Chironomidae	Amphipoda	Diptera pupae
Oligochaeta	Gastropoda	<u>Mysis relicta</u>
	Ephemeroptera	Fish
	Trichoptera	Coleoptera
	Odonata	
	Chironomidae	

In general the major food items from fish in Ross Lake appear to be mainly of shoreline origin while those of Emerald Lake are mainly of benthic origin. Brook trout from Ross Lake had the lowest average percent fullness of the three lakes, but these fish had a wide variety of food items which included 9 categories. Diptera pupa, diptera larva and trichoptera were the most common food items being found in 75, 62, and 62% of the stomachs examined, respectively.

Brook trout from Porcupine Creek, Ross Creek, Kicking Horse River, and Amiskwi River contained from 2 to 6 categories of food items with miscellaneous Insecta, Hymenoptera, and Plecoptera being among the more common items. Fish from this group of streams had average stomach fullness values ranging from 40 to 80% (Table 58).

Stomach contents of brook trout from the remaining streams (Hoodoo, Otterhead, Emerald, Cataract) had average fullness values of 40 to 57% and had from 8 to 12 different categories of food items (Table 58). A common feature of the food items found was the lack of dominance by any single item in the stomach examined. With the exception of Trichoptera in 80% of the fish from Otterhead River, all other food items were found in less than 50% of the fish examined from these streams.

A general comparison of the invertebrates collected in kick samples with those found in stomach contents can be made. At Cataract Brook, for example, chironomid larvae appear to form a greater portion of the stomach contents than would be expected from their frequency in kick samples as shown below:

Composition in decreasing order of importance (data from Table 18 and 58)	
Kick sample	Stomach contents
Ephemeroptera	Chironomidae
Trichoptera	Trichoptera
Plecoptera	Ephemeroptera
Chironomidae	Plecoptera
Misc. Diptera	Acarina
Acarina	

Lake Trout (*Salvelinus namaycush*).

Lake trout are relatively large and long-lived char which are widespread in Canadian Lakes. Like other chars, lake trout spawn in the fall usually over a boulder or rubble bottom in lakes. Spawning usually takes place at depths less than 40 feet and sometimes as shallow as 1 foot or, in rare instances, spawning may occur in rivers. Growth is fairly rapid with sexual maturity being attained at age 6 or 7. Lake trout commonly live for 15-18 years of age and individuals of 23 years are known. Lake trout are predaceous and feed upon a wide range of organisms including freshwater sponges, crustaceans, aquatic and terrestrial insects, many species of fish, and even small mammals (Scott and Crossman 1973).

Two lakes, Sherbrooke and Wapta, contain lake trout although there are no records of lake trout introductions in the Park. Schultz (1953) collected 7 fish from Sherbrooke Lake which he "positively identified" as lake trout. Stocking records indicate Atlantic salmon (*Salmo salar*) were introduced to this lake in 1918 and 1921 and rainbow trout were introduced between 1932 and 1941 (Schultz 1953; stocking records). Several possibilities for the origin of the lake trout populations may

apply in this case:

1. The lake trout are native to Sherbrooke Lake.
2. There was a misidentification of the fish stocked.
3. There was a misidentification of the fish collected.

As Schultz (1953) was aware of the possibility of Atlantic salmon being present we can safely reject the third possibility. Although it appears the question of origin cannot be resolved on the basis of present information the fact remains that collections by Schultz indicate a lake trout population was established at that time.

Thirteen lake trout were collected at Wapta Lake during the present study. Wapta Lake also has no official record of lake trout introductions although splake (S. namaycush X S. fontinalis) were stocked in 1961, 1962, and 1968. The present specimens were positively identified on the basis of pyloric caeca counts which numbered 101, 106, 104, 119, 116, and 113 in 6 individuals examined. According to Scott and Crossman (1973) the number of pyloric caeca in splake is intermediate between the two parent species as follows: brook trout 23-55; lake trout 93-208; splake 65-85. Three possibilities for the origin of the lake trout of Wapta Lake might apply:

1. The lake trout are native to Wapta Lake.
2. There was a misidentification of the species stocked.
3. Offspring of introduced splake have reverted to the parental lake trout type.

The first possibility seems unlikely as there are no records of lake trout being caught in this lake prior to the introductions of splake in 1961. Again it appears resolution of the question of origin is impossible with the present information.

The growth rate of lake trout from Wapta Lake was found to

be less than for lake trout from 6 lakes in Quebec, Ontario, Saskatchewan, and the Northwest Territories reported by various authors and summarized by Scott and Crossman (1973). Rawson and Elsey (1950), Cuerrier and Schultz (1952), and Cuerrier (1954) report growth rates of lake trout from Waterton Lakes (WLNP), Lake Minnewanka (BNP), and Pyramid Lake (JNP) which are considerably higher than the rate for specimens from Wapta Lake. For comparative purposes the size of fish in various age classes is given below:

Age	Mean length of lake trout (mm)			
	Wapta	Pyramid	Waterton	Minnewanka
4	-	292	327	271
5	215	355	370	304
6	-	431	424	341
7	247	495	508	394
8	278	563	553	584
9	300	624	713	655
10	353	685	825	718
11	434	749	-	785
12	450	-	-	-

The formula describing the length-weight relationship of lake trout from Wapta Lake is:

$$\text{Log}_{10} \text{ weight} = -12.24 + 3.15 \text{ Log}_{10} \text{ length}$$

$$n=13 \quad r=0.99$$

Except for cutthroat trout from Lake O'Hara the lake trout were generally heavier for their length than other salmonids collected in the Park.

Sex was determined for the 7 lake trout from Wapta Lake and these fish included 2 males and 5 females.

The stomach contents of lake trout from Wapta Lake included food items in 9 different categories (Table 58). One stomach

was empty and the average fullness was very low at 10.7%. The most frequently encountered food items were Amphipoda and Ephemeroptera which were found in 84.6 and 46.1% of the fish examined, respectively. A comparison of the relative abundance of potential food items in benthic and shoreline samples with stomach contents is given in the following table:

Composition in decreasing order of abundance (data from Table 14, 16, and 58)		
Benthic	Shoreline	Stomach contents
Diptera larvae	Ephemeroptera	Amphipoda
Pelecypoda	Adult Diptera	Ephemeroptera
Oligochaeta	Trichoptera	Adult Diptera
Hirudinea	Plecoptera	Plecoptera
Misc. Insecta	Amphidopda	Diptera pupae
	Oligochaeta	Acarina

It appears the stomach contents have a greater similarity to the shoreline fauna than to the benthic fauna.

Cutthroat trout (*Salmo clarki*).

The natural distribution of cutthroat trout is limited to coastal and inland populations in western North America. The biology of cutthroat trout has been outlined by Scott and Crossman (1973). Yoho National Park is included within the range of the inland population of cutthroat trout which is generally given subspecies status (*S. clarki lewisi*). Unlike the chars previously discussed cutthroat spawn in spring and early summer about 3 to 5 weeks after ice breakup, when water temperatures are near 50°F (10°C). Spawning takes place only in small, gravelly streams during both day and night. Fry emerge in August and move to larger streams or lakes. The inland type of cutthroat trout usually grows to about 12 in (305 mm) in length although larger specimens are known. Sexual maturity is reached by males as early as 2 years of age and by females at 5 or 6. The

average age at first spawning is 2-4 years. Ten years would appear to be maximum life expectancy but 4 to 7 is more common (Scott and Crossman 1973).

Food of this species consists mainly of insects, both aquatic and terrestrial, small fishes, planktonic crustacea as well as other items.

During the present study, cutthroat trout were collected only at Lake O'Hara (Table 57). Stocking records and Schultz (1953) indicate several other lakes in the Park have had cutthroat trout as follows:

Mary- because of its low mean depth this lake is subject to winter kill - no fish were seen in the lake during 1973-1974 studies although cutthroat trout have been introduced several times, the latest being 1967 (in the official stocking records this lake is referred to as "Schaffer Lake"). Large numbers of dead fish were noted on the lake bottom in 1970, indicating extensive winterkill the previous winter (R. S. Anderson, unpublished data).

Lower Morning Glory Lakes- these lakes are subject to occasional winterkill (Schultz 1953) and no fish were seen during the present study- cutthroat trout were stocked as recently as 1968.

Linda Lake- "hundreds" of cutthroat trout were seen in this lake by Schultz (1953) while only a few fish of an unidentified species were seen during the present study. Cutthroat have not been stocked since 1954 and

rainbow trout were introduced in 1969. A number of large cutthroat were observed spawning or attempting to spawn in the shallows of the lake in 1970 (R.S. Anderson unpublished data).

Marpole Lake- Cutthroat trout were first introduced to this lake in 1968 although there are unconfirmed reports of cutthroat prior to this time (Schultz 1953). This lake was not examined during the present study.

Yoho Lake- Cutthroat trout were stocked in this lake between 1949 and 1959. Schultz (1953) examined 3 cutthroat trout and noted growth was "poor". This lake was not examined during the present study.

McArthur Lake- Cutthroat trout were introduced to Lake McArthur in 1957 and brook trout have been stocked between 1957-1965. During visits to this lake in 1973 and 1974 no fish were seen. On one occasion a park visitor in the area reported seeing a fish of unknown species in the lake. No fish collections were made during the present study. The apparent increase in numbers of the large copepod Diaptomus arcticus in this lake since 1970 may be indicative of the decline or demise of the introduced populations of fish

Wapta Lake- cutthroat trout were introduced to this lake on several occasions, the latest being 1959. No cutthroat were collected by Schultz (1953) or during the present study.

A total of 11 cutthroat trout were collected from Lake O'Hara by gillnet. No other species were collected from Lake

O'Hara although rainbow trout were frequently stocked prior to 1955. The growth rate of the Lake O'Hara cutthroat trout (Figure 45) appears to be about average when compared to data from some alpine and subalpine lakes in Banff National Park (Smiley 1974; Mudry and Anderson 1974, unpublished data). Cutthroat trout from O'Hara appear to grow slower than those from Baker Lake but faster than those from Peyto and Shadow Lake. Statistical data for various age classes are given below:

Mean length (mm) and weight (g) of cutthroat trout from O'Hara			
Age	number	length	weight
3	2	172	47.1
4	2	272	236.2
5	3	266	223.8
6	3	293	292.8
7	1	317	391.0

The formula describing the length-weight relationship of cutthroat trout from Lake O'Hara is:

$$\log_{10} \text{ weight} = -13.94 + 3.45 \log_{10} \text{ Length}$$

$n = 11$

$r = 0.99$

$$\log_{10} W = 3.45 \log L - 6.05$$

The slope of the regression equation indicates the cutthroat trout from Lake O'Hara are considerably heavier for their length than other salmonids from the Park.

Only a single male was among the 11 cutthroat collected from Lake O'Hara. All the females collected were gravid.

The stomach contents of cutthroat trout from Lake O'Hara included food items in 9 different categories (Table 58).

None of the stomachs were empty and the average fullness was 60.9%. The most frequently encountered food items were amphipods, Diptera (Chironomidae) larvae and pupae, copepods, and Trichoptera.

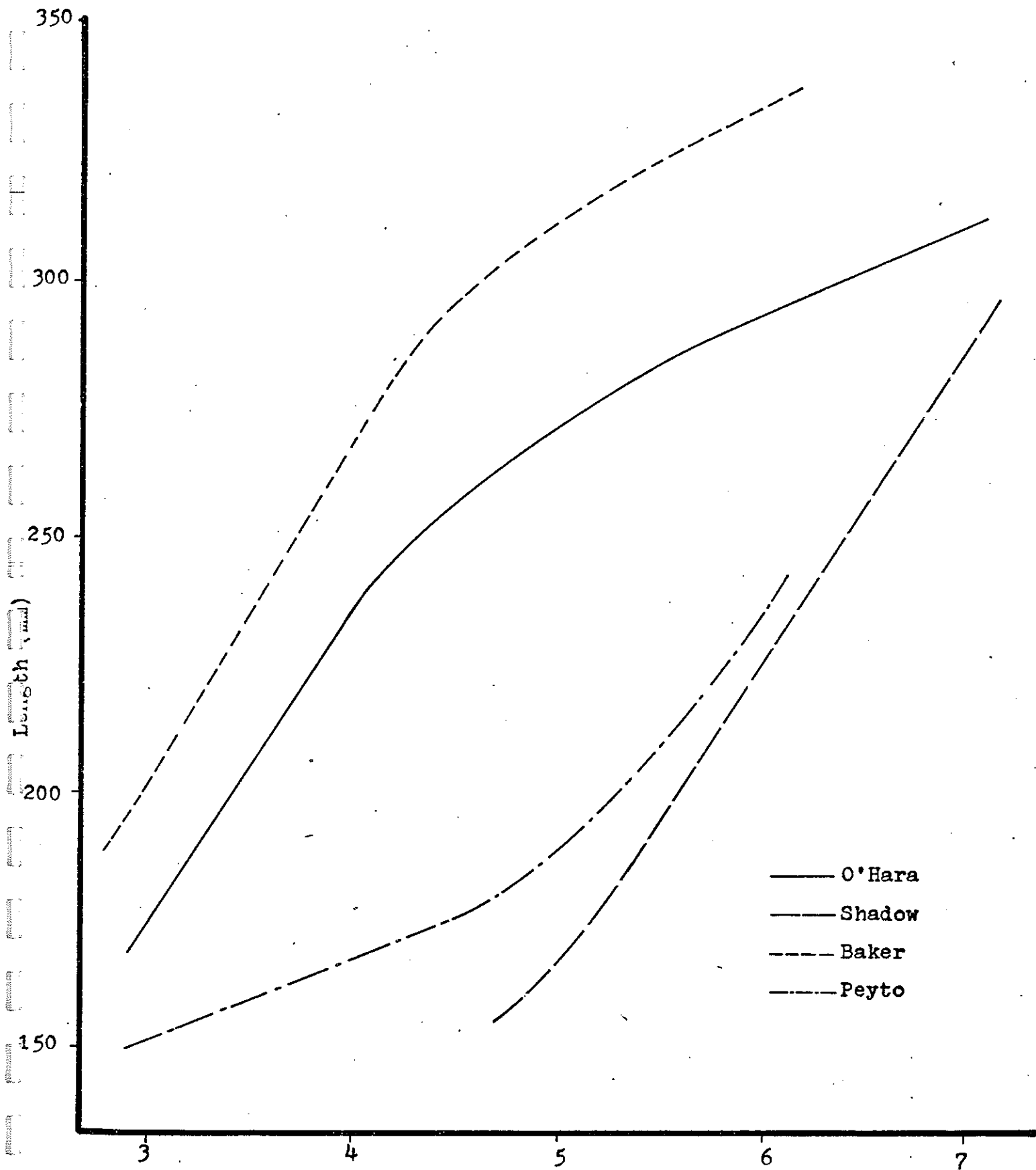


Figure 45. Age-length relationship for cutthroat trout from Lake O'Hara: as compared with other areas (supplimentary data from Smiley 1974).

A general comparason of the relative abundance of potential food items in benthic and shoreline samples with stomach contents is given in the following table:

Composition in decreasing order of importance (From Tables 14, 16, and 58)		
Benthic	Shoreline	Stomach
Chironomidae	Chironomidae	Amphipoda
Pelecypoda	Trichoptera	Chironomidae
Copepoda	Coleoptera	Copepoda
Cladocera	Oligochaeta	Trichoptera
Oligochaeta	Misc. Insecta	Coleoptera
Amphipoda		

Potential food items from both benthic and shoreline samples were found in stomach contents. The high frequency and abundance of amphipods in stomach contents may indicate a predominantly benthic origin for the food items. In a detailed study of feeding habits of two different strains of cutthroat trout in a small Colorado lake Trójnar and Behnke (1974) found significant differences: one strain fed mostly on pelagic and benthic organisms while the other fed at or near the surface. These authors noted the inter- and intraspecific feeding segregation exhibited among trout populations in the lake studied has significant ramifications for fisheries management by demonstrating that genetic diversity can be utilized to more effectively take advantage of niche diversity, not only with representatives of different species, but also divergent stocks of a single species.

Rainbow Trout (*Salmo gairdneri*).

Rainbow trout have been stocked in at least 15 lakes and ponds in the Park. Scott and Crossman (1973) have described

the high degree of variability in both form and life history found in this species. Rainbow trout are basically spring spawners. They spawn on fine gravel in smaller tributaries of rivers, or inlet or outlet streams of lakes, from March to August but mainly from mid-April to late June. There is little evidence that rainbow trout can successfully spawn on beaches of lakes that do not have streams flowing into them. Fry usually emerge from mid-June to mid-August. Growth is highly variable and depends on area, habitat, life history type, and quantity and type of food. Rainbow trout usually mature at 3 to 5 years with adults living from 3 to 8 years depending on habitat and other factors. In general rainbow trout feed on various invertebrates including larger crustaceans, insects, snails, and leeches. The size attained by rainbow trout appears to be dependent on the type and amount of food items available and they may range from 1 to 14 pounds in maximum weight (Scott and Crossman 1973).

A total of 19 rainbow trout were examined from 3 lakes in the Park (Table 57). All of these samples represent populations of rainbow which have been introduced or are descendants of introduced fish. At least 6 of the 15 lakes and ponds in which rainbow trout have been introduced are potential winterkill lakes (Table 59).

Rainbow trout collected from Sink Lake on June 13, 1973, originated from fish stocked 13 days before on May 31, 1973. Official stocking records indicate only brook trout were stocked in Summit during 1973 although 10 rainbow trout were taken on August 9, 1973. As noted previously a single brook trout was

also collected from Summit Lake. The two rainbow trout collected from Emerald Lake were 3 years old and may have originated from a group of yearling rainbow trout stocked in 1971.

The regular winterkill in Sink and Summit Lakes allows growth for only a very short summer period. Calculations based on official stocking records indicate rainbow trout planted in Sink Lake were approximately 20 g in weight when introduced. Thirteen days later the weights ranged from 40-75.5 g indicating a very rapid growth. Prairie ponds are known to support growth rates which are comparable to those found in Sink Lake (Johnson et al. 1970). Rates of growth for rainbow trout from Summit Lake could not be determined because of a lack of data on date of stocking and initial size.

The rainbow trout from Emerald Lake were approximately the same size as those from Sink and Summit Lakes although they were estimated to be 3 years old when captured. Due to the small number of specimens, growth rates and length-weight relationships are unavailable for rainbow trout in Emerald Lake. From data presented by Scott and Crossman (1973) three year old rainbow trout from several Canadian Lakes ranged in length from 190-419 mm indicating the Emerald Lake population is very slow growing.

The stomach contents of rainbow trout from Sink, Summit, and Emerald lakes were low in both percent fullness and variety of food items (Table 58). In Sink and Summit, 7 types of food items were present, the most important items being Cladocera and Diptera. In Emerald lake, only Diptera larvae and pupae

were in the stomachs. In Sink and Summit lakes, the stomach contents included items found in both benthic and shoreline samples while those from Emerald indicated a predominantly benthic feeding behavior as shown below:

Composition in decreasing order of importance (data from Table		
Benthic	Shoreline	Stomach
	<u>Sink Lake</u>	
Chironomidae	Amphipoda	Cladocera
Hirudinoidea	Ephemeroptera	Chironomidae
Oligochaeta	Trichoptera	Amphipoda
Acarina	Odonata	Ephemeroptera
Trichoptera	Gastropoda	Plecoptera
Amphipoda	Chironomidae	
	<u>Summit Lake</u>	
Chironomidae	Ephemeroptera	Cladocera
Misc. Diptera	Cladocera	Chironomidae
Hirudinea	Trichoptera	Coleoptera
Oligochaeta	Chironomidae	Misc. Insecta
Pelecypoda	Acarina	Plecoptera
Ephemeroptera	Odonata	
	<u>Emerald Lake</u>	
Chironomidae	Amphipoda	Chironomidae
Oligochaeta	Gastropoda	
	Ephemeroptera	
	Trichoptera	
	Odonata	
	Chironomidae	

In a study of feeding habits of fish in a small Colorado lake Trojnar and Behnke (1974) found more than half of the food of rainbow trout was of benthic origin.

Pygmy whitefish (Prosopium coulteri).

Specimens of pygmy whitefish were collected at three stream sites in the Park (Table 56). Scott and Crossman (1973) have reviewed the biology of this small species and indicate they spawn during the fall in shallow waters of streams or lakes. Growth is slow with females being larger and living longer than males. A maximum age of 5-6 for males and 7-9 for females

appears to be normal. Crustaceans, chironomids, and other aquatic insects are the primary foods. Predation on pygmy whitefish is poorly documented although kingfishers and terns have been observed catching them.

Six pygmy whitefish were collected on August 1, 1973 in the Kicking Horse River, Hoodoo Creek, and Ottertail River close to their confluences with the Kicking Horse River. At Ottertail River they were collected along with Dolly Varden and slimy sculpin, and at Hoodoo Creek and Kicking Horse brook trout and slimy sculpin were also present.

The specimens of pygmy whitefish represented 3 age groups and some indication of the growth rate was obtained as shown below:

Age	Mean length and weight of pygmy whitefish		
	n	mean length (mm)	mean weight (g)
1	4	76	4.7
2	1	92	8.7
3	1	104	12.8

These results are quite similar to those presented by Scott and Crossman (1973) for three lake populations of pygmy whitefish.

The formula describing the length-weight relationship of the combined sample of pygmy whitefish is

$$\text{weight} = -17.68 + 0.29 \text{ length}$$

$$n=6 \quad r=0.99$$

and indicates a linear relationship during the early years of growth.

The sex was not determined for any of the individuals collected.

Some differences were noted in the types of food items in stomach contents from the three stream sites (Table 58), although the small sample size may have biased these results. In general, Diptera larvae (Chironomidae) were the most important food items found, with smaller numbers of Plecoptera, Ephemeroptera, and Trichoptera.

Slimy sculpin (Cottus cognatus).

Seventeen slimy sculpin were collected at four stream sites in the Park (Table 56). In a review of the biology of this species, Scott and Crossman (1973) indicate it is found in both streams and lakes throughout most of Canada. Slimy sculpin are spring spawners and spawn under rocks or ledges in streams and rivers. Females are mature by age three but details of growth rates are largely unavailable. Available evidence suggests that the primary food is invertebrate bottom fauna, particularly aquatic insect larva. A number of larger, predaceous fishes such as lake trout feed upon this sculpin to a greater or lesser degree, depending upon its availability (Scott and Crossman 1973). Three of the nine brook trout collected from Emerald Lake contained sculpin (presumably slimy sculpin) in their stomach contents.

The distribution of slimy sculpin in the Park was found to be similar to that of pygmy whitefish. Slimy sculpin were collected in the Kicking Horse River and in three tributaries close to their confluence with the Kicking Horse River. Ages of the specimens collected ranged from 3 to 7 with lengths and weights for the combined samples as shown below:

Mean length and weight of slimy sculpin			
Age	n	mean length (mm)	mean weight (g)
3	9	63.5	2.9
4	3	75.3	4.9
6	2	81.2	6.3
7	3	84.6	7.1

The formula describing the length-weight relationship of the combined samples of slimy sculpin is:

$$\text{weight} = -8.3 + 0.17 \text{ length}$$

$$n = 17 \quad r = 0.94$$

and indicates a linear relationship. The larger, older specimens were usually males while the smaller, younger specimens were mostly females.

Stomach contents of slimy sculpin from Ottertail River had 6 different types of food items, and those from lower Amiskwi River had 5 types (Table 58). Fish from Hoodoo Creek and Kicking Horse River had only 2 and 3 types, respectively. In general the main food items appear to be Diptera larvae (Chironomidae), Plecoptera, Trichoptera, and miscellaneous Insecta. A comparison of potential food items at site 108 (Ottertail River) with the stomach contents of slimy sculpin from that site is given below:

Composition in order of decreasing importance (data from Tables 18 and 58)	
Kick samples	Stomach contents
Ephemeroptera	Chironomidae
Trichoptera	misc. Insecta
Chironomidae	Ephemeroptera
Plecoptera	Plecoptera
misc. Insecta	Trichoptera

Differences between available foods and stomach contents are not great and this may be an indication of the opportunistic feeding habits of this species.

FISH PARASITES

A total of 94 fish, including representatives of all 7 species collected in the Park, were examined for parasites. Approximately 2640 helminth parasites representing 8 different species of monogeneans, digeneans, cestodes, and nematodes were recovered from the fish examined (Table 60). From an esthetic point of view this large number of "worms" may seem both remarkable and unpleasant. Most of the parasite species collected, however, are quite small and not easily detected by the casual observer. What is equally or more important, from the standpoint of a fishery, is whether these worms interfere with the health and growth of the host fish. Freeman (1964) has pointed out that flatworms rarely cause serious harm to fish although some deleterious effects are occasionally found. There are records of extensive fish mortality in natural waters due to parasites, but apparently such catastrophies are uncommon. Generally young fish are more seriously affected than old fish, and this usually happens when they are crowded. In a National Park situation where maintenance of natural communities is desirable these parasites should be regarded as an integral and sometimes interesting part of the total aquatic ecosystem.

Monogenea

Tetraonchus variabilis was the only monogenetic trematode collected in the Park. Monogenetic trematodes, which occur mainly on the skin and gills of fish, do not require an intermediate host and actively transfer from fish to fish. Since no intermediate host is necessary, monogeneans can reproduce rapidly under certain

Table 60. Summary of parasite species and numbers collected from fish hosts in Yoho National Park.

Site and host	Parasite	Number of fish examined/infected (%)			Inf. intensity range mean	
Hoodoo Creek						
Pygmy whitefish	R. milleri	4	2	(50)	0-2	0.7
Brook trout	C. farionis	3	1	(33)	0-24	8.0
	R. milleri	3	2	(66)	0-2	1.0
Slimy sculpin	R. cotti	3	1	(33)	0-1	0.3
Ottertail River						
Brook trout	C. farionis	5	3	(60)	0-21	8.4
	E. salvelini	5	1	(20)	0-2	0.4
	R. milleri	5	4	(80)	0-39	12.2
Dolly Varden	B. luciopercae	3	2	(66)	0-1	0.6
	C. farionis	3	3	(100)	1-3	2.3
	R. milleri	3	3	(100)	29-50	41.6
Slimy sculpin	R. cotti	4	3	(75)	0-3	1.2
Lower Amiskwi River						
Brook trout	C. farionis	2	1	(50)	0-1	0.5
	E. salvelini	2	1	(50)	0-1	0.5
	R. milleri	2	2	(100)	6-134	70.0
Dolly Varden	R. milleri	1	1	(100)	46	46.0
Upper Amiskwi River						
Dolly Varden	C. farionis	5	3	(60)	0-7	1.8
Otto Creek						
Dolly Varden	R. milleri	5	5	(100)	2-46	18.8
Emerald Creek						
Brook trout	C. farionis	5	2	(40)	0-127	27.2
	Diphyllbothrium sp.	5	1	(20)	0-4	0.8
	R. milleri	5	3	(60)	0-5	2.0
Cataract Brook						
Brook trout	C. farionis	5	1	(20)	0-52	10.4

Table 60. -Cont'd.

Site and host	Parasite	Number of fish			Inf. intensity	
		examined/infected (%)			range	mean
Ross Creek Brook trout	<i>C. farionis</i>	3	3	(100)	1-75	31.3
Lake O'Hara Cutthroat trout	<i>C. farionis</i>	5	2	(40)	0-132	30.8
	<i>Diphylllobothrium</i> sp.	5	2	(40)	0-2	0.6
Ross Lake Brook trout	<i>B. luciopercae</i>	5	1	(20)	0-3	0.6
	<i>C. farionis</i>	5	2	(40)	0-10	2.4
	<i>E. salvelini</i>	5	1	(20)	0-36	7.2
Wapta Lake Lake trout	<i>B. luciopercae</i>	5	4	(80)	0-62	20.0
	<i>C. farionis</i>	5	1	(20)	0-110	22.0
Emerald Lake Brook trout	<i>C. farionis</i>	5	4	(80)	0-24	8.0
Sink Lake Rainbow trout	<i>C. farionis</i>	5	1	(20)	0-1	0.2
	<i>H. milleri</i>	5	1	(20)	0-1	0.2
Summit Lake Brook trout	<i>C. farionis</i>	1	1	(100)	273	273.0
Rainbow trout	<i>C. farionis</i>	5	4	(80)	0-258	121.0

conditions and produce serious damage to fish. The very low infection rate found in the present study probably represents little ill effect to the hosts.

Gills of a single specimen of Prosopium coulteri from the lower Ottertail River had 6 T. variabilis. No parasites have been previously reported from pygmy whitefish while the closely related mountain and round whitefish are known to harbour T. variabilis (Dechtiar 1972).

Digenea

The small digenetic trematode Bunodera sp. was one of the most frequently encountered parasites of fish in the Park (Table 60). It was found in 5 of the 7 species of fish examined with the exceptions being pygmy whitefish and slimy sculpin. The life cycle of Bunodera is complex, with several stages including a free swimming miracidium; redia and ceraria which develop in the gills of clams (Pisidium and Sphaerium); metacercaria encysted in Daphnia and amphipods; and adults in the intestine of many types of fish (Cannon 1971). The distribution and abundance of Bunodera in the Park is determined to a great extent by the availability of suitable intermediate and final hosts. The relatively high incidence in lakes (45.1%) as compared to streams (6.3%) probably reflects the greater availability of the intermediate hosts in lake situations.

The highest infection intensity of Bunodera was found at Summit Lake where mean numbers per fish were 121.8 in rainbow and 273 in the single brook trout collected (Table 60). Cutthroat

trout from Lake O'Hara and lake trout from Wapta Lake also had fairly heavy infections. None of the brook trout from Emerald Lake had Bunodera although 2 from Emerald Creek (site 114B) were infected with Bunodera. Lower Ottertail River was the only other stream site with fish containing Bunodera. At this site 2 Dolly Varden had one Bunodera each.

Crepidostomum sp. is a small digenetic trematode closely related to Bunodera and exhibits many of the same traits in its life cycle. It was found in the gut of all fish species collected except slimy sculpin and rainbow trout (Table 60). As in Bunodera, early stages develop in the gills of clams (Pisidium and Sphaerium) while metacercariae are found encysted in mayflies and amphipods (Choquette 1954).

The highest incidence and intensity of Crepidostomum infections was in S. fontinalis from Emerald Lake while the lowest was in lake trout from Wapta Lake. In general the number of Crepidostomum in fish from lakes was much lower than Bunodera. In Lake O'Hara, amphipods are the most-likely intermediate hosts from which cutthroat trout acquire Crepidostomum, noting that amphipods were very numerous in stomach contents.

Crepidostomum infections were found in fish from all of the stream sites examined except for Otto Creek (Table 60). Brook trout was the most common host species. Mean infection intensities were highest at stream sites downstream from lakes (such as Ross Creek, Cataract Brook) and at relatively slow flowing sites (such as Otterhead River and Hoodoo Creek).

Cestoda

Two species of Cestoda (tapeworms) were collected from fish in the Park: larval stages of Diphyllbothrium sp. and adult Eubothrium salvelini.

Cutthroat trout from Lake O'Hara and brook trout from Emerald Lake and Emerald Creek contained larval stages of Diphyllbothrium. Diphyllbothrium comprise a large number of imperfectly known species which, as adults, infect piscivorous birds and mammals and, as plerocercoid larvae, infect certain fishes, especially the Salmonidae. The life cycle is complex: eggs hatch in water releasing a free swimming coracidium which may be eaten by one of several species of copepods, chiefly cyclopoids (Meyer and Vic 1963). If eaten by a copepod, the tapeworm larvae develops as a proceroid stage in from 2 to 4 weeks. The tapeworm remains in this stage until the copepod host is eaten by a fish, in which case the proceroid emerges from the copepod and penetrates the stomach wall of the new fish host and develops into a plerocercoid stage. The plerocercoid stage is about $\frac{1}{2}$ inch long and is usually found in the stomach wall or in the mesenteries which support the intestine. Plerocercoids are very often seen by fishermen when cleaning fish and are most often the source of comments about "wormy fish". These plerocercoid stages pose no problem to the fisherman if the fish are cleaned in the normal manner, because the parasites are generally restricted to the gut area and do not enter the muscle tissues of the body. The plerocercoid stages remain in the fish host and may accumulate in large numbers in older fish. The life cycle is completed when the fish is eaten

by a suitable final host such as a fish eating bird or mammal. In the Park the bird hosts would likely included gulls, merganzers, loons, and grebes. Once in the final bird host, the tapeworms develop to adult stages and release eggs which drop with bird feces into the water, where the cycle begins again.

The brook trout from Emerald Lake had the largest number of Diphyllbothrium plerocercoids with an average of 15.2 per fish (Table 60). Two of the 5 cutthroat trout from Lake O'Hara had a small number of plerocercoids. The more intense infection from Emerald Lake probably indicated more frequent use of the area by fish eating birds.

The second species of tapeworm, Eubothrium salvelini, collected from fish in the Park has a more direct life cycle than that described above for Diphyllbothrium. Eubothrium develops as a larval stage in copepods and when eaten by a suitable fish host the larval cestode develops directly to an adult stage in the fish gut. Specimens of Eubothrium were collected only from brook trout at two stream sites (Otterhead and Amiskwi) and one lake (Ross). There is some evidence that young fish infected with E. salvelini may have reduced chance of surviving to adulthood (Freeman 1964).

Nematoda (roundworms).

Two species of Rhabdochona were found in fishes of the Park. Rhabdochona cotti was collected only from slimy sculpin while R. milleri was found in 4 different host species (Table 60).

The life cycles of species of Rhabdochona are not well understood although larval stages of some species are known to develop in mayfly nymphs of the genus Hexagenia (Moravec and Arai 1971). Fish no doubt acquire the infection upon eating infected mayflies. In the fish host, the adult worms live in the intestine where they are thought to do little harm.

Rhabdochona cotti was collected in low numbers from the type host Cottus cognatus at three localities in the Park (Table 60). Highest infection incidence and intensity observed was in sculpin from lower Amiskwi River where the three hosts examined contained from 3 to 8 worms.

In a review of the North American representatives of Rhabdochona, Moravec and Arai (1971) note that R. milleri has been recovered only from hosts of the family Catostomidae. The specimens recovered from Salvelinus malma, S. fontinalis, Salmo gairdneri, and Prosopium coulteri in the present study compare favorably with the redescription of R. milleri provided by Moravec and Arai (1971). Specimens of the four host species infected with R. milleri were collected at one lake site and 9 stream sites (Table 60).

A single pygmy whitefish was found to be infected with young of another nematode: Cystidicola. Adult Cystidicola are rather large nematodes which live in the swimbladder of salmonids and coregonids. Cystidicola stigmatura has been reported from mountain whitefish and round whitefish in British Columbia (Bangham and Adams 1954), but there are no published reports on

parasites from the pygmy whitefish. The life cycle of Cystidicola is unknown but is believed to involve an arthropod intermediate host for larval development. Margolis (1967) reported that the cystidicoline nematode Salvelinema walkeri feeds on blood in the swim bladder of coho salmon. Although further study is required a similar feeding pattern might reasonably be expected for Cystidicola in the swim bladder of pygmy whitefish. Implications regarding the possible pathogenicity of the blood feeding habit of swim bladder nematodes suggested by Margolis (1967) have not been investigated.

The four larval Cystidicola collected from the pygmy whitefish represents a very light infection since as many as 1700 Cystidicola were recovered from a single mountain whitefish from Pyramid Lake (BNP) (Mudry and Anderson 1974, unpublished data).

AQUATIC MACROPHYTES

These plants are characterized by the possession of conductive tissues (xylem and phloem) for the transport of materials throughout the plant body. Most aquatic macrophytes exhibit structural specialization into true roots, stems, and leaves. The recognition of a category to be labelled "true aquatic plants" demands a certain amount of latitude and qualification, for within this group we find a very broad spectrum of adaptation to water. We may define "aquatic plants" as those whose seeds germinate in the water and in which most spend part of their life cycle in water. This ecological grouping included plants which grow completely submerged as well as a variety of emergent types (Reid 1961).

In lakes and ponds of the Park, 11 species of aquatic macrophytes representing 7 families were collected (Table 61). of these 11 species only 4 were listed in the preliminary checklist of flora of the Park prepared by Chuang (1972).

Family Najadaceae (pondweeds).

Three species of the genus *Potamogeton* were collected from 6 lakes in the Park (Table 61). The most common species was *P. praelongus* which was found in 4 lakes including Duchesnay and Ottertall Flats Lake where it produced thick growths throughout large areas of these lakes. The remaining two species were less widespread with *P. pectinatus* only in Emerald Lake and *P. gramineus* in both Emerald and Sink lakes. In the latter two lakes, the *Potamogeton* spp. were generally restricted

Table 61. Distrubition of aquatic macrophytes in Yoho National Park.

Species	Lake	<i>Hot. Mary S. Nar. N. Nar. Wapta Emerald Ditchaprey Sink Summit</i>								
		6*	10	18	19	20	26	42	48	49
Potamogeton gramineus		-	-	-	-	-	+	-	+	-
Potamogeton pectinatus		-	-	-	-	-	+	-	-	-
Potamogeton praelongus		+	-	+	-	-	-	+	-	+
Carex rostrata		-	+	+	+	+	+	-	+	+
Chara sp.		-	-	-	-	+	+	-	+	+
Ranunculus aquatilis		-	-	-	-	+	+	-	-	-
Equisetum arvense		-	-	-	-	-	+	-	-	-
Equisetum fluviatile		-	-	-	-	+	-	-	-	-
Myriophyllum exalbescens		-	-	+	-	+	-	-	-	-
Hippuris vulgaris		-	-	-	-	+	-	-	-	-
Drepanocladus aductus		-	-	-	-	+	-	-	-	-

*(+) indicates species is present

to shoreline areas.

Gaeveskaya (1966) has pointed out a large number of animal species are found in both trophic and ecological association with various species of Potamogeton. Various chironomids, trichoptera, and birds, for example, are known to feed on Potamogeton while fishes and carnivorous invertebrates are attracted to Potamogeton beds where prey species may be available.

Family Cyperaceae (Sedges).

Carex rostrata was the most widespread of all the aquatic macrophytes. This emergent plant was collected near shore in 7 lakes (Table 61) where it frequently formed a band up to 5 m wide,

Several types of invertebrates including chironomids and Trichoptera are known to feed on Carex sp. (Gaevskaya 1966).

Family Characeae.

Chara sp was collected at 4 lakes where it was usually found at depths greater than one metre. In Sink, Summit, Wapta, and Emerald lakes it covered wide areas of the bottom.

Family Ranunculaceae (buttercup, crowfoot).

Ranunculus aquatilis is a small aquatic plant which was found near shore in Emerald and Wapta lakes. Individual specimens were widely dispersed and did not form thick growths.

Family Equisetaceae (horsetails).

Equisetum arvense and E. fluviatile, two emergent species of horsetails, were collected from Emerald and Wapta lakes, respectively. These plants were confined to the shoreline areas.

Family Haloragaceae (water milfoils).

Myriophyllum exalbescens was found along the shore of South Narao lake and in dredge samples from Wapta Lake. A second milfoil, Hippuris vulgaris, was collected only from the shoreline of Wapta Lake.

Family Hypnaceae.

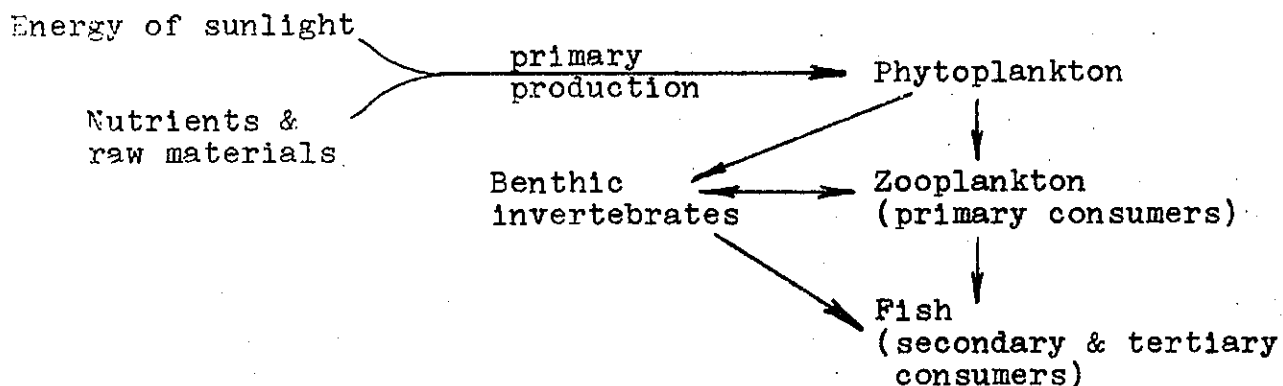
Drepanocladus aductus was collected only in dredge samples from Wapta Lake.

PHYTOPLANKTON

In addition to the macrophyte species discussed, there are over 150 species of small, unicellular and colonial aquatic plants in the Park. The majority of these small plants are found free floating in the water of lakes and as a group are termed phytoplankton. As noted previously the phytoplankton can be subdivided further into two groups: the net phytoplankton (discussed with the zooplankton) and the nanophytoplankton which is treated in this section. Phytoplankton may be present in sufficient numbers to colour the water, but more often they are so sparse that special means must be employed to obtain a quantity sufficient for microscopic examination. A majority of the species found in the phytoplankton are unicellular rather than colonial (Smith 1950).

Some appreciation of the great diversity of phytoplankton shape and size may be gained by examination of Plates 6 through 13. The wide range of morphological types shown is an indication of the diverse habitat requirements and physiological differences between species which make up the phytoplankton. Nearly all of the physical and chemical factors discussed in the early sections of this report have been shown to be of importance in determining the distribution and abundance of phytoplankton species. Variations in light intensity, secchi visibility, lake depth, temperature, water chemistry and other factors often act directly on the phytoplankton in a selective and controlling fashion. Using sunlight as an energy source, aquatic plants, like those on land, perform a basic biological

function in the production of carbohydrates and proteins from dissolved nutrients and raw materials. This production of carbohydrates and proteins is termed "primary production" and forms the first step in food chains leading to animal consumers as shown in the following diagram:



Complex interrelationships between the physical and chemical properties of lakes and the phytoplankton often result in the development of characteristic communities of phytoplankton species. In other words, the overall ecology of a lake or pond may be classified on the basis of the type and abundance of the phytoplankton present. The type of phytoplankton community also has direct effects on the types and numbers of primary and secondary consumers such as zooplankton and fish. Thus the entire aquatic community may often be characterized by its phytoplankton component.

The problem of classifying lakes for the purpose of defining their ecology or productivity is one which can be approached from a number of different points of view. Many of the parameters which may be used to establish a classification of lakes are interrelated. These include factors such as surface

area, mean depth, temperature regime, phytoplankton counts and biomass, numbers of invertebrates, as well as other factors. Because of the interrelationships mentioned, any one of these factors may be selected as a basis for lake classification with some assurance of success in predicting productivity or defining general lake ecology. The necessity of such a classification is obvious when one is faced with a discussion of over 20 lakes inhabited by several hundred species of flora and fauna in all manner of combinations and numbers. Such a classification allows one to observe the general trends in spite of all the minute differences.

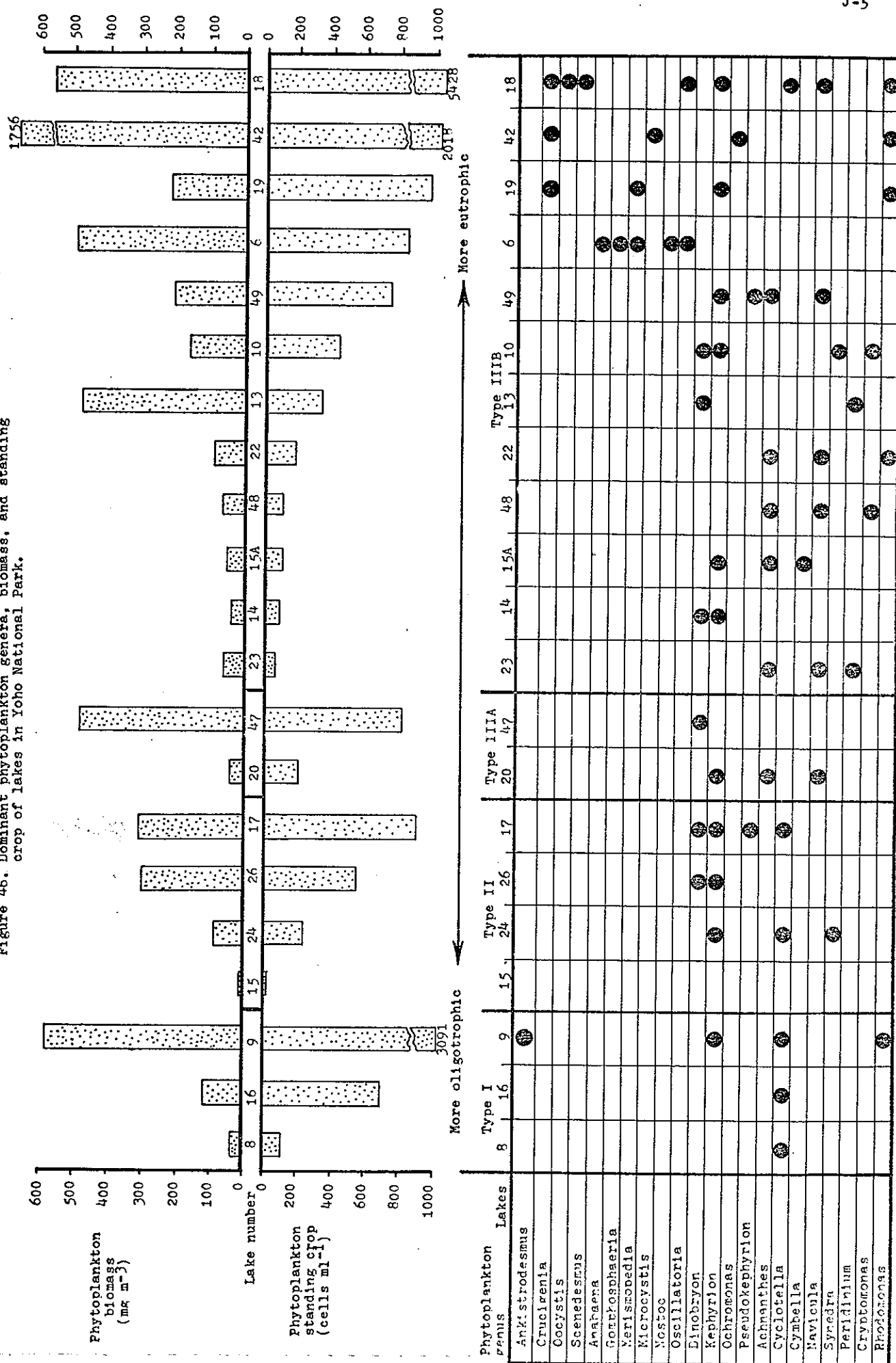
Rather than devise a new classification useful in a discussion of the phytoplankton we will rely on one already described in the physical section of this report: lake thermal properties. This parameter was selected for a number of reasons but mainly as follows: (1) the thermal characteristics of a lake are determined mainly by physical characteristics such as depth, morphometry, water renewal rate, surface area, and geographic location; (2) the thermal characteristics of a lake very often affect the distribution of dissolved nutrients and oxygen; (3) temperature is a major environmental factor which affects growth and reproduction of both animals and plants. As previously described four different types or "orders" of thermal characteristics were observed in the lakes and ponds of Yoho National Park as follows:

- I. Deep, cold thermally stratified lakes- these lakes are relatively unproductive as a result of low temperatures, thermal resistance to mixing, and the constant loss of nutrients to the hypolimnion.

- II. Deep, warm, thermally stratified lakes- these lakes are also relatively unproductive and differ from the first mainly as a result of their slightly higher hypolimnion temperatures.
- IIIA. Deep unstratified lakes- these are unstratified as a result of constant winds and/or high water renewal rates. Their relatively high potential productivity may be modified by high water renewal rates which tend to remove nutrients and organic materials.
- IIIB. Shallow unstratified (polymictic) lakes- these lakes are relatively productive as a result of higher temperatures, lack of stratification, and high surface to volume ratios.

Within the context of North American lakes, most in the Park must be considered very unproductive (oligotrophic), and the remainder only moderately productive (mesotrophic) lakes (Vollenweider 1968). With this overall low productivity of Park lakes in mind it is probably best to think of the productivity of individual lakes only in relative rather than absolute terms. In classifying the Park lakes in the four groups as shown above, the general trophic characterization ranges from relatively oligotrophic (unproductive) lakes in groups I and II to relatively eutrophic (productive) lakes in groups IIIA and IIIB (Figure 46). As a result of the many different factors which may modify the productivity of individual lakes, the trophic character of lakes within each group will show some variation. Thus lakes in group I do not all have the same productivity but show a range which reflects individual differences. The same situation also prevails in the other groups with a general trend to more eutrophic conditions from group I to group IIIB. Figure 47 illustrates morphoedaphic characteristics which generally accompany conditions of oligotrophy and eutrophy.

Figure 46. Dominant phytoplankton genera, biomass, and standing crop of lakes in Yoho National Park.



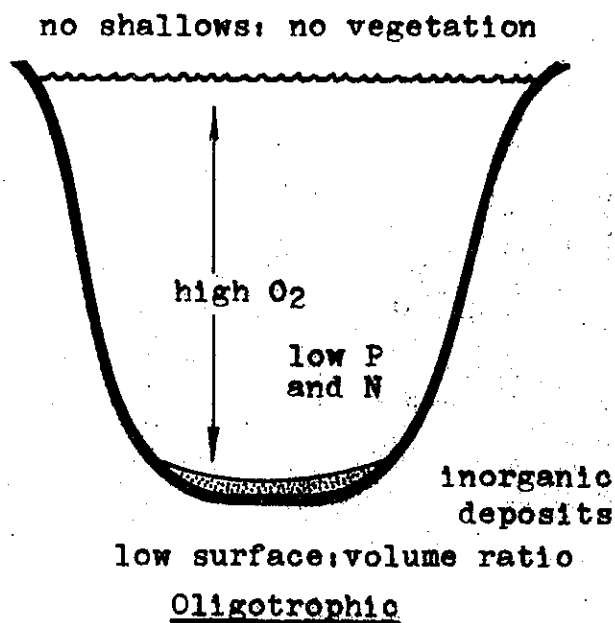
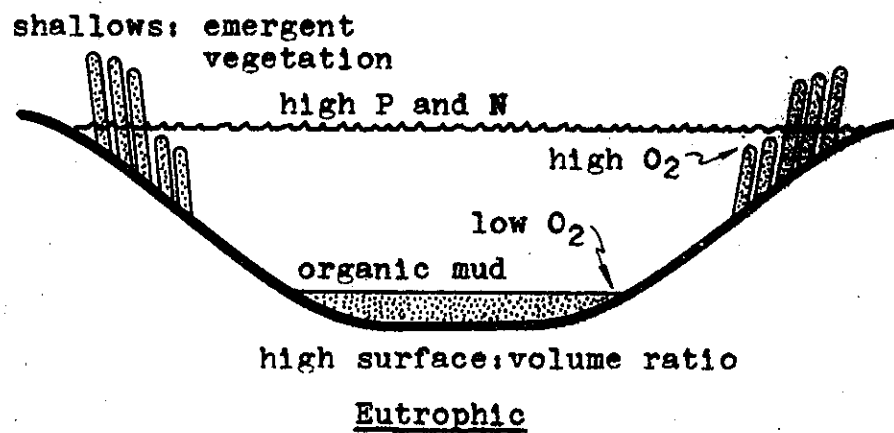


Figure 47

Stylized cross sections of typical eutrophic and oligotrophic lake types (from Russell-Hunter 1970)

Using maximum live phytoplankton biomass values Vollenweider (1968) classified lakes as follows:

Class	mg phytoplankton m ⁻³
Ultra-oligotrophic	1000
Mesotrophic	3000-5000
Highly eutrophic	10000

Kling and Holmgren (1972) summarized the phytoplankton communities of some lakes in the Experimental Lakes Area (Ontario) as follows:

Class	mg phytoplankton m ⁻³
A (large, deep, exposed lakes)	70-1200
B (small, deep, protected lakes)	1000-3000
C (small, shallow lakes)	1000-5000

None of the lakes surveyed by Kling and Holmgren could be considered "highly eutrophic" as defined by Vollenweider (1968). A similar situation exists in the mountain National Parks where lakes are of relatively low productivity.

Phytoplankton taxonomy

Seven groups of algae were found to be represented in phytoplankton collections in the Park. Cell structure, pigment, and morphology are the main characteristics used to differentiate between these groups.

Division Chlorophyta (green algae).

This division is characterized by grass green chloroplasts and a starch-filled pyrenoid body. Species may be unicellular or colonial and have motile (flagellated) reproductive stages. Forty species of green algae were identified from lakes and ponds of the Park with 5 species in 4 genera occupying important

positions in some of the lakes where they were found (Figure 46). With the exception of Ankistrodesmus sp. in Lake O'Hara, the green algae were found in high numbers only in the relatively eutrophic lakes. From a numerical point of view the Chlorophyta were least important during the summer months in group I, II, and IIIA lakes although winter samples often had relatively high numbers. The opposite situation appears to be the case in polymictic (IIIB) lakes where numbers of chlorophyta are high in summer and low in winter as shown by the samples from South Narao and Sink Lake (Figure 48). Very oligotrophic or silty lakes (Oesa, McArthur, Upper Opabin, Sherbrooke, Emerald) had very few or no chlorophyta (Figure 48).

Division Cyanophyta (blue-green algae, Plate

The blue-green algae are a distinctive group sharply delimited from other algae in a number of respects. They are the only algae in which the pigments are not localized in definite chromatophores. Equally important are the lack of flagellated reproductive cells and the total absence of gametic union in all its members (Smith 1950).

Although blue-green algae are found in a wide variety of habitats they were absent from deep, thermally stratified (group I and II) lakes in the Park. Among the 18 species of blue-green algae collected in the Park several were found to be numerically important in the more eutrophic (group IIIB) lakes (Figure 46).

Figure 48.

Percentage composition (by numbers) of major phytoplankton groups in lakes of Yoho National Park.

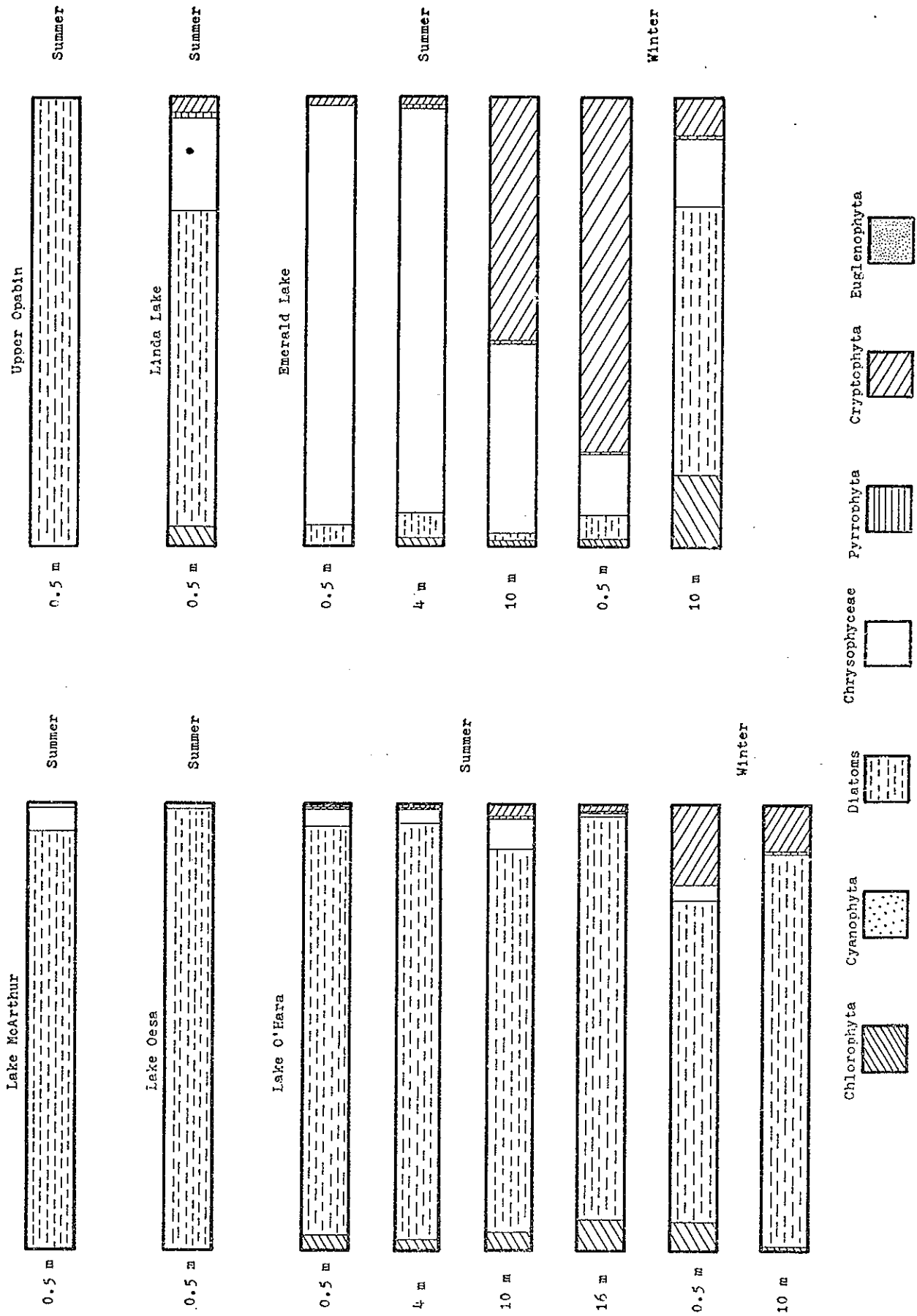


Figure 48 (Cont'd)

Percentage composition (by numbers) of major phytoplankton groups in lakes of Yoho National Park.

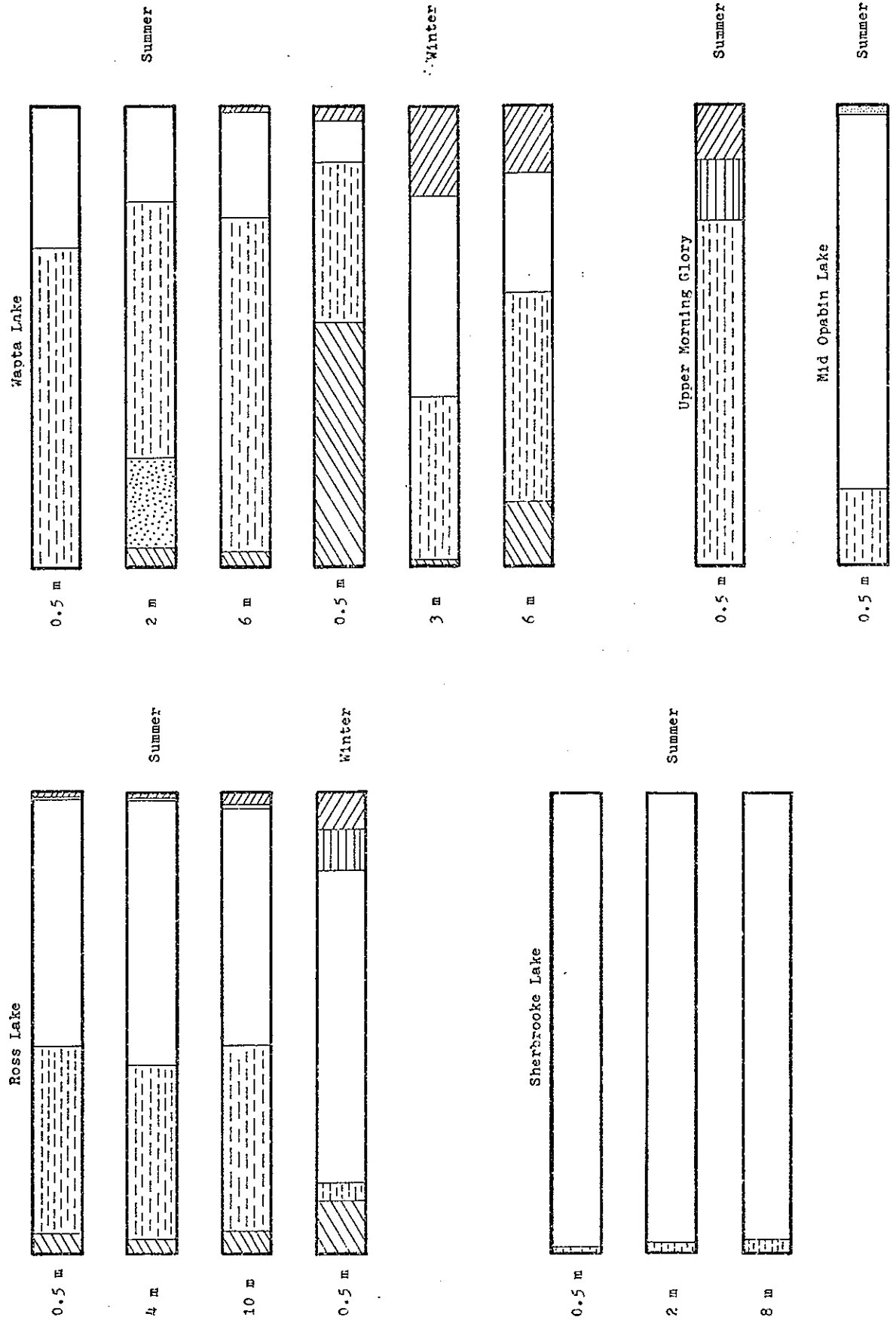
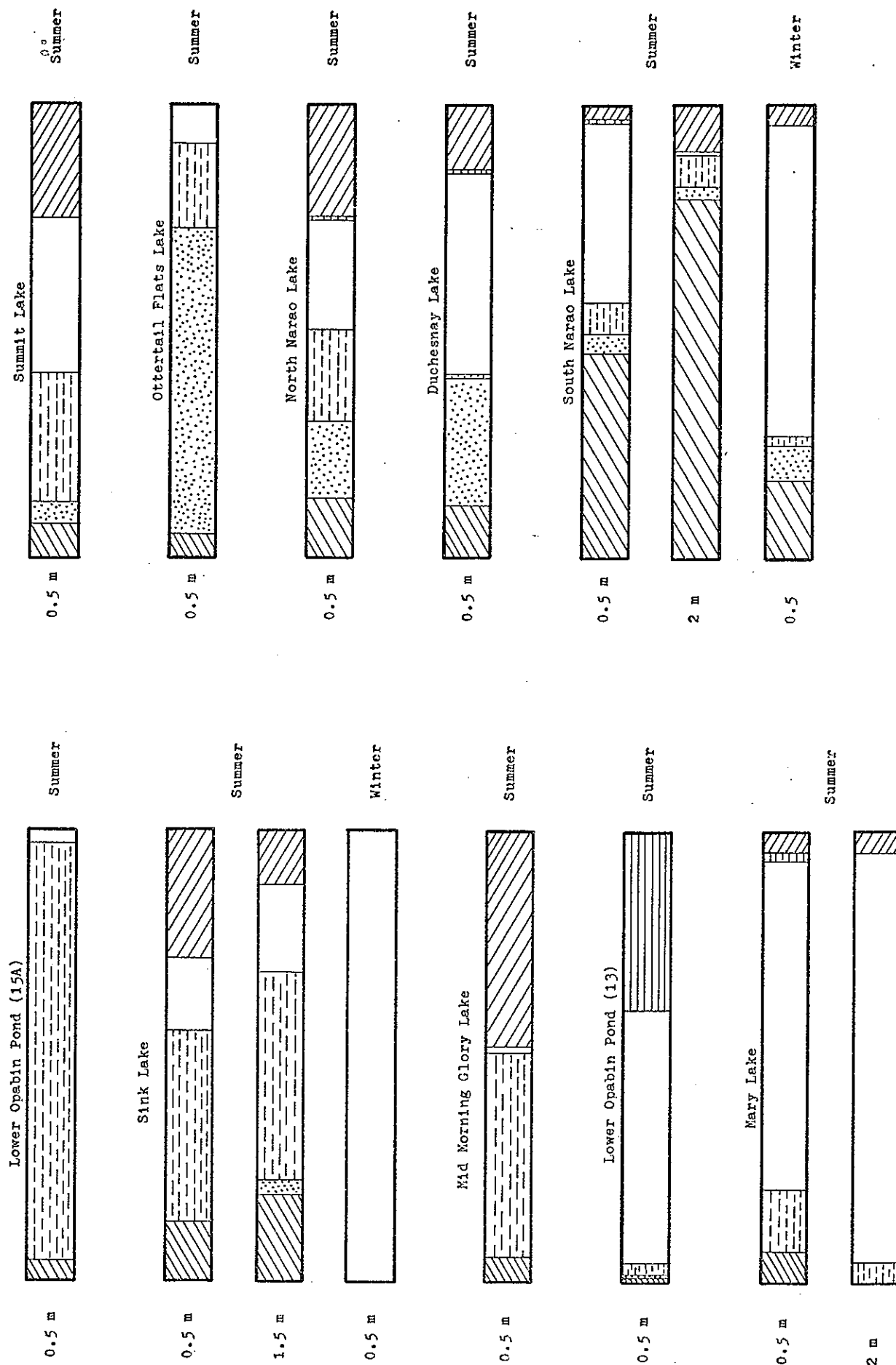


Figure 48 (Cont'd)
 Percentage composition (by numbers) of major phytoplankton
 groups in lakes of Yoho National Park.



Division Chrysophyta (Yellow-green or yellow-brown algae and diatoms).

This division is a rather heterogenous assemblage of algae. Starch is absent, the food substances being stored primarily as other carbohydrates or as oils. Silica, rather than cellulose, is the major component of cell walls. The silica impregnated cell wall is generally composed of overlapping halves. The cells may be flagellated or nonflagellated, and solitary or united in colonies of definite or indefinite shape.

For convenience this rather large group of algae may be divided into the usually flagellated Chrysophyceae and the nonflagellated Diatomaceae. Together, the 26 species of Chrysophyceae and the 60 species of Diatomaceae made up the majority, in both numbers and species, of the phytoplankton found in the lakes and ponds in the Park.

Three genera of Chrysophyceae formed a significant part of the phytoplankton in several of the lakes examined (Figure 46). Species of Kephyrion, for example, were important in 11 lakes ranging from the oligotrophic Opabin lakes to the more eutrophic Narao lakes. In general the Chrysophyceae made up less than 10% of the total numbers of phytoplankton in deep, cold, thermally stratified (1st order) lakes, whereas in most other lake types they made up about 20-70% of the phytoplankton by numbers.

Among the chrysophytes, diatoms (Diatomaceae) are probably of greater importance in the energy cycle of natural waters.

This is especially true in the relatively oligotrophic lakes in the Park where diatoms frequently dominated the phytoplankton. The genus Cyclotella, for example, dominated phytoplankton counts in O'Hara, Oesa, and McArthur lakes (1st order lakes). Similar high percentages of diatoms were found in other more oligotrophic lakes while in the more eutrophic lakes they were of considerably less importance and were replaced by Chrysophyceae or other groups (Figure 48).

Division Pyrrophyta (Dinoflagellates).

Dinoflagellates are characterized by the presence of two flagellae, and the formation of starch by chromatophores that are usually greenish tan to golden brown. Most of the dinoflagellates are unicells, some possessing covering plates of cellulose while others are naked. Peridinium and Ceratium (Figures 99 and 100, respectively) are examples of armored types while Gymnodinium (Figure 98) is a naked type.

Eight species of dinoflagellates were collected in the Park. Usually they were found in very low numbers and they formed an important part of the phytoplankton in only two lakes (Figure 46). Peridinium made up about 14% of the counts from Upper Morning Glory Lake and about 40% from Lower Opabin Pond (Site 13).

Division Cryptophyta (Cryptomonads).

This group included unicellular flagellates with asymmetrical, compressed cells, surrounded by a firm periplast, and with two flagellae which are slightly different in length.

Four cryptomonad species were collected in the Park and members of the genus Cryptomonas were found to form a numerically important part of the counts from Sink and Mary lakes.

Rhodomonas minuta was an important part of the phytoplankton in 5 other lakes (Figure 46). In type I, II, and IIIA lakes where winter samples were available (Figures 48), the percentage of Cryptophyta generally showed an increase over the summer values. A similar situation does not appear to be the case in the shallower type IIIB lakes as exemplified by winter samples from South Narao and Sink lakes. In all the deeper lakes the percentage of Cryptophyta generally increased with depth during the summer and decreased with depth during the winter.

Division Euglenophyta (Euglenodis).

Most members of this division are naked, free-swimming cells with one, two, or three flagellae. A gullet may be present at the anterior end of the cell and nearby a red eye spot is usually present.

Only a single specimen of the genus Trachelomonas was collected in Mid-Opabin Lake (Site 14). Euglenoids are most often found in small pools rich in organic matter. The presence of Trachelomonas sp. in Mid-Opabin Lake indicates this species may be found in other lakes of the Park under suitable conditions.

Phytoplankton of lakes in the Park.

First order (type I) lakes.

In general, the phytoplankton of type I lakes is dominated

by diatoms during both winter and summer. McArthur Lake appears to be the most oligotrophic of the group and has the lowest number of phytoplankton species, cells, and biomass. Lake Oesa is intermediate and Lake O'Hara has the highest values for the three parameters mentioned (Table 61). As a group the type I lakes all have their highest cell counts in late summer or early fall.

McArthur Lake. Three species of diatoms and one each of Chrysophyceae and Pyrrophyta are known to be part of the phytoplankton of Lake McArthur as a result of the samples collected during 1973 and 1974. On the basis of biomass and cell counts the diatoms from the dominant group (Table 62 and Figure 46).

Lake Oesa. Five species of diatoms and one chrysophyceae were collected from Lake Oesa during 1973. Phytoplankton biomass and cell counts were both approximately five times higher in Lake Oesa than in Lake McArthur (Table 62 and Figure 46).

Lake O'Hara. Phytoplankton samples from Lake O'Hara indicate that this lake has the greatest diversity of species and highest productivity of the three type I lakes examined in the Park. Diatoms (especially Cyclotella minuta?) were the most important group, but this lake also had representatives of other groups in substantial numbers (Table 62 and Figure 46). As indicated by Figure 48 the number of phytoplankton cells was generally higher with increased depth in both summer and winter months.

Table 62. Summary of phytoplankton numbers, biomass, and related parameters for lakes in Yoho National Park.

Lake No.	Number phyto. species	Number ¹ phyto. cells	Phyto. biomass mg m ⁻³	Primary prod. mg C m ⁻³ day ⁻¹	Mean (μ ³) phyto. cell. vol	Activity ²
6	36	837	498	-	594	-
8	5	116	32	-	282	-
9	22	3091	581	10.0	187	0.017
10	22	433	165	21.1	381	0.127
13	8	330	476	-	1440	-
14	5	98	43	-	443	-
15	1	1	0.7	-	43	-
15A	11	110	56	-	510	-
16	6	691	155	-	840	-
17	24	895	301	9.0	330	0.03
18	34	5428	559	94.0	100	0.16
19	37	957	214	14.7	220	0.068
20	30	199	42	12.7	210	0.29
22	11	182	96	-	520	-
23	8	74	61	-	820	-
24	12	226	86	-	380	-
26	17	545	292	8.2	530	0.028
42	24	2018	1756	-	870	-
47	9	807	482	10.4	590	0.021
48	25	112	69	10.7	610	0.154
49	40	732	205	26.6	280	0.129

1. Cells ml⁻¹

2. Primary production/biomass

Winter cell counts were approximately 10% of summer values. Changes in biomass closely followed the cell counts.

Primary productivity (Figure 49) of phytoplankton during July was roughly correlated with cell counts and was generally higher with depth. During August, however, the productivity at 0 and 4 m was higher than at 10 and 16 m even though the number of cells and corresponding biomass was much greater at the deeper stations. The lower photosynthetic activity of the phytoplankton at deeper stations may be explained in part by a reduction in Secchi visibility in August as compared to July. The average primary production observed was $10.04 \text{ mg C m}^{-3} \text{ day}^{-1}$.

Second order (type II) lakes.

The phytoplankton of the relatively oligotrophic second order lakes was dominated by diatoms while the relatively eutrophic ones exhibited a greater variety of phytoplankton groups. In general Upper Opabin Lake and Linda Lake appear to be considerably less productive than Ross and Emerald. In second order lakes cell counts are lowest in spring and highest in late summer and early fall.

Upper Opabin Lake. In Upper Opabin Lake a single diatom was collected indicating a very sparse phytoplankton population was present. This lake exhibited both the lowest cell count and biomass of any lake examined in the Park (Figure 46).

Linda Lake. The diatoms Synedra spp. and Cyclotella minuta (?)

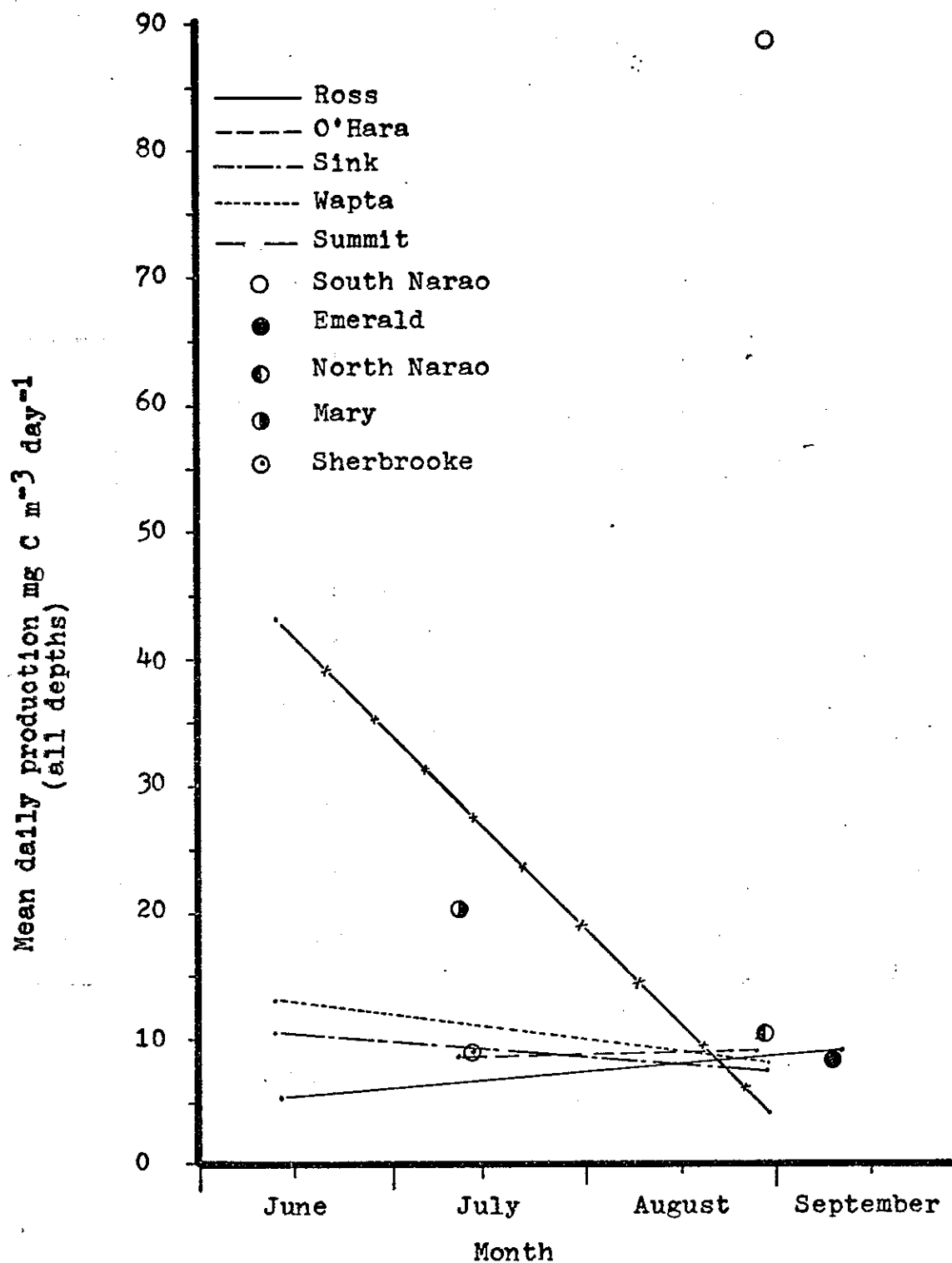


Figure 49. Primary productivity of phytoplankton in lakes of Yoho National Park.

dominated the phytoplankton from this lake and were collected along with 10 other species of phytoplankton. A low phytoplankton biomass of 86.5 mg m^{-3} indicates this lake has relatively low productivity (Figure 46).

Emerald Lake. The phytoplankton counts from Emerald Lake during the summer months were dominated by Chrysophyceae. Dinobryon sociale was the most numerous species. Species of Cryptophyta (Cryptomonas sp. and Rhodomonas sp.) were important in cell counts from deep samples in summer and winter (Figure 48). A total of 17 species of phytoplankton were collected from Emerald Lake. The summer cell counts were higher from the deeper stations but in winter the shallow and deep counts were very similar even though the species composition was different (Figure 48).

Primary productivity (Figure 49) during early September, 1973, was generally higher with depth from 0 to 10 m. The average primary production observed was $8.28 \text{ mg C m}^{-3} \text{ day}^{-1}$.

Ross Lake. Phytoplankton cell counts and biomass from Ross Lake were very similar to the values for Emerald Lake (Figure 46) although the species assemblage was quite different and included 24 species. During the summer the diatom Cyclotella sp. was important at all three sample depths. During the winter the chlorophytes Chlamydomonas sp. and Ankistrodesmus sp. dominated counts. The cell counts and biomass were generally higher at deeper stations although the species composition was very similar

at all depths (Figure 48).

Primary production in Ross Lake was generally higher with increased depth during both June and September, 1973 (Figure 49). The average primary production observed was $9.09 \text{ mg C m}^{-3} \text{ day}^{-1}$.

Deep third order (type IIIA) lakes.

Wapta and Sherbrooke lakes had quite different phytoplankton populations (Figure 48). These differences were most likely due to differences in light penetration and water replacement rate. Seasonal samples from Wapta Lake indicate cell counts are low in June and higher in August (Figure 48).

Wapta Lake. The phytoplankton of Wapta Lake was characterized by low cell counts and low biomass (Figure 46) but had very high rates of photosynthetic activity (Table 62). One Chrysophyceae (Kephyrion sp.) and two diatoms (Achnanthes sp. and Navicula sp.) dominated the counts during summer months and were also present in winter samples. The presence of Achnanthes in the phytoplankton samples from this lake is an indication of the holomictic nature of the lake as Achnanthes is usually sessile and borne either on gelatinous stalks or with one valve apposed directly to the substrate (Smith 1950). The holomictic nature of the lake as a result of high water renewal rates no doubt causes considerable turbulence along the bottom which carries parts of the periphyton up into the phytoplankton where it is eventually lost from the lake via the kicking Horse River.

A number of observations on conditions in Wapta Lake may be suitably explained by the high water replacement rate and

holomictic nature of this lake. These observations are as follows:

1. phytoplankton cell counts are low,
2. phytoplankton biomass is low,
3. light penetration is to the bottom and phytoplankton activity is the highest of any lake in the Park,
4. zooplankton counts are extremely low,
5. benthic invertebrates (mostly chironomids) m^{-2} are the highest for any lake in the Park,
6. the percentage of organic material in the bottom mud is among the lowest for lakes in the Park (Table 62).

A general account of how these observations may be interrelated is as follows: the phytoplankton is subject to removal from the lake because of the high water renewal rate and this results in both low cell counts and low biomass. Such a small phytoplankton standing crop would support only a very small population of zooplankton. Light penetration to the bottom probably allows rapid growth of the periphyton which both supports the high chironomid population observed and contributes to the phytoplankton population as a result of scouring due to turbulence. A considerable amount of the organic material represented by the chironomids is probably lost from the lake during migration to the surface for emergence during the flight and mating phase of the life cycle; many eggs deposited may also be washed out of the lake. As a result of these losses the accumulation of organic material in the mud is low.

Sherbrooke Lake. The phytoplankton of Sherbrooke Lake was very different from Wapta Lake and was dominated at all depths by the Chrysophycean Dinobryon cylindricum. In addition to the differences in the species present, the cell counts and phytoplankton biomass were about 4 and 10 times higher, respectively, than for Wapta Lake. In spite of the higher counts

and biomass, the primary productivity was about the same ($10.46 \text{ mg C m}^{-3} \text{ day}^{-1}$) as Wapta and the photosynthetic activity for the phytoplankton was about 10% of the value from Wapta Lake (Table 62). The striking differences in the phytoplankton of these two comparatively deep holomictic lakes may be accounted for by the presence of silt in Sherbrooke Lake which limits light penetration and the lower rate of water renewal which allows some accumulation of phytoplankton even though primary productivity is low.

Sherbrooke Lake has a much more restricted phytoplankton population with only 9 species present as compared to 30 in Wapta Lake. Low light intensities are known to favor some chrysophyceae such as Dinobryon and Kephyrion. This may account for the dominance of this group over diatoms in the silty conditions of Sherbrooke Lake.

Third order (polymictic, type IIIB) lakes.

The phytoplankton of the shallow polymictic lakes is highly variable and reflects the wide range of conditions in this group of lakes. Generally, the more oligotrophic polymictic lakes were dominated by diatoms, whereas in the more eutrophic lakes Cryptophyta and Cyanophyta formed an important part of the phytoplankton. The phytoplankton counts from these shallow lakes were generally high in June and low in August, in contrast to the type I, II, and IIA lakes.

Upper Morning Glory Lake. This lake had both the lowest phytoplankton cell counts and biomass of any of the polymictic lakes examined (Figure 46). Eight species were collected in the phytoplankton with the diatoms Achnanthes and Navicula occupying

dominant positions.

Mid Morning Glory Lake. Eleven phytoplankton species were collected from this lake. The cryptophyte Rhodomonas minuta had high counts as did the diatoms Navicula and Achnanthes (Figure 46). Although biomass and cell counts were higher than for Upper Morning Glory Lake they still reflect the general oligotrophic nature of this lake.

Mid Opabin Pond (site 14). Phytoplankton samples from this oligotrophic pond contained only 5 species of algae at low cell counts and low biomass (Table 62). The low production of the phytoplankton is likely a reflection of the near absence of nutrients as indicated by the pond's low conductivity (Table 8).

Lower Opabin Pond (13). Although Mid Opabin Pond is only a few yards from Lower Opabin Pond the phytoplankton counts and biomass (Figure 46) of the lower pond were much higher. The lower pond is about one-half the depth of the middle pond and consequently temperatures are higher with little gradient from surface to bottom. Eight species of algae were present including one of the few Chlorophyta found in the Park (Tetraedon minimum). Cell counts were dominated by Peridinium sp. and also by Dinobryon attenuatum which was found only in the mid and lower Opabin ponds and is a species known mainly from Arctic lakes (Hilliard 1971).

As noted previously the concentration of dissolved major cations in mid and lower Opabin Ponds very closely resembles that of rainwater or snow meltwater (Table 7). In nearly all respects the morphometry and exposure of these two ponds is

similar. Probably the major difference is depth which allows higher temperatures in the lower pond and no doubt contributes to much higher productivity of this pond.

Opabin Pond (15A). This small pond is basically a wide section of the creek which drains Upper Opabin Lake. The phytoplankton was dominated by Chrysophyta such as Achnanthes, Fragilaria, and Navicula. These diatoms are normally important constituents of the periphyton of streams and further illustrates the streamlike nature of this site as pointed out in the discussion of Ephemeroptera (page E-32) from this pond.

Sink Lake. In spite of a rather diverse assemblage of 25 phytoplankton species, the cell counts and phytoplankton biomass of Sink Lake proved to be quite low in relation to some other polymictic lakes (Figure 46). Counts were about twice as high in June as in August with corresponding differences in biomass. In June Achnanthes microcephala was the most common alga while in August Rhodomonas minuta dominated the phytoplankton counts. Although Photosynthetic activity of the phytoplankton was high, the overall low numbers resulted in relatively low rates of primary production (Figure 49). Grazing by the uncommonly high numbers of crustacea present in the zooplankton during the summer months (Table 54) may account in part for the relatively low phytoplankton numbers. Low phytoplankton standing crops and high photosynthetic rates in the presence of moderately dense zooplankton populations have been documented for similar lakes in the general vicinity of this study area (Anderson 1974).

Summit Lake. Although in close proximity to Sink Lake,

Summit Lake was characterized by a much higher phytoplankton production rate than was Sink Lake (Figure 49). Forty species of phytoplankton were collected from Summit Lake and the dominant genera included Kephyrion, Pseudokephyrion, Achnanthes, and Navicula (Figure 46). The rate of primary production was over twice that of Sink Lake and cell counts and biomass were also higher (Figure 49). In spite of the higher phytoplankton biomass, Summit Lake contains lower numbers of zooplankton than does Sink Lake. In general the production of the phytoplankton community in Summit Lake appears to be about average for polymictic lakes in the Park.

Mary Lake. Phytoplankton counts and biomass from Mary Lake indicate that it is intermediate between the oligotrophic and relatively eutrophic polymictic lakes in the Park (Figure 46). The phytoplankton is dominated by the chrysophytes Kephyrion and Dinobryon. Phytoplankton primary production and activity are moderately high relative to other polymictic lakes.

North Narao Lake. The phytoplankton of North Narao Lake was not dominated by any particular group but contained approximately equal numbers of Chlorophyta, Cyanophyta, Diatoms, Chrysophyceae and Cryptophyta (Figure 48). Moderately high cell numbers and biomass indicate this is one of the more eutrophic polymictic lakes (Figure 46).

South Narao Lake. South Narao Lake had the highest phytoplankton cell count and highest primary production of any lake in the Park (Figure 49). A high rate of turnover in the phytoplankton is indicated by the high primary productivity, low

mean cell volume, and relatively low biomass (Table 62).

This lake supports moderately high numbers of crustacean plankters and higher numbers might be present were it not for the very small size of the phytoplankton cells present. The high cell counts, primary production, and accumulation of organic materials in bottom sediments as indicated by the asking weight loss (Table 62) all reflect the relatively eutrophic nature of this lake.

Ottertail Lake. The phytoplankton of Ottertail Lake probably undergoes many changes throughout the summer as a result of temporary connections with the Kicking Horse River. When examined during August, 1974, Ottertail Lake had 37 species of algae with a fairly high cell count at 837 ml^{-1} . Assuming this lake follows the seasonal trend demonstrated by other polymictic lakes even higher counts may be present earlier in the summer. The dominant species collected were blue-green algae (Cyanophyta) including Oscillatoria sp., Merismopedia elegans, Gomphosphaeria lacustris, Nostoc paludosum, and Anabaena sp.

Duchesnay Lake. Duchesnay Lake had high phytoplankton cell counts and the highest biomass of any lake examined in the Park (Figure 46). Chrysophyceae and Cyanophyta dominated the phytoplankton (Figure 48) and included such species as Ochromonas sp. and Microcystis incerta. The high standing crop of phytoplankton exists in spite of the grazing pressure of the densest zooplankton populations determined for lakes in Yoho National Park. The shallow nature of this lake coupled with the high heat content contributes to the high productivity of this lake which is the most eutrophic of those examined in the Park.

Plate 6. Phytoplankton of Yoho National Park: Chlorophyta.

- Figure 1. *Carteria* sp.
2. *Chlamydomonas* sp.
3. *Sphaerocystis schroeteria*
4. *Ankistrodesmus falcatus*
5. *Ankistrodesmus spiralis*
6. *Dictyosphaerium pulchellum*
7. *Lagerheimia ciliata*
8. *Lagerheimia longiseta*
9. *Lagerheimia quadriseta*
10. *Nephrocytium agardhianum*
11. *Oocystis borgei*

Plate 7. Phytoplankton of Yoho National Park: Chlorophyta.

- Figure 12. *Oocystis crassa*
13. *Oocystis eremosphaeria*
14. *Oocystis parva*
15. *Oocystis* nr. *arcticus*
16. *Schroederia setigera*
17. *Tetraedon minimum*
18. *Coelastrum microporum*
19. *Crucigenia irregularis*
20. *Crucigenia quadrata*
21. *Crucigenia rectangularis*
22. *Scenedesmus bujuga*
23. *Scenedesmus brasiliensis*
24. *Scenedesmus denticulatus*
25. *Scenedesmus obliquus*
26. *Scenedesmus quadricauda*

Plate 8. Phytoplankton of Yoho National Park: Chlorophyta and Cyanophyta.

- Figure 27. *Pediastrum tetras*
28. *Ulothrix subconstricta*
29. *Cosmarium tenue*
30. *Cosmarium bioculatum*
31. *Staurostrum bienneanum*
32. *Cosmarium* nr. *subcucumis*
33. *Chroococcus minor*
34. *Merismopedia glauca*
35. *Merismopedia punctata*
36. *Merismopedia tenuissima*

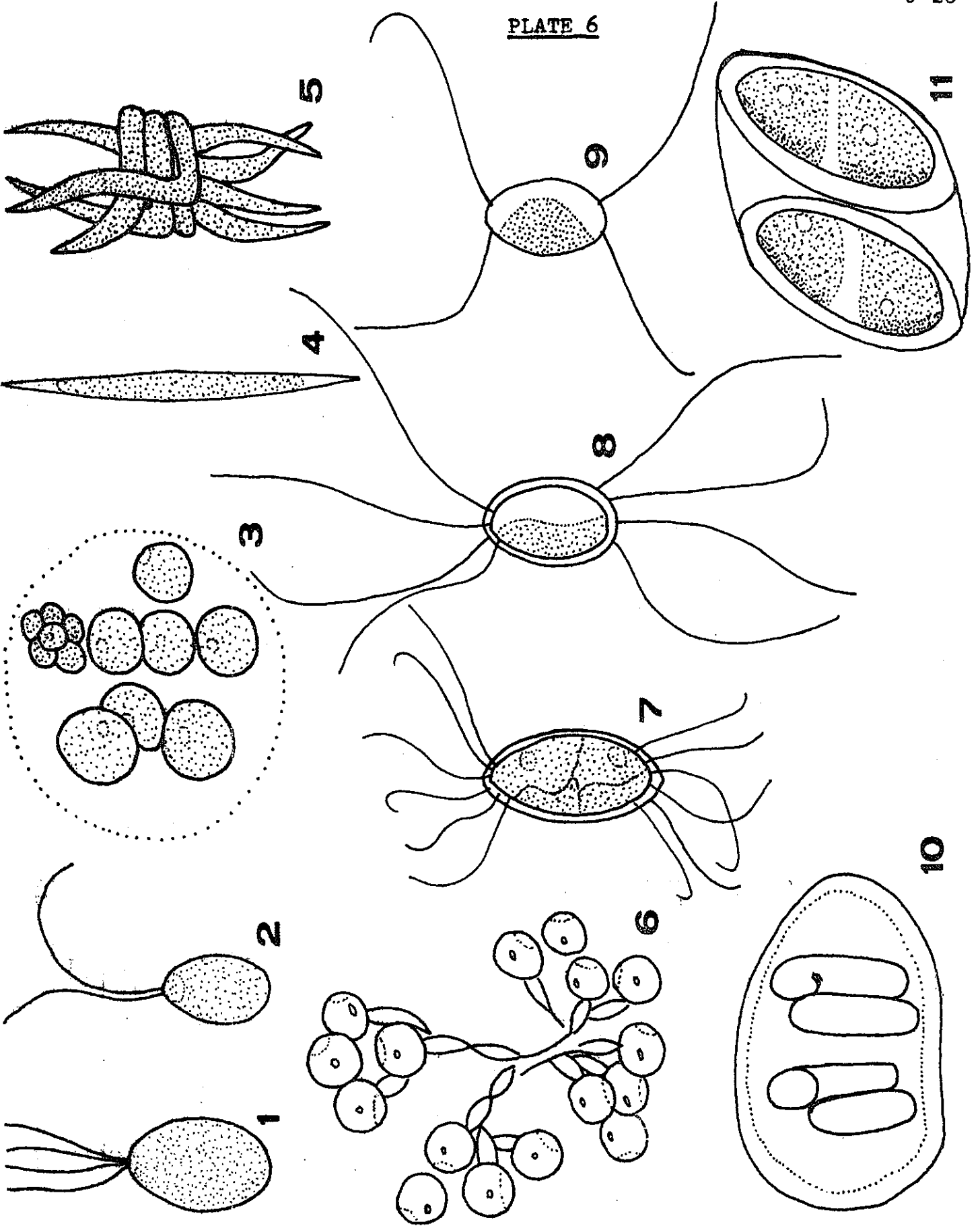
PLATE 6

PLATE 7

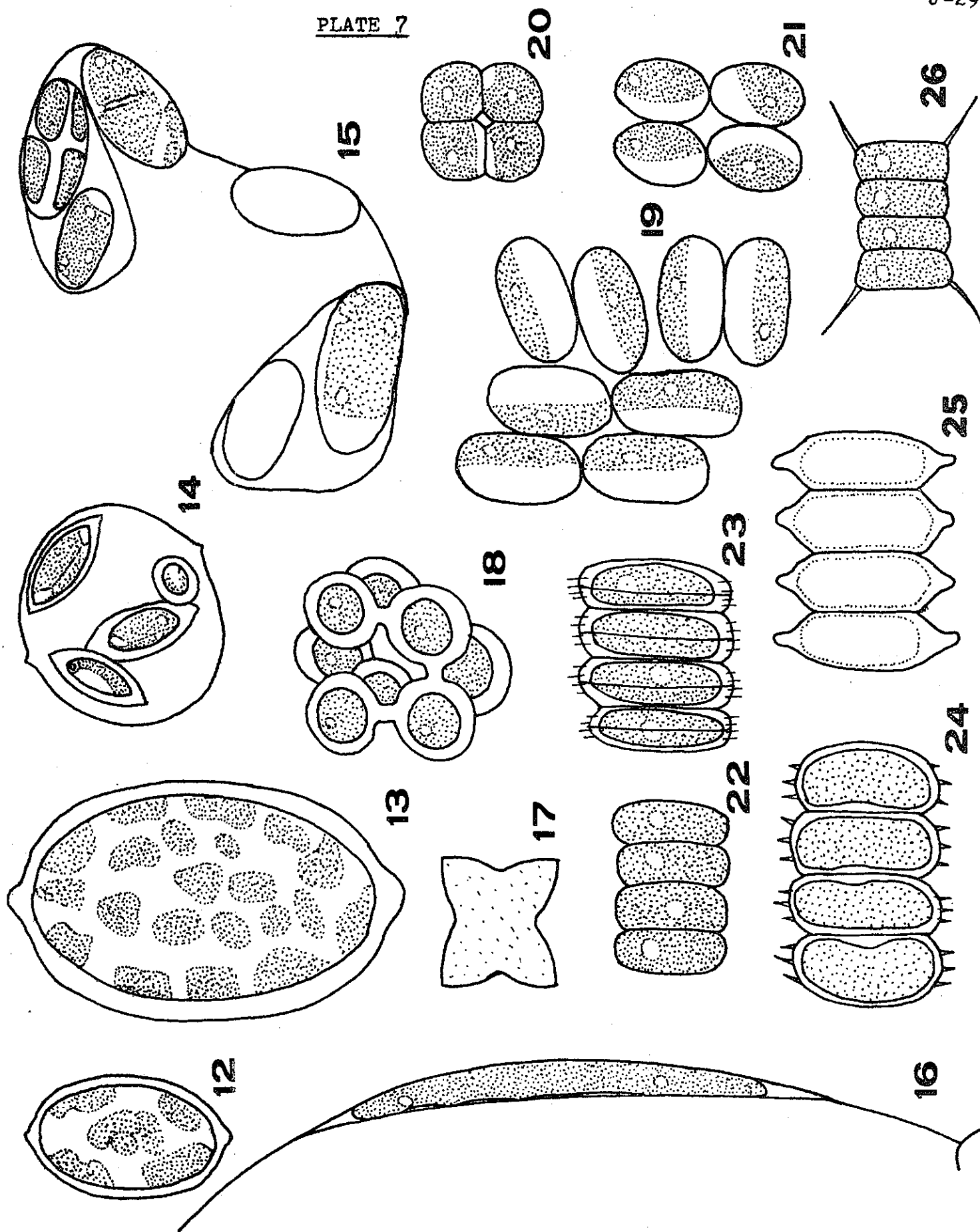


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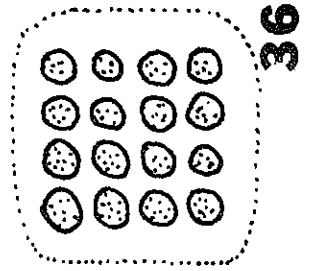
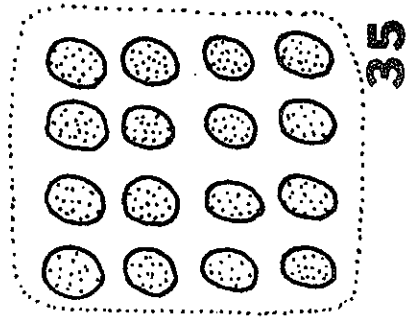
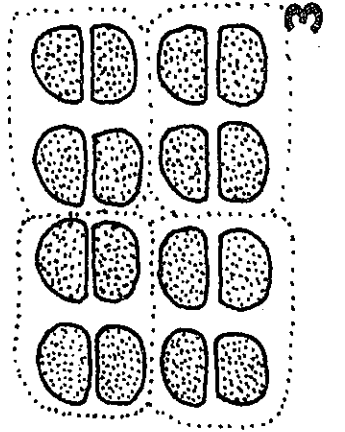
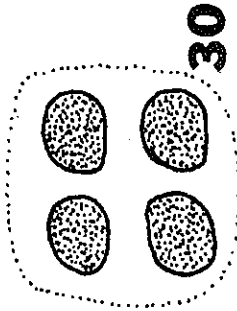
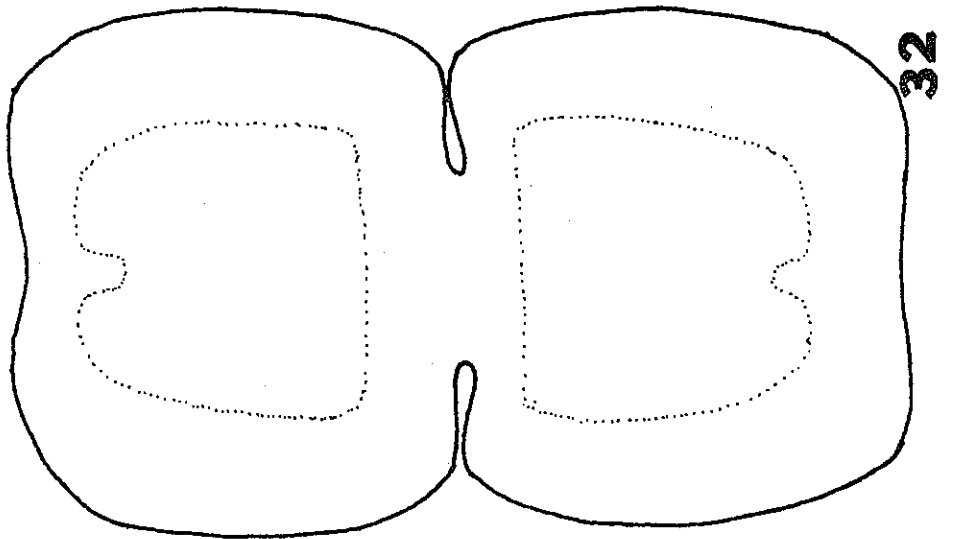
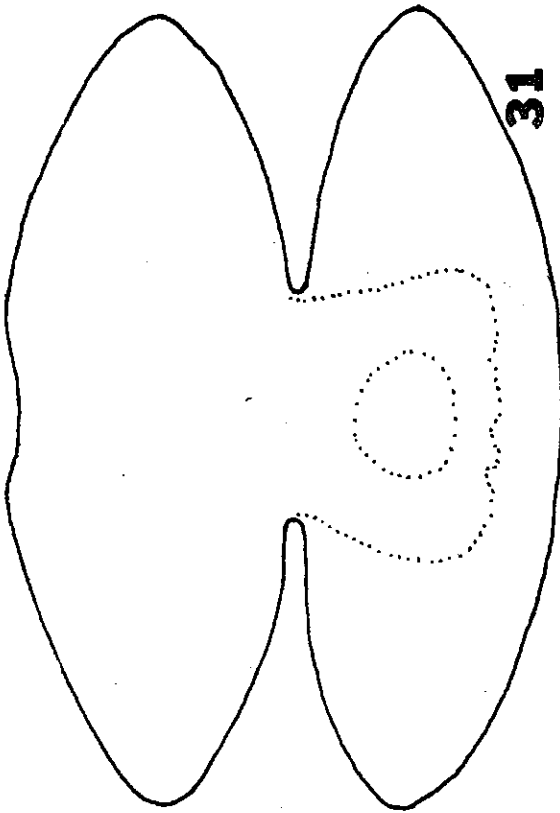
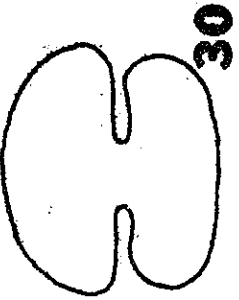
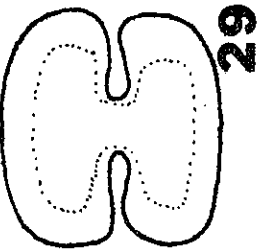
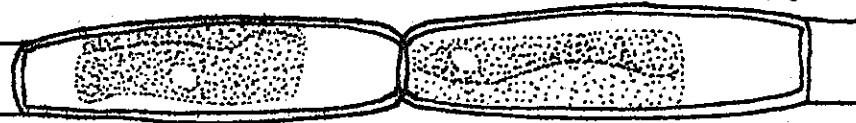
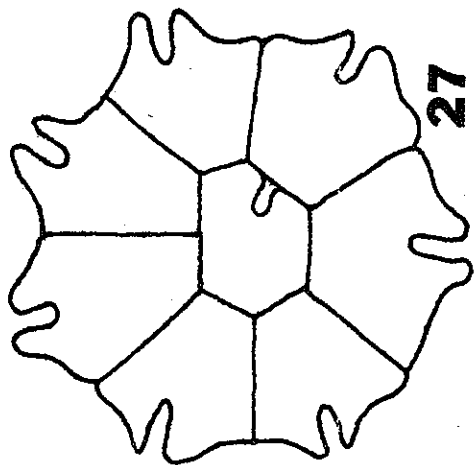


Plate 9. Phytoplankton of Yoho National Park: Cyanophyta
and Chrysophyceae.

- Figure 37. *Microcystis incerta*
 38. *Arthrospira jenneri*
 39. *Oscillatoria geminata*
 40. *Oscillatoria limnetica*
 41. *Oscillatoria rubescens*
 42. *Bitrichia chodatii*
 43. nr. *Lagynion* sp.
 44. *Chromulina* sp.
 45. *Kephyrion* sp. A
 46. *Kephyrion* sp. B
 47. *Kephyrion* sp. C
 48. *Kephyrion littorale*
 49. *Kephyrion obliquum*
 50. *Kephyriopsis* sp.
 51. *Stenocalyx* sp.
 52. *Ochromonas* sp.
 53. *Chrysolykos planktonicus*
 54. *Chrysolykos skujae*

Plate 10. Phytoplankton of Yoho National Park: Chrysophyceae
and Diatomeae.

- Figure 55. *Dinobryon attenuatum*
 56. *Dinobryon cylindricum*
 57. *Dinobryon sertularia*
 58. *Dinobryon sociale*
 59. *Dinobryon sociale* var. *americanum*
 60. *Pseudokephyrion* sp.
 61. *Pseudokephyrion hiemale*
 62. *Pseudokephyrion parvum*
 63. nr. *Monosiga varians*
 64. *Cyclotella minuta* (?)
 65. *Cyclotella ocellata*
 66. *Diatoma hiemale* var. *mesodon*
 67. *Diatoma vulgare*
 68. *Fragilaria brevistriata*
 69. *Fragilaria brevistriata* var. *capitata*
 70. *Fragilaria construens*

PLATE 9

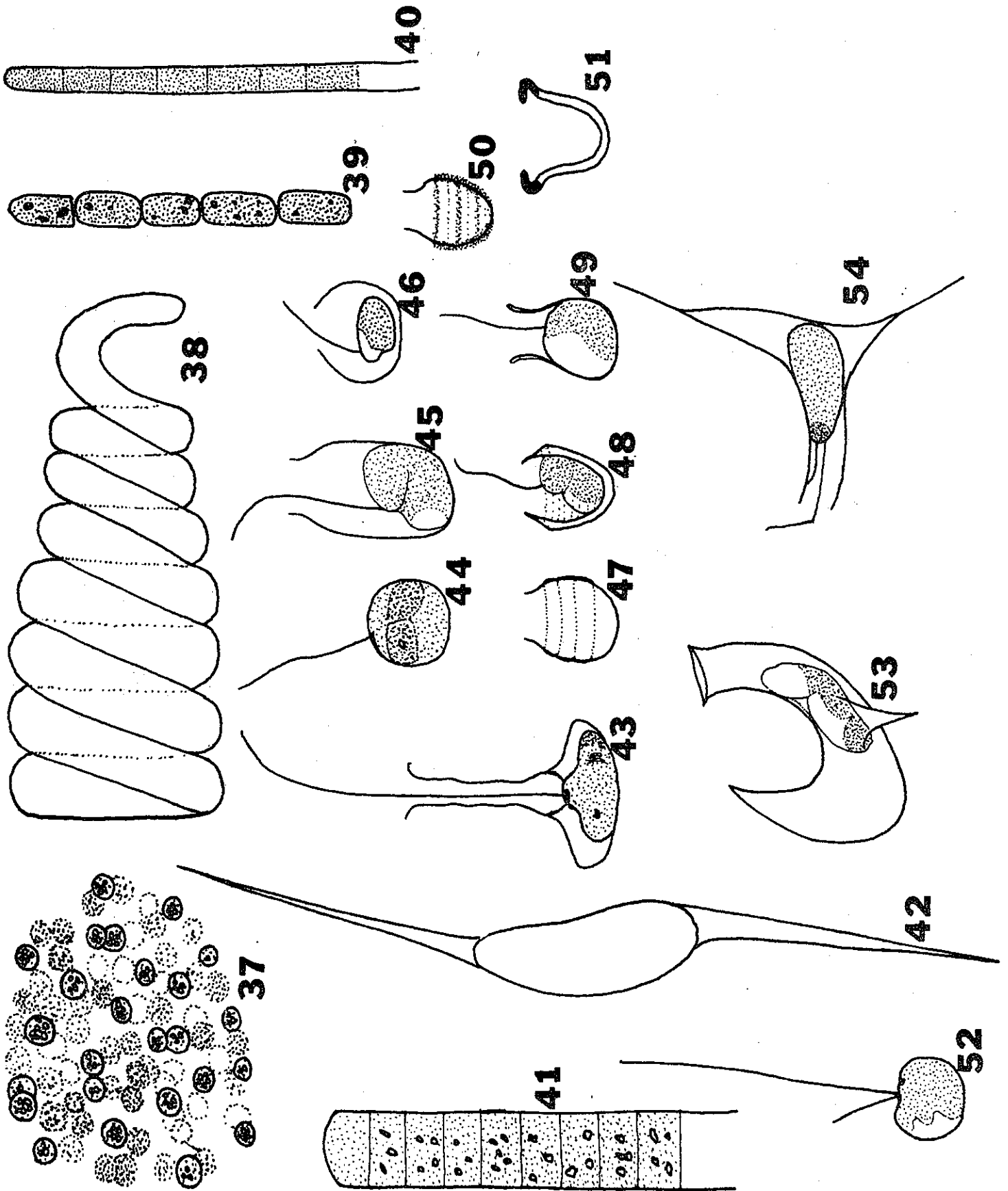


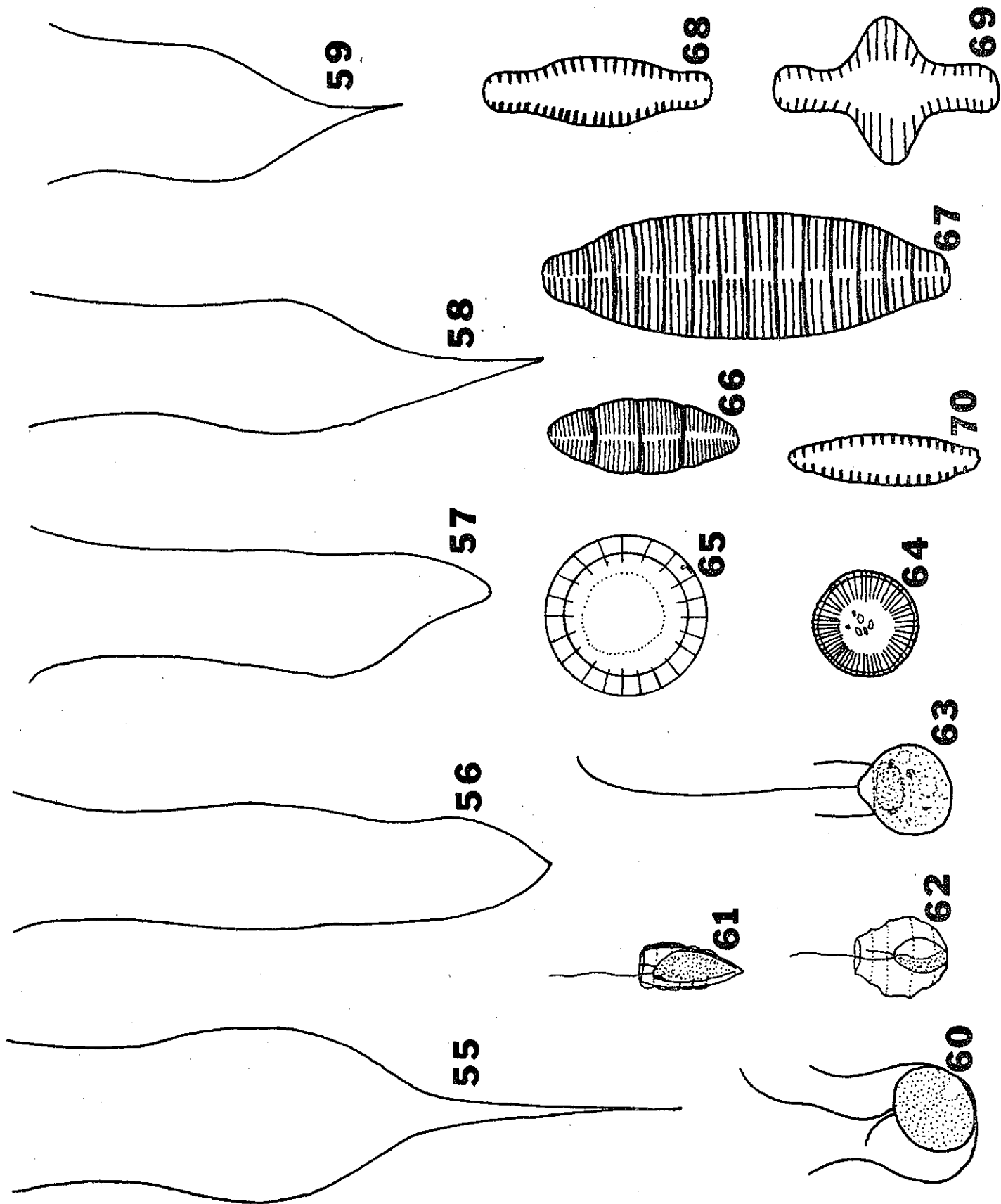
PLATE 10

Plate 11. Phytoplankton of Yoho National Park: Diatomeae.

- Figure 71. *Fragilaria crotonensis*
72. *Fragilaria pinnata*
73. *Hannea arcus*
74. *Synedra acus*
75. *Synedra radians*
76. *Synedra ulna*
77. *Achnanthes exigua* var. *heterovalvata*
78. *Achnanthes flexella*
79. *Achnanthes lanceolata* var. *dubia*
80. *Achnanthes linearis* (nr var. *curta*)
81. *Achnanthes microcephala*
82. *Achnanthes minutissima*
83. *Cocconeis placentula*
84. *Amphipleura pellucida*
85. *Diploneis puella*
86. *Diploneis elliptica*
87. *Navicula elginensis*

Plate 12. Phytoplankton of Yoho National Park: Diatomeae and Pyrrophyta.

- Figure 88. *Navicula menisculus* var. *upsaliensis*
89. *Navicula radiosa*
90. *Neidium binode*
91. *Gomphonema acuminatum*
92. *Gomphonema olivaceum*
93. *Cymbella affinis*
94. *Cymbella ventricosa*
95. *Rhopalodia gibba*
96. *Nitzschia palea*
97. *Nitzschia sigma*
98. *Gymnodinium helveticum*
99. *Peridinium inconspicuum*

Plate 13. Phytoplankton of Yoho National Park: Pyrrophyta, Cryptophyta, and Euglenophyta.

- Figure 100. *Ceratium hirundinella*
101. *Cryptomonas erosa*
102. *Cryptomonas ovata*
103. *Rhodomonas minuta*
104. *Trachelomonas* nr. *pulchella*

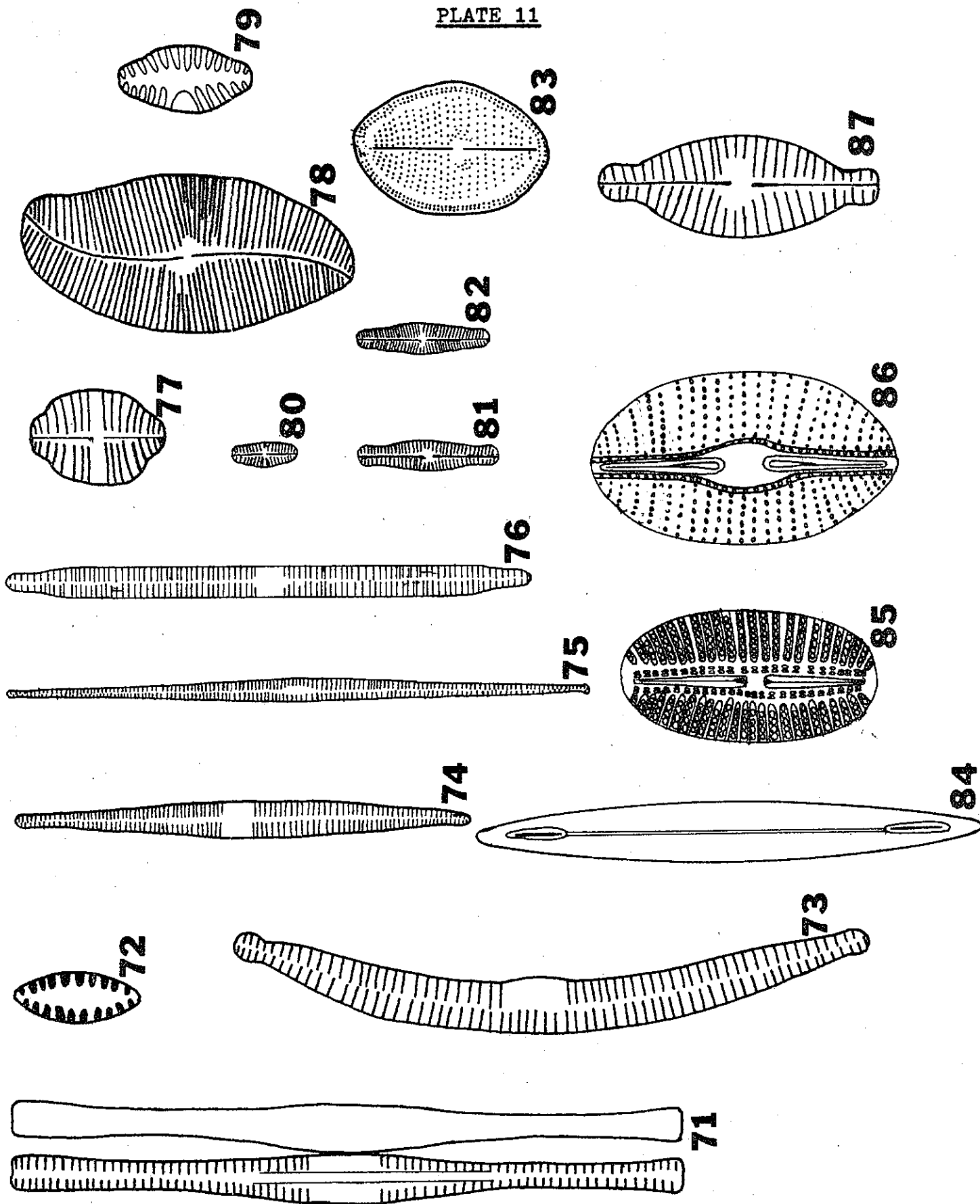
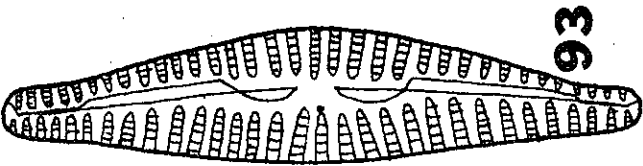
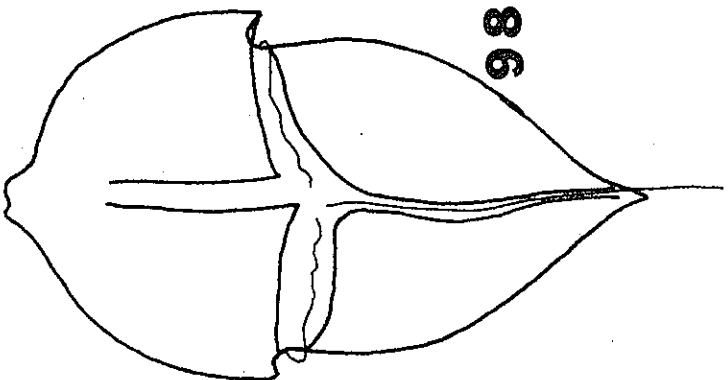
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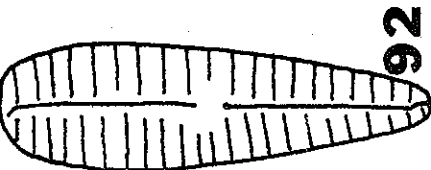
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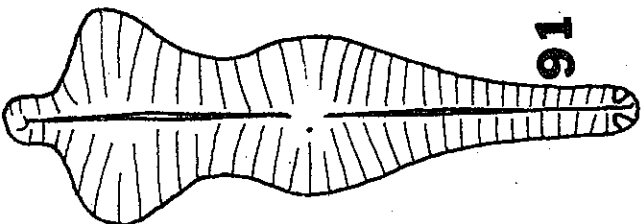
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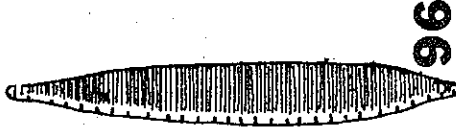
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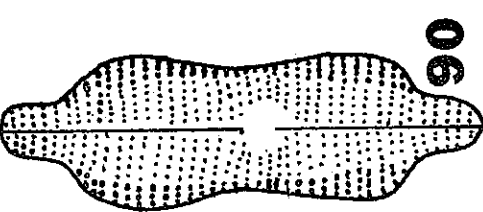
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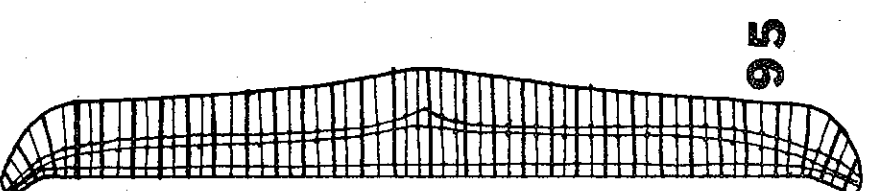
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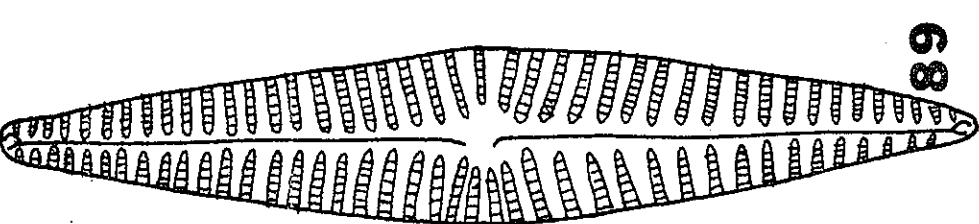
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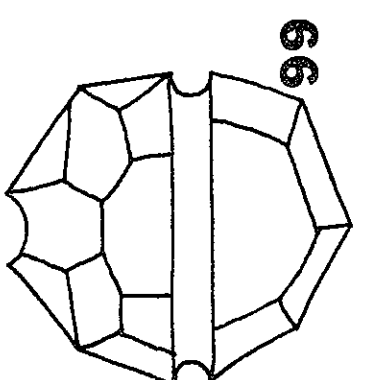
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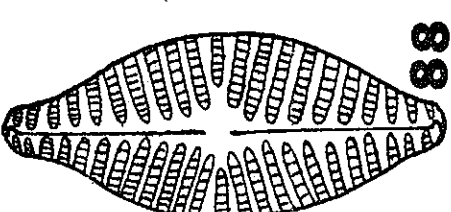
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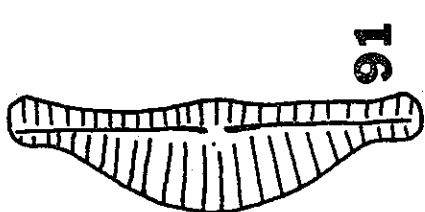
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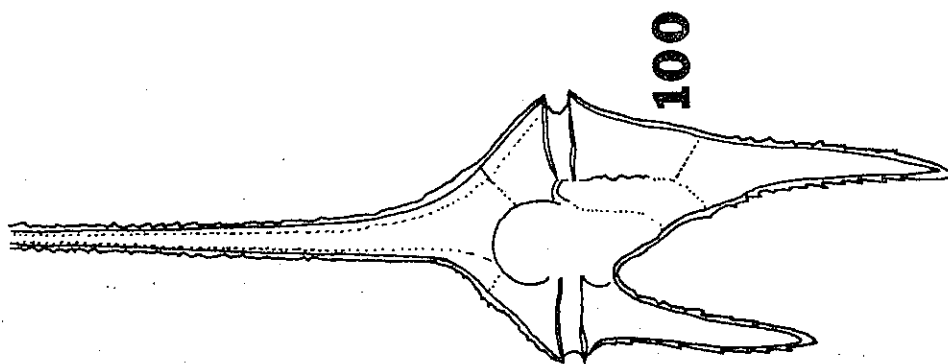
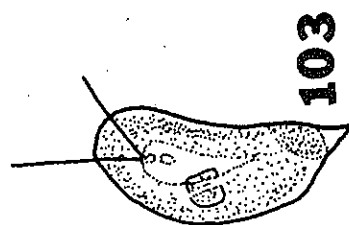
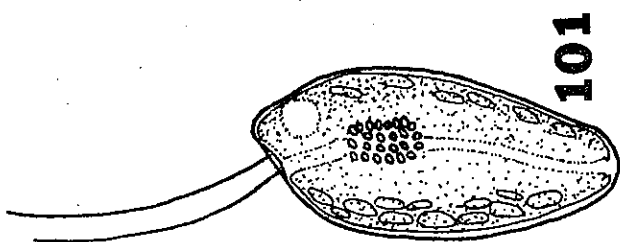
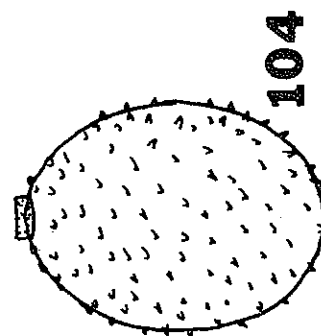
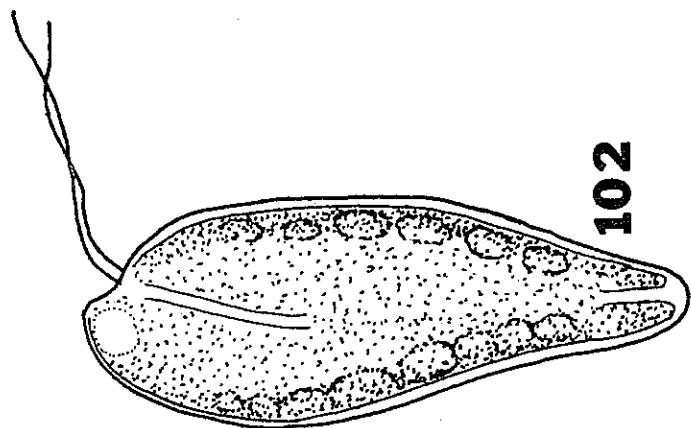
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PLATE 13

AQUATIC RESOURCES: A SUMMARY

Composition of some representative communities.

The physical, chemical and biotic parameters examined during the present study reveal a wide diversity in the types of aquatic communities available in the Park. In summarizing the information on these communities it is of interest to compare lakes which are representative of the communities in the Park. As noted in the discussion of phytoplankton the trophic levels of lakes and ponds in the Park are all of a relatively oligotrophic (unproductive) nature when compared to other water bodies in North America. Three lakes which demonstrate the range of trophic conditions available within the Park are McArthur, Emerald, and Duchesnay.

McArthur Lake is one of a group of extremely oligotrophic lakes in the Park. Oesa, Upper Opabin, and Upper Morning Glory lakes are all similarly unproductive. McArthur Lake exhibits the classic morphoedaphic features indicative of low productivity as illustrated in Figure 47 (page J-6). Characteristics such as low surface: volume ratio, lack of shallows, no macrophytic vegetation, and low temperatures all contribute to low productivity. A mean depth of 25.6m and very low total dissolved solids also indicate low productivity (Table 63) when expressed in the form of a morphoedaphic index as described previously.

The biotic communities of McArthur Lake and other highly oligotrophic lakes in the Park also reflect the morphoedaphic conditions described above. The planktonic and benthic communities

Table 63. Summary of benthic, zooplankton, and phytoplankton biomass for lakes in Yoho National Park. The morphoedaphic index (TDS/mean depth) is also given.

Lake No.	Benthic g m ⁻²	Zooplankton mg m ⁻³	Phytoplankton mg m ⁻³	Morphoedaphic index
6	4.3	45.0	498.9	16.4
7	6.0	131.0	-	-
8	3.6	227.0	32.8	2.4
9	10.7	532.4	581.9	2.6
10	2.1	2394.0	165.6	23.0
13	12.9	780.0	476.1	4.0
14	1.7	401.8	43.5	9.0
15	0.2	384.4	0.7	7.9
15A	1.9	8.8	-	67.0
16	7.7	235.8	155.1	3.8
17	6.4	447.8	301.4	14.6
18	56.3	1186.4	559.9	41.6
19	44.0	82.6	214.2	157.0
20	21.5	3.0	42.2	20.0
22	2.5	0.0	96.6	46.6
23	3.2	40.6	61.7	35.5
24	0.2	3.8	86.5	23.0
26	21.5	318.6	292.3	6.5
42	6.6	5510.4	1756.4	8.8
47	11.6	62.4	482.0	24.7
48	16.9	10692.0	69.1	7.4
49	42.1	2439.6	205.0	125.0

are low in both numbers and biomass (Table 63). In general, the sparse phytoplankton is dominated by diatoms such as Cyclotella sp. Diaptomus arcticus is the main zooplankter while the chironomid Tanytarsus sp. is characteristic of the benthos.

Emerald Lake is an example of lakes in the Park with an intermediate level of productivity. Morphoedaphic features between the extremes shown in Figure 47 allow a moderate level of productivity when compared to other lakes in the Park. Lakes of a similar type include O'Hara, Linds, Ross, Wapta, Sherbrooke, and middle Morning Glory. Within this group, of course, there is a wide range in productivity, although they all exhibit similar morphoedaphic features. An average surface: volume ratio, presence of some shallows and macrophytes, and average TDS values all indicate higher levels of productivity.

The chrysophyceans Dinobryon and Kephyrion are characteristic of the phytoplankton community of Emerald Lake. The zooplankton usually contains a wider range of species than is found in the lakes of low productivity and very often no particular species is dominant. Chironomids such as Procladius and Tanytarsus dominate benthic samples but other invertebrates such as oligochaetes and pelecypods (small clams) are also found. Most of the lakes in this second group support fish populations.

The last, and generally most productive, group of lakes included those shallow lakes with high surface: volume ratios, mud high in organic content, extensive macrophytes, and high temperatures. This group includes Sink, Opabin Ponds 13 and 14, Mary, Summit, Ottertail, North Narao, South Narao, and Duchesnay.

Again, these lakes show a range of productivity levels although as a group they have similar morphoedaphic features. Duchesnay Lake is fairly representative of this group. Its shallow depth, high TDS values, and high temperatures result in a large phytoplankton population dominated mainly by the cryptophyte Rhodomonas. Both the zooplankton and benthic communities include a large number of species with relatively high biomass values. Most of the lakes in this group are subject to winterkill and consequently cannot sustain natural or introduced fish populations.

The Yoho Lakes on the whole, tend to resemble small arctic "thaw lakes" of northern Alaska in terms of mean temperatures and annual productivity of phytoplankton and benthic communities (Livingstone, et al. 1958). The biological communities of arctic and alpine or subalpine lakes are relatively simple. In a temperate lake you may find several dozen species of fish; in lakes of higher latitude (or altitude) there may be only one. A similar situation exists for benthic, phytoplankton; and zooplankton communities. Generally there are one or two dominant species in each community. It is generally believed that these simple systems are somehow "more fragile" than more complex communities. Perhaps this belief derives from the theory that diversity confers stability on ecosystems (Rigler 1974). Rigler et al. (1974) have pointed out there is no sign of gross instability-as indicated by violent fluctuations of population size from year to year-that might be expected in simplified ecosystems. Serious changes in stability of the simple natural ecosystems, as a result of unnatural nutrient enrichment, can and

do occur (Schindler et al. 1974). The essence of the eutrophication problem is to determine the effect of added amounts of nutrients on standing crops and the general ecology of receiving lakes. Experiments designed to quantify these effects are underway (Schindler and Fee 1974) although at present an index or formula useful in describing the "fragility" or "carrying capacity" of natural waters is unavailable.

Assuming that fragility is related to diversity and diversity is related to productivity, the lakes and ponds in the Park may be classified as to their relative ability to withstand unnatural nutrient enrichment. In general, the levels of phytoplankton numbers and biomass shown in Figure 46 (page J-5) probably reflect the relative "fragility" of the Park's lakes and ponds. The more oligotrophic lakes and ponds would probably undergo greater change as a result of unnatural enrichment than the more eutrophic ones. Again, it is important to stress that all of the lakes and ponds in the Park are of a relatively unproductive nature and would suffer from unnatural nutrification.

Productivity of Park waters relative to fish production.

Lakes. Calculation of theoretical fish production on the basis of information on benthic and phytoplankton communities may be done in a manner similar to that considered in the discussion of zooplankton. Many of the same limitations which must be taken into consideration when predicting potential fish production from zooplankton biomass also apply in similar estimates from phytoplankton and benthic invertebrate biomass (see pages

F-34 to F-37). With these restrictions in mind, the potential fish production which might result from utilization of the phytoplankton primary production and benthic invertebrate production was calculated and is presented in Table 64. In reviewing the fish biomass which may potentially exist in lakes in the Park one must keep in mind the values presented are maximum theoretical values and in most cases a much lower fish biomass might reasonably be expected. Examination of the data in Table 64 indicates some lakes in the Park would produce very little (less than $10 \text{ kg ha}^{-1} \text{ yr}^{-1}$) in the way of fish biomass. These lakes which are lowest in potential fish production are as follows:

Ottertail
McArthur
Middle Opabin (14)
Upper Opabin (15)
Lower Opabin (15A)
Oesa
Lower Morning Glory
Linda
Sherbrooke

With regard to potential fish production all of these lakes appear to offer very little. Furthermore, relatively intense stocking of fish over long periods could result in decimation or elimination of populations of potential food organisms because of (a) slow growth rates and regeneration times and (b) absence of cover or refuge from predators.

The next most productive group of lakes ($10\text{--}20 \text{ kg ha}^{-1} \text{ yr}^{-1}$) includes:

O'Hara
Mary
Opabin (13)
Ross
North Narao
Wapta
Duchesnay

Table 64. Potential fish production in lakes of Yoho National Park. Productivity is based on calculation of theoretical yield from benthic, phytoplankton, and zooplankton sources.

Source of production	6	8	9	10	13	Lakes 14	15	16	17	18	19	20	22	23	24	26	42	47	48	49
Benthos																				
Mean weight of benthic samples $\bar{x}$ m ⁻²	4.3	3.6	10.7	2.1	12.9	1.7	0.2	7.7	6.4	56.3	44.0	21.5	2.5	3.2	0.2	21.5	6.6	11.6	16.9	42.1
Calc. available benthic ¹ . prod. kg ha ⁻¹ yr ⁻¹	43.0	17.5	53.7	10.7	129.0	8.5	1.0	77.4	64.5	563.0	220.0	215.0	12.5	16.0	2.1	107.5	32.5	57.5	83.7	210.0
Equiv. fish prod. ² . kg ha ⁻¹ yr ⁻¹	3.4	1.4	4.2	0.8	10.3	0.6	0.8	6.1	5.1	45.0	17.6	17.2	1.0	1.2	0.1	8.5	2.6	4.6	6.6	16.8
Phytoplankton																				
Primary prod. ³ . mg C m ⁻² day ⁻¹	(59.0)	(0.6)	10.0	21.1	(56.0)	(5.1)	0.06	3.1	9.0	94.0	14.7	12.7	(11.4)	(7.3)	(7.7)	8.2 (208.0)	10.4	10.7	26.9	
Calc. annual prod. kg ha ⁻¹ yr ⁻¹	944.0	18.2	2357.9	519.0	688.8	62.7	26.9	517.8	881.7	4314.6	156.0	816.7	210.3	179.0	378.8	2153.6	2218.5	612.0	246.3	406.9
Calc. primary consumer ⁴ . prod. kg ha ⁻¹ yr ⁻¹	75.5	1.4	188.6	41.5	55.1	5.0	2.1	41.4	70.5	345.1	12.4	65.3	16.8	14.3	30.2	172.2	177.4	48.9	19.6	32.4
Equiv. fish prod. ⁵ . kg ha ⁻¹ yr ⁻¹	6.0	0.1	15.0	3.3	4.4	0.4	0.17	3.3	5.6	27.6	0.9	5.2	1.3	1.1	2.4	13.7	14.1	3.9	1.5	2.5
Zooplankton																				
Equiv. fish prod. (Table 54) ⁶ . kg ha ⁻¹ yr ⁻¹	0.1	7.2	18.1	25.5	1.4	0.5	1.9	3.9	11.5	11.2	0.2	0.0	-	0.1	0.1	9.6	10.6	0.7	46.9	7.9
Mean equiv. fish prod. from primary consumer & zoopl. sources kg ha ⁻¹ yr ⁻¹	3.8	3.6	15.4	14.4	2.6	0.4	1.0	3.6	8.5	19.2	0.5	0.0	0.6	0.7	1.2	11.6	12.3	2.2	24.0	5.2
All sources																				
Total calc. fish prod. kg ha ⁻¹ yr ⁻¹	7.2	5.0	19.2	15.2	12.6	1.0	1.1	9.7	13.6	64.2	18.0	17.1	0.07	1.7	0.2	20.1	14.9	6.8	30.0	22.0
Total calc. fish prod. kg per lake	13.6	107.0	144.4	5.5	3.0	1.1	0.2	57.2	30.6	31.5	52.8	414.5	1.0	2.0	0.4	986.0	9.1	161.0	33.0	33.6
Equiv. number of 225g (1/2 pound) fish per lake	129	1722	3002	441	17	8	15	696	363	200	242	1840	7	13	23	10391	232	1070	680	195

1. Assumes P/B ratio approx. equal to 2.0 for lakes high in chironomid numbers and equal to 1.5 for other.
2. Assumes total production is available to fish with 8% trophic efficiency.
3. () indicate estimates based on biomass and estimated activity.
4. Assumes total production is available to primary consumer with 8% trophic efficiency.
5. Assumes total primary consumer biomass is converted to fish biomass with 8% trophic efficiency.
6. See Table 54 for calculations.

Opabin (13) has only a small surface area which would allow only a total of 3.8 kg fish production in the entire lake. This amounts to less than 17 fish at 225g ($\frac{1}{2}$ pound) each. Ross Lake (at $13.6 \text{ kg ha}^{-1} \text{ yr}^{-1}$) is one of the least productive lakes in this group and its total potential production of 81.8 kg must be considered marginal. Lake O'Hara is the only lake in this group with a naturally reproducing fish population (cutthroat trout) and is the only one likely to maintain a stable population over long periods of time. The alternative value of lakes in this second group as examples of unproductive natural communities must be weighed carefully against rather marginal short-term benefits associated with sport-fish utilization.

The last group included those lakes with a potential fish production in excess of $20 \text{ kg ha}^{-1} \text{ yr}^{-1}$. These are:

South Narao
Emerald
Sink
Summit

On a per unit of surface area basis Emerald is the least productive of the group, although its total surface area results in a relatively large potential production for the whole lake (Table 64). Although the four lakes listed above have the highest potential fish production in the Park their productivity is low when compared to some other North American lakes. Chapman (1967) lists several Canadian lakes where actual salmonid production ranges from $50\text{-}100 \text{ kg ha}^{-1} \text{ yr}^{-1}$.

It is of interest to compare the theoretical potential fish production with data from recent stocking records as shown below:

Lake	Mean No. of fish introduced per year stocked (1964-1973)	No. of years stocked (1964-1973)	Calc. Max. No. 225g fish prod. per year
Ottertail	750	2	129*
McArthur	10000	2	1722*
Mary	2625	2	441*
South Narao	522	4	200
Wapta	4968	7	1840
Morning Glory (22)	3500	2	7*
Linda	2100	1	23*
Emerald	25811	9	10391
Duchesnay	4000	2	232*
Sink	1795	10	1070**
Summit	600	5	195
Ross	4500	4	363*

On this basis it is apparent that some of these lakes have been grossly overstocked (*) whereas only one has received fish at a rate compatible with calculated potential productivity (**), the remaining lakes have been slightly overstocked.

Streams. The potential fish biomass which could be supported by streams in Yoho National Park was calculated to give some indication of the relative productivity of Park waters. The availability of benthic invertebrates as food items has been shown to be dependent on the drift of these animals downstream (for review see Mundie 1974). The bulk of the aquatic organisms drift at night; therefore, many items may not be visible to fish (Tanaka 1970). On the basis of evidence that large quantities of drift leave rivers permanently, it is clear that much of the potential food is not eaten by fish in streams (Mundie 1974). In the calculations of potential fish biomass in streams, certain assumptions have been made: production; biomass ratios for benthic invertebrates are near 2.0; all production in excess of maintenance requirements is available for consumption by fish;

a 100g (less than 4 oz.) fish requires approximately 0.96g per day at 5°C for maintenance (see Feldmeth 1973). The calculated values shown in Table 65 are very likely in excess of the actual biomass which the streams can support. The relative productivity of each site can be determined from the mean biomass figures (m^{-2}) for the benthic fauna. The number of fish which any particular 100m section of stream may support is directly proportional to the width of the stream, all other factors being equal. It should be remembered that the calculated fish carrying capacity of streams is a maintenance value only and does not include any allowance for growth. On the basis of the age-length relationship of fish collected in certain streams (see section G) it is reasonable to assume that much of the food is utilized for maintenance only.

Summary of limnological studies (1973-74).

1. Extensive limnological investigations were conducted on 22 lakes in the Park and some data is provided on 20 other lakes in the Park.
2. Limnological investigations were conducted at 30 stream sites in the Park.
3. Field and laboratory investigations included: benthic samples, shoreline survey, shore trawl, phytoplankton, zooplankton, macrophytes, fish, fish parasites, sounding, primary production, water chemistry, water temperature, pH, conductivity, and light penetration.
4. Lakes, ponds, and streams in the Park were found to exhibit a wide diversity of morphological types.

Table 65. Calculated potential fish carrying capacity of streams in Yoho National Park. Calculations are based on benthic biomass, approximate stream width, and consumption of 0.96 g day⁻¹ wet weight of benthic invertebrates to maintain a 100 g fish at 5°C (see Feldmeth 1973). See text for discussion.

Stream site	Benthic biomass g m ⁻²	Approximate stream width m	No. of 100 g fish maintained per year in 100m stream section
102	3.88	13	14
104	1.03	25	7
106	1.73	100+	49
107	0.73	12	2
108	1.23	21	7
109	0.96	18	5
110	6.28	18	31
111	1.19	19	6
112	2.12	100+	60
113	1.06	2	1
114	0.50	20	3
115	6.20	10	18
116	3.63	6	6
117	5.50	6	9
118	7.09	100+	202
119	2.69	23	17
120	3.55	24	24
121	2.67	10	7
122	1.40	6	2
123	2.28	8	5
124	2.05	5	3
125	4.58	9	11
126	4.67	10	13
127	3.37	8	7
128	5.15	4	6
129	2.38	3	2
130	2.15	6	3
132	3.60	4	4
133	5.15	2	2
134	1.79	1	1

5. Chemical limnology of Park waters is described and discussed.
6. The taxonomy, species composition, numbers, and distribution of benthic, shoreline, phytoplankton, and zooplankton communities are described and discussed. The biology of fish species collected in the Park is described.
7. Lakes and ponds in the Park are classified on the basis of thermal properties, trophic levels, phytoplankton communities, zooplankton communities, and potential fish production.
8. Whenever possible the information collected is compared with data from other mountain National Parks.
9. The biotic communities of the Park were generally found to be relatively sparse and the lakes oligotrophic, although a fairly wide range of habitat types was observed.
10. General levels of productivity were comparable to those characteristic of many arctic lakes. Slow growth rates and long generation times characterize such oligotrophic waters.
11. Among the various physical, chemical, and biological parameters for which quantitative data were gathered none proved to be a good consistent overall indicator of lake productivity. Although there were general relationships among biomass measurements at the different trophic levels in the lakes, the relationships were not entirely clear and there were a number of significant exceptions.
12. No single parameter emerged as the best all-round indicator of potential sport-fish production. There was good correlation between phytoplankton standing crop and primary production as determined by the ^{14}C technique, and one of these measurements could be omitted from future studies without seriously hampering

productivity estimates. Although phytoplankton identifications and counts are more time consuming than primary production measurements, data from phytoplankton are more useful as indicators of nutrient status, food available for zooplankton, and general community type.

13. Analysis of benthic mud samples for organic content provided little insight into lake biology, although often interesting from a speculative point of view.
14. The variability and lack of consistency among parameters that might have been useful as productivity indicators is due mainly to the wide range of altitudinal, morphometric, silt-loading, and water renewal-rate differences in the rather small number of lakes investigated.
15. The fish in Yoho National Park waters generally had very slow growth rates, much lower than many other mountain lake and stream studies indicate, and in many cases as low as the rates reported anywhere in the literature.
16. The prediction of a maximum sport-fish carrying capacity was possible, although the reliability of yield estimates through some form of morphoedaphic or other index depend on some actual fish-yield data. Such data are difficult to gather from small, unproductive lakes without decimating or even eradicating the fish populations.
17. Optimum sport-fish production estimates from a National Parks point of view are difficult to make; the estimated potentials made in this study attempted to show concern for the maintenance of natural communities.

18. Prerequisites for moderate to high sport fisheries production in lakes seem to include a well-developed littoral zone with macrophytes and a well-developed benthic community, usually associated with high shoreline development (i.e. high perimeter-to-area ratio), variable basin morphometry, moderately warm temperatures, and at least 6 months without ice-cover. Few lakes in Yoho National Park satisfy any of these requirements.

ANNOTATED BIBLIOGRAPHY

Anderson, R.S. 1968. A brief survey of some lakes in Yoho National Park. Canadian Wildlife Service, Manuscript Report, 45pp.

Morphometric data, water chemistry analysis, fish activity, stocking records, and results of observations on zooplankton communities are presented for ten lakes and ponds in Yoho National Park. A large variation in morphometry, water chemistry, and biotic communities was observed in the lakes and ponds studied. Suggestions are made relative to fish stocking in the various lakes and ponds included in the study.

Anderson, R. S. 1970. Limnological studies of high altitude lakes in Western Canada. VIII. A survey of some alpine and subalpine waters in Northern Yoho National Park. Canadian Wildlife Service, Manuscript Report, 25pp.

The classification of mountain lakes on the basis of elevation and terrestrial plant communities is presented and discussed. The author suggests six vegetational belts (alpine, treeline, subalpine, montane, colline, and planar) are useful in classification of lakes in Western Canada. The ten lakes examined in the study were in alpine, treeline, or subalpine zones. Morphometric data, water chemistry analysis, and results from plankton collections are presented in tabular form. The data collected indicates the lakes examined were low in productivity and supported rather simple biotic communities. The author suggests it is desirable to allow these lakes to remain in a pristine state.

Anderson, R. S. 1970. A report on the oil spill into the Kicking Horse River. Canadian Wildlife Service, Manuscript Report, 28pp.

This report provides an assessment of possible ecological damage caused by an oil spill from C. P. Rail waste ponds on August 21, 1970. Conditions contributing to the accident, as well as cleanup operations, are documented. Long-term ecological damage to the river was thought to be slight due to a number of fortunate circumstances. The author makes several recommendations for preventing or limiting damage in future accidents of this type. Recommendations include: assessment of potential problem areas, inventory of equipment and personnel needed to cope with such problems, designation of a "pollution control officer", establishment of contingency plans, and a policy on dissemination of official statements for public information in the event of such accidents.

Anderson, R. S., and D. K. Krochak. 1972. Report on a preliminary survey of the distribution and abundance of coliform bacteria in natural waters of the Western Canadian National Parks. Canadian Wildlife Service, Manuscript Reports, 60pp.

Emerald Lake was the only lake in Yoho National Park examined during this study. "Laboratory results indicated water was of doubtful quality, but no faecal coliforms were detected on the three sampling dates.

Robinson, D. J. 1972. A survey of water quality and stream invertebrate communities in the vicinity of Lake Louise and Lake O'Hara during the summer of 1971. Canadian Wildlife Service, Manuscript Report, 52pp.

Difficulties in assessing the effects of enrichment on highly oxygenated mountain streams are discussed. The author suggests water chemistry data in combination with species diversity and other biological parameters may be useful in assessing ecological damage. Data on the invertebrate communities and water quality collected from six stream sites near Lake O'Hara is presented in figures and tables. Nutrient levels in the Lake O'Hara area were generally lower than in Louise Creek (BNP), although some enrichment was indicated. The author suggests prevention of further enrichment may be possible if the Summary of Sanitary Survey (Wishart 1970) recommendations are followed.

Schultz, F. H. 1953. A limnological study of lakes and streams in Yoho National Park. Canadian Wildlife Service, Manuscript Report, 80PP.

A general limnological survey of 17 lakes and 6 rivers was carried out from July 17 to September 10, 1953. General descriptions and some morphometric data are presented. Observations on success of previous fish stocking programs as well as recommendations for future stocking are included.

Ward, J. C. 1974. The fishes and their distribution in the mountain National Parks of Canada. Canadian Wildlife Service, Manuscript Report,

Using a series of maps and tables this report documents the early history of fisheries in the mountain National Parks. A master map of water bodies in Yoho National Park is presented along with fish distribution maps.

Ward, J. C. 1972. Two decades of fisheries management in the mountain National Parks. Canadian Wildlife Service, Manuscript Report. 216pp.

A general review of stocking history and philosophy are presented. Park waters have been grouped according to stocking requirements. The following groups are used: (A) lakes where reproduction is not adequate and therefore require intermittent stocking, (B) lakes requiring some stocking every year or two, (C) lakes requiring annual stocking, and (D) lakes which require further investigation for proper fish management. Some lakes in Yoho were included in each group.

Wishart, S. 1970. Summary of sanitary survey of waste disposal facilities and receiving waters, Yoho National Park. Public Health Engineering Division, Vancouver, B. C.

A sanitary and bacteriological survey was carried out from August 19 to August 25, 1970, in the vicinity of Emerald and O'Hara lakes, and the Kicking Horse River. Results indicated sewage disposal methods in use were not satisfactory, producing aesthetically displeasing situations and a health hazard to park visitors. Detailed recommendations were made for substantial changes in the sewage disposal methods in the areas studied in order to allow effluents to meet the minimum requirements of the water pollution control and abatement program for federal facilities.

LITERATURE CITED

- Alimov, A.F., and G.G. Winberg. 1972. Biological productivity of two northern lakes. *Int. Ver. Theor. Angew. Limnol. Verh.* 18: 65-70.
- American Fisheries Society. 1960. A list of common and scientific names of fishes from the United States and Canada. *Amer. Fish. Soc. Spec. Pub.* 2: 1-102.
- Anderson, R.S. 1968a. The limnology of Snowflake Lake and other high altitude lakes in Banff National Park, Alberta. Ph.D. Thesis, Dept. Biology, Univ. of Calgary. 218 pp.
- Anderson, R.S. 1968b. Limnological studies of high altitude lakes in Western Canada. I. A brief survey of some lakes in Yoho National Park. Canadian Wildlife Service, Manuscript Reports. 45 pp.
- Anderson, R.S. MS 1969a. Limnological studies of high altitude lakes in the National Parks of Western Canada. IV. Aspects of the physical and chemical limnology of a large number of lakes in Banff National Park. *Limnol. Sect., Can. Wildlife Service, Ms Reports*, 82 pp.
- Anderson, R.S. MS 1969b. Limnological studies of high altitude lakes in the National Parks of Western Canada. VI. Aspects of the basic limnology of several alpine and subalpine lakes, Jasper National Park, Alberta. *Limnol. Section, Canadian Wildlife Service, Ms Reports*, 61 pp.
- Anderson, R.S. MS 1970a. Limnological studies of high altitude lakes in the National Parks of Western Canada. VIII. A survey of some alpine and subalpine waters in northern Yoho National Park. Canadian Wildlife Service, Manuscript Reports. 25 pp.

- Anderson, R.S. 1970b. A report on the oil spill into the Kicking Horse River, Yoho National Park, August 21, 1970. Limmology Section, Canadian Wildlife Service, Manuscript Reports. 28 pp.
- Anderson, R.S. MS 1970c. Observations on the 1970 collections of Mysis relicta Loven in Waterton Lakes National Park, and some related limnological data. Canadian Wildlife Service, Limmology Section, Manuscript Report. 14 pp.
- Anderson, R.S. 1970d. Diaptomus (Leptodiaptomus) connexus Light 1938 in Alberta and Saskatchewan. Can. J. Zool. 48: 41-47.
- Anderson, R.S. 1970e. Effects of rotenone on zooplankton communities and a study of their recovery patterns in two mountain lakes in Alberta. J. Fish. Res. Bd. Canada 27: 1335-1356.
- Anderson, R.S. 1970f. Predator-prey relationships and predation rates for crustacean zooplankters from some lakes in Western Canada. Can. J. Zool. 48: 1229-1240.
- Anderson, R.S. 1970g. The physical and chemical limnology of two mountain lakes in Banff National Parks, Alberta. J. Fish. Res. Bd. Canada 27(2): 233-249.
- Anderson, R.S. 1971a. Crustacean plankton of 146 alpine and subalpine lakes and ponds in Western Canada. J. Fish. Res. Bd. Canada 28(3): 311-321.
- Anderson, R.S. 1971b. A nomen novum to replace the junior homonym, Diaptomus (Leptodiaptomus) intermedius, Anderson and Fabris 1970. Can. J. Zool. 49: 133.
- Anderson, R.S. 1972. Zooplankton composition and change in an alpine lake. Verh. internat. Verein. Limnol. 18: 264-268.

- Anderson, R.S. 1974a. Crustacean plankton communities of 340 lakes and ponds in and near the National Parks of the Canadian Rocky Mountains. J. Fish. Res. Board Can. 31: 855-869.
- Anderson, R.S. 1974b. Diurnal primary production patterns in seven lakes and ponds in Alberta (Canada). Oecologia (Berl.) 14: 1-17.
- Anderson, R.S. 1974c. An assessment of sport-fish production potential in two small alpine waters in Alberta, Canada. Annals, Hungarian Academy of Science (in press).
- Anderson, R.S., D.B. Donald, and D.K. Krochak. 1972. A limnological survey of the aquatic habitats of Waterton Lakes National Park. Can. Wildlife Service, Limnol. Sec., Ms report. 234 pp.
- Anderson, R.S., and D.K. Krochak. 1972. Report on a preliminary survey of the distribution and abundance of coliform bacteria in natural waters of some of the Western Canadian National Parks. Canadian Wildlife Service, Ms reports. 60 pp.
- Anderson, R.S., and L.G. Raasveldt. 1974. Gammarus predation and the possible effects of Gammarus and Chaoborus feeding on the zooplankton composition in some small lakes and ponds in Western Canada. Canadian Wildlife Service, Occasional Paper 18: 1-23.
- Armstrong, F.A.J. and D.W. Schindler. 1971. Preliminary chemical characterization of waters in the Experimental Lakes Area, Northwestern Ontario. J. Fish. Res. Bd. Can. 28(2): 171-187.
- Baird, D.M. 1962. Yoho National Park, Geological Survey of Canada, Misc. Report 4, Ottawa.
- Ball, I.R., and C.H. Fernando. 1968. On the occurrence of Polycelis (Turbellaria, Tricladida) in Western Canada. Can. Field-Naturalist. 82: 213-216.

- Bangham, R.V. and J.R. Adams. 1954. A survey of the parasites of freshwater fishes from the mainland of British Columbia. J. Fish. Res. Bd. Can. 11: 673-708.
- Beavers, R.A., and R.H. Stavn. 1975. Seasonal changes in diaptomid copepod populations as a function of vertebrate predation. Verh. Internat. Verein. Limnol. 19: (in press).
- Berg, C.O. 1950. Biology of certain Chironomidae reared from Potamogeton. Ecol. Monogr. 20: 83-101.
- Bolen, H.M. 1938. Planarians of the Reelfoot Lake region. Jour. Tennessee Acad. Sci. 13.
- Branson, E.B., W.A. Tarr, and W.D. Keller. 1952. Introduction to Geology. McGraw-Hill Co. Toronto 492 pp.
- Brinkhurst, R.O. and B.G.M. Jamieson. 1971. Aquatic Oligochaeta of the world. Oliver and Boyd, Edinburgh. 860 pp.
- Brooks, A.R. and L.A. Kelton. 1967. Aquatic and semiaquatic heteroptera of Alberta, Saskatchewan, and Manitoba (Hemiptera). The Entomological Society of Canada. 92 pp.
- Brooks, J.L. 1968. The effects of prey size selection by lake planktivores. Syst. Zool. 17: 272-291.
- Brooks, J.L., and S.I. Dodson. 1965. Predation, body size, and composition of plankton. Science, 150(3692): 28-35.
- Brundin, L. 1966. Transantarctic relationships and their significances as evidenced by chironomial midges. K. svenska Vetensk. - Akad. Handl., 11: 1-472.
- Burgis, M.J. 1975. Biomass comparisons of cyclopoids in two Thames Valley reservoirs. Verh. Internat. Verein. Limnol. 19:(in press).

- Cannon, L.R.G. 1971. The life cycles of Bunodera sacculata and B. luciopercae (Trematoda:Allocreadiidae) in Algonquin Park, Ontario. Can. J. Zool. 49: 1417-1429.
- Carpenter, G.F., E.L. Mansey, and N.H.F. Watson. 1974. Abundance and life history of Mysis relicta in the St. Lawrence Great Lakes. J. Fish. Res. Bd. Can. 31: 319-325.
- Chapman, D.W. 1967. Production in fish populations in The biological basis of freshwater fish production. Ed. S.D. Gerking. Blackwell Sci. Pub., Oxford. 455 pp.
- Cheng, Lanna, and C.H. Fernando. 1970. The Water-Striders of Ontario (Heteroptera:Gerridae). Royal Ontario Museum Life Sciences Miscellaneous Publications 1-23.
- Choquette, L.P.E. 1954. A note on the intermediate hosts of the trematode, Crepidostomum cooperi Hopkins, 1931, parasitic in speckled trout [Salvelinus fontinalis (Mitchill)] in some lakes and rivers of the Quebec Laurentide Park. Can. J. Zool. 32: 375-377.
- Chuang, C.C. 1972. A preliminary checklist of flora of the Yoho National Park. Manuscript Report, Parks Canada. 32 pp.
- Clemens, W.A., J.T. Barnaby, and W.E. Ricker. 1938. Production of bodies of water. Prog. Fish Cult. 39: 36-43.
- Coffman, W.P. 1967. Community structure and trophic relations in a small woodland stream, Linesville Creek, Crawford County, Pennsylvania. Ph.D. Thesis. Univ. Pittsburgh, Pittsburgh, Pa.
- Colbeck, A.C. and E.K. Goble. 1967. Mysis collection, Waterton Lakes National Park. Unpublished report. National and Historic Parks Branch, Calgary.

- Conroy, J.C. 1968. The water-mites of Western Canada. National Museum of Canada. Bulletin 223. pp. 22-43.
- Cordone, A.J., S.J. Nicola, P.H. Baker, and R.C. Frantz. 1971. The Kokanee salmon in Lake Tahoe. Calif. Fish Game 57(1): 28-43.
- Cummins, K.W., and J.C. Wuycheck. 1971. Caloric equivalents for investigation in ecological energetics. Int. Ver. Theor. Angew. Limnol. Mitteil. 18: 1-158.
- Cuerrier, J.P. 1954. The history of Lake Minnewanka with reference to the reaction of lake trout to artificial changes in environment. Canadian Fish Culturist No. 15: 1-9.
- Cuerrier, J.-P., and F.H. Schultz. 1952. Growth study of the lake trout in Waterton Lakes, Waterton Lakes National Park, Alberta. Dept. Resources & Devel., Can. Wildlife Serv., Ms. Report, 7 pp.
- Davies, R.W. 1971. A key to the freshwater Hirudinoidea of Canada. J. Fish. Res. Bd. Canada 28: 543-552.
- Davies, R.W. 1973. The geographic distribution of freshwater Hirudinoidea in Canada. Can. J. Zool. 51: 531-545.
- Day, W.C., 1963. Ephemeroptera. In Usinger, R.L. (ed.), Aquatic insects of California. Univ. of Calif. Press. Berkeley.
- Dechtiar, A.O. 1972. Systematic status of tetraonchus loftusi n. sp. (Monogenoidea: Tetraonchidae) and comparative studies of T. monenteron (Wagener, 1857) Diesing, 1858, and T. variabilis Mizelle and Webb, 1953. Can. J. Zool. 50: 1489-1495.
- Dodson, S.I. 1970. Complementary feeding niches sustained by size-selective predation. Limnol. Oceanogr. 15: 131-137.
- Dodson, S.I. 1974. Zooplankton competition and predation: an experimental test of the size-efficiency hypothesis. Ecology 55: 605-613.

- Drake, C.J. and Harris, H.M. 1934. The Gerrinae of the Western Hemisphere (Hemiptera). Ann. Carneg. Mus. 23: 179-240.
- Dumont, H.J., I. Van de Velde, and S. Dumont. 1975. The dry weight estimate of biomass in a selection of Cladocera, Copepoda, and Rotifera from the plankton, periphyton and benthos of continental waters. Manuscript submitted for publication.
- Edmondson, W.T. ed. 1959. Ward and Whipple's Freshwater Biology, 2nd Edition, John Wiley and Sons, Inc. 1248 pp.
- Freeman, R.S. 1964. Flatworm problems in fish. Can. Fish. Cult. 32: 11-18.
- Feldmeth, C.R. 1973. An estimate of energy expenditure by rainbow trout (Salmo gairdneri) in a small mountain stream. J. Fish. Res. Bd. Can. 30: 1755-1759.
- Galbraith, M.G. Jr. 1967. Size-selective predation on Daphnia by rainbow trout and yellow perch. Trans. Amer. Fish. Soc. 96: 1-10.
- Galbraith, M.G., Jr. 1975. The use of large Daphnia as indices of fishing quality for rainbow trout in small lakes. Verh. internat. Verein. Limnol. 19: (in press).
- Gibbons, D.R., and E.O. Salo. 1973. An annotated bibliography of the effects of logging on fish of the western United States and Canada. USDA Forest Service General Tech. Report PNW-10, 145 pp.
- Hairston, N. 1959. Species abundance and community organization. Ecology 40: 404-416.
- Hamilton, A.L., A.O. Saether, and D.R. Oliver. 1969. A classification of the nearctic Chironomidae. Fish. Res. Bd. Can. Tech. Report No. 124: 1-42.

- Hanson, J. 1965. Mysis-shrimp cocktails for Lake Tahoe. Outdoor California. 26(1): 14-15.
- Hartland-Rowe, R. 1965. The Anostraca and Notostraca of Canada with some new distributional records. The Canadian Field-Naturalist 79: 185-189.
- Henderson, H.F., R.A. Ryder, and A.W. Kudhongania. 1973. Assessing fishery potentials of lakes and reservoirs. J. Fish. Res. Bd. Canada. 30(12): 2000-2009.
- Herzig, A. 1974. Some population characteristics of planktonic Crustacea in Neusiedler See. Oecologia 15: 127-141.
- Hilliard, D.K. 1971. Notes on the occurrence and taxonomy of some planktonic chrysophytes in an Alaskan lake, with comments on the Genus Bicocca. Arch. Protistenk. Bd. 113: 92-122.
- Hutchinson, G.E. 1957. A treatise on limnology, vol. I. John Wiley and Sons, Inc., New York. 1015 pp.
- Hutchinson, G.E. 1967. A treatise on limnology, vol. II. John Wiley and Sons, Inc., New York. 115 pp.
- Hyman, L.H. 1951. The invertebrates. Vol. 2. McGraw-Hill, New York.
- Jewett, S.G., Jr. 1959. The stoneflies (Plecoptera) of the Pacific Northwest. Oregon State Monographs, Studies in Entomology, No. 3: 95 pp.
- Johannsen, O.A. 1935. Aquatic Diptera. Mem. Cornell Univ. Agri. Exp. Station. Reprinted 1969. Entomological Reprint Specialists, Los Angeles.
- Johnson, L., G.H. Lawler, and L.A. Sunde. 1970. Rainbow trout farming in central Canada. Fish. Res. Bd. Canada Tech. Report No. 165. 17 pp.

- Klekowski, R.Z., and A.E. Shushkina. 1966. Feeding, respiration, growth, and energy transformation in Macrocyclus albidus. (Trans. title). Verh. Internat. verein. Limnol. 16: 399-418.
- Knight, A.W. and A.R. Gaufin. 1966. Altitudinal distribution of stoneflies (Plecoptera) in a Rocky Mountain drainage system. J. Kansas Entom. Soc. 39: 668-675.
- Larkin, P.A. 1948. Pontoporeia and Mysis in Athabasca, Great Bear, and Great Slave lakes. Fish. Res. Bd. Can. Bull. 78:33 pp.
- Lasenby, D.C., and R.R. Langford. 1972. Growth, life history, and respiration of Mysis relicta in an arctic and temperate lake. J. Fish. Res. Bd. Can. 29: 1701-1708.
- Lasenby, D.C., and R.R. Langford. 1973. Feeding and assimilation of Mysis relicta. Limnol. Oceanogr. 18(2): 280-285.
- Lawler, G.H., L.A. Sunde, and J. Whitaker. 1974. Trout production in prairie ponds. J. Fish. Res. Board Can. 31: 929-936.
- Lindsey, C.C., and W.G. Franzin. 1972. New complexities of zoogeography and taxonomy of the pygmy whitefish (Prosopium coulteri). J. Fish. Res. Bd. Can. 29(12): 1772-1775.
- Livingstone, D.A., K. Bryan, and R.G. Leaky. 1958. Effects of an arctic environment on the origin and development of freshwater lakes. Limnol. Oceanogr. 3: 192-214.
- Macan, T.T. 1963. Freshwater ecology. Camelot Press, London. 338 pp.
- Margolis, L. 1967. Blood feeding in Salvelinema walkeri (Nematoda: Cystidicolinae), a parasite of coho salmon (Oncorhynchus kisutch). Can. J. Zool. 45: 1295-1297.
- Mason, W.T. 1973. An introduction to the identification of chironomid larvae. U.S. Environmental Protection Agency, Cincinnati.

- Mayhood, D.W., and R.E. Smith. 1972. Final report on the Bow and Pipestone Rivers near Lake Louise, Banff National Park, Alberta. (Winter 1971-1972). Can. Wildlife Service Ms. Reports. 44 pp.
- McCart, P. and M. Jones. 1974. Red Deer River flow regulation proposal fisheries study. Aquatic Environments Ltd. 171 pp.
- McLeod, C.L. 1971. Food and feeding habits of the cisco, Coregonus (Leucichthyes) artedii, in Waskesiu Lake, Prince Albert National Park, Saskatchewan. M.Sc. Thesis, University of Calgary.
- Meyer, M.C., and R. Vik. 1963. The life cycle of Diphyllbothrium sebago (Ward, 1910). J. Parasit. 49: 962-968.
- Moravec, F., and H.P. Arai. 1971. The North and Central American species of Phabdochona Railliet 1916 (Nematoda:Rhabdochonidae) of fishes, including Rhabdochona canadensis sp. nov. J. Fish. Res. Bd. Can., 28: 1645-1662.
- Morry, C.J. 1973. A survey of the limnetic zooplankton of Gatineau Park, Quebec. M.Sc. Thesis, Dept. Biology, Carleton University. 123 pp.
- Mudry, D.R., and R.S. Anderson. 1973. Coliform bacteria in the natural waters of Yoho National Park - preliminary investigations. Canadian Wildlife Service, Manuscript Reports. 26 pp.
- Mundie, J.H. 1974. Optimigration of the salmonid nursery stream. J. Fish. Res. Bd. Can. 31: 1827-1837.
- Nauwerck, A. 1963. Die Beziehungen zwischen Zooplankton und Phytoplankton im See Erken. Symb. Bot. Upsal. 17: 1-163.
- Needham, J.G., Traver, J.R., and Hsu, Y.-C. 1935. The Biology of Mayflies. Comstock Publishing Company, Inc., Ithaca, New York. 759 pp.

- Northcote, T.G. 1972. Some effects of mysid introduction and nutrient enrichment on a large oligotrophic lake and its salmonids. Verh. Int. Ver. Limnologie. 18: 1096-1106.
- Northcote, T.G., and R. Clarotto. 1975. Limnetic macrozooplankton and fish predation in some coastal British Columbia lakes. Verh. internat. Verein. Limmol. 19: (in press).
- Oliver, D.R. 1971. Life history of the Chironomidae. Ann. Rev. Ento. 16: 211-230.
- Paterson, R.J. 1968. The lake trout, Salvelinus namaycush of Swan Lake, Alberta. Alberta Fish and Wildlife Division, Fish. Section Research Report No. 2. 149 pp.
- Pennak, R.W. 1953. Freshwater invertebrates of the United States. Ronald Press Co. 769 pp.
- Pennak, R.W. 1955. Persistent changes in the dominant species composition of limnetic Entomostracan populations in a Colorado mountain lake. Trans. Amer. Microsc. Soc. 74: 116-118.
- Rabe, F.W. 1970. Brook trout populations in Colorado beaver ponds. Hydrobiologia. 35(3-4): 431-448.
- Rawson, D.S. 1939. A biological survey and recommendations for fisheries management in waters of the Banff National Park. Dept. Mines and Resources (Canada). Unpubl. Report, Natl. Parks Bur., 128 pp.
- Rawson, D.S. 1940. Biological survey and fisheries management in Jasper National Park. Dept. Mines and Resources (Canada), Unpubl. Report, Natl. Parks Bureau, 98 pp.
- Rawson, D.S. 1961. The lake trout of Lac la Ronge, Saskatchewan. J. Fish. Res. Board Can. 18: 423-462.

- Rawson, D.S., and C.A. Elsey. 1950. Reduction in the longnose sucker population of Pyramid Lake, Alberta, in an attempt to improve angling. Am. Fisheries Society 78(1948): 13-31.
- Reid, G.K. 1961. Ecology of inland waters and estuaries. Reinhold Publishing Corp., New York. 375 pp.
- Reynolds, J.B., and G.M. DeGraeve. 1972. Seasonal population characteristics of the opossum shrimp, Mysis relicta, in southeastern Lake Michigan, 1970-71. Proc. 15th Conf. Great Lakes Res. 117-131 pp.
- Reynoldson, T.B. 1974. An investigation into some aspects of the biology of the Hirudinoidea. M.Sc. Thesis, University of Calgary.
- Richards, R.C., C.R. Goldman, T. Frantz, and R. Wickwire, 1974. Where have all the Daphnia gone? - Decline of a major cladoceran in Lake Tahoe, California. Int. Assoc. Limnol. XIX Congress. Abstract p. 171.
- Ricker, W.E. 1943. Stoneflies of Southwestern British Columbia. Indiana University Publications, Science Series. pp. 1-145.
- Rigler, F.H. 1974. Char Lake project PF-2. Final Report 1974. Canadian Comm. for the Int. Biol. Programme. 96 pp.
- Rigler, F.H., M.E. MacCallum, and J.C. Roff. 1974. Production of zooplankton in Char Lake. J. Fish. Res. Bd. Can. 31: 637-646.
- Roback, S.S. 1971. The subfamily Tanypodinae in North America. Monographs of the Acad. Nat. Sci. Phila. No. 17: 1-410.
- Robinson, D.J. 1972. A survey of water quality and stream invertebrate communities in the vicinity of Lake Louise and Lake O'Hara during the summer of 1971. Can. Wildlife Service Ms Report. 52 pp.

- Robinson, D.J., and R.E. Smith. 1974. Limnological study of the Bow River - Pipestone River watershed in the vicinity of Lake Louise, Banff National Park, June 1972 to July 1973. Limnos. Associates (Calgary), Canadian Wildlife Service Manuscript Report, 153 pp.
- Russell-Hunter, W.D. 1970. Aquatic productivity. Macmillan Co., London. 306 pp.
- Sayer, R.C. and W.H. Stout. 1965. Opossum shrimp collection No. 16. Habitat Improvement Project. Oregon State Game Comm. 15 pp. (Mimeo.).
- Schindler, D.W. 1970. Production of phytoplankton and zooplankton in Canadian Shield lakes. Productivity of Freshwaters, IBP-UNESCO Symp. Product. Probs. Freshwat., Poland, 1970: 311-331.
- Schindler, D.W. 1971. Light, temperature, and oxygen regimes of selected lakes in the Experimental Lakes Area, northwestern Ontario. J. Fish. Res. Bd. Can. 28: 157-169.
- Schindler, D.W., and E.J. Fee. 1974. Experimental Lakes Area: whole-lake experiments in eutrophication. J. Fish. Res. Bd. Can. 31: 937-953.
- Schindler, D.W., J. Kalff, H.E. Welch, G.J. Brunskill, H. Kling, and N. Kritsch. 1974. Eutrophication in the high arctic - Merretta Lake, Cornwallis Island (75°N lat.). J. Fish. Res. Bd. Can. 31: 647-662.
- Schultz, F.H. 1953. A limnological study of lakes and streams in Yoho National Park. Canadian Wildlife Service, Unpublished Report, Natl. Parks. Bur., 80 pp.

- Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184, Fisheries Research Board of Canada, Ottawa.
- Smiley, B.D. 1974. Report on fisheries investigations in the Ptarmigan-Baker Lake complex, Banff National Park. Can. Wild. Service, Manuscript Report (preliminary draft).
- Smith, G.M. 1950. The fresh-water algae of the United States. McGraw-Hill Co. Toronto.
- Smith, N.D. 1972. Sedimentation and bar formation in the upper Kicking Horse River, a braided meltwater stream. National and Historic Parks Branch, Manuscript Report.
- Solman, V.E.F. 1947. Limnological investigations, Yoho National Park, 1947. Canadian Wildlife Service, unpublished report.
- Sparrow, R.W., P.A. Larkin, and R.A. Rutherglen. 1964. Successful introduction of Mysis relicta into Kootenay Lake, British Columbia. J. Fish. Res. Bd. Can. 21: 1325-1327.
- Steemann-Nielsen, E. 1952. The use of radioactive carbon (C^{14}) for measuring organic production in the sea. Jour. du Conseil. 18: 177.
- Tanaka, H. 1970. On the nocturnal feeding activity of rainbow trout (Salmo gairdnerii) in streams. Bull. Freshwater Fish. Res. Lab. 20: 73-82.
- Thomas, J.F.J. 1953. Industrial water resources of Canada, Water Survey Report No. 1: Scope, procedure and interpretation of survey studies. Canada, Dept. Mines and Tech. Surveys, Pub. No. 833. 69 pp.
- Threinen, C.W. 1962. What's new in fish management? Wisconsin Conservat. Bull. 27: 14.

- Trojnar, J.R. and R.J. Behnke. 1974. Management implications of ecological segregation between two introduced populations of cutthroat trout in a small Colorado lake. Trans. Amer. Fish. Soc. 103(3): 423-430.
- Usinger, R.L. 1956. Aquatic Insects of California. University of California Press, Berkeley. 508 pp.
- Varley, J.D., A.F. Regenthal, and R.W. Wiley. 1971. Growth of rainbow trout in Flaming Gorge Reservoir during the first six years of impoundment. in Reservoir fisheries and limnology. G.E. Hall, ed. Amer. Fish. Soc. Special Pub. No. 8.
- Vollenweider, R.A. 1968. The scientific basis of lake and stream eutrophication, with particular reference to phosphorus and nitrogen as eutrophication factors. Tech. Rep. O.E.C.D. Paris DAS/CSI/68 27: 1-182.
- Ward, J.C. 1967. Progress report 0 Fishery Investigations - Mountain National Parks. 1966-67 Fiscal Year. Canadian Wildlife Service unpublished report. 22 pp.
- Ward, J.C. 1972. Two decades of fisheries management in the mountain National Parks. Canadian Wildlife Service Manuscript Report. 26 pp.
- Ward, J.C. 1974. The fishes and their distribution in the mountain National Parks of Canada. Manuscript Report, Canadian Wildlife Service. 216 pp.
- Water Survey of Canada. 1970. Historical streamflow summary, British Columbia (to 1970). Ottawa.
- Wilson, M.S. 1958. New records and species of calanoid copepods from Saskatchewan and Louisiana. Can. J. Zool. 36: 489-497.

- Winberg, G.G. 1971. Methods for the estimation of production of aquatic animals. (translated from Russian by A. Duncan). Academic Press, London. 175 pp.
- Wirth, W.W. and A. Stone. 1963. Aquatic Diptera. in Usinger, R.L. 1963. Aquatic insects of California. U. of Calif. Press, Berkeley.
- Wishart, S. 1970. Summary of sanitary survey of waste disposal facilities and receiving water, Yoho National Park. Public Health Engineering Division, Vancouver, B.C.
- Zyblut, E.R. 1970. Long-term changes in the limnology and macrozooplankton of a large British Columbia lake. J. Fish. Res. Bd. Canada 27: 1239-1250.

DATA

Introduction.

Volume III of this report contains a compilation of data collected in field and laboratory studies. The data are grouped by collection site number: lakes first, followed by streams. For each site the reader will find the data presented in the following order:

Map- a map for each lake site is presented and shows the location of benthic, shoreline, trawl, and fish collection sites. Depth contour lines are shown for lakes which have been sounded.

Locality information- data on the location of each site are presented along with basic morphometric information

Collections- a list of collections made at each site is given.

Temperature data- water temperature by depth (m) is presented for lakes.

Invertebrate samples- a list of species and numbers collected from benthic, shoreline, and trawl samples in lakes or kick samples in streams is presented (data on Crustacea and Rotifera is in section F of this report). The counts for invertebrates are reported as follows:

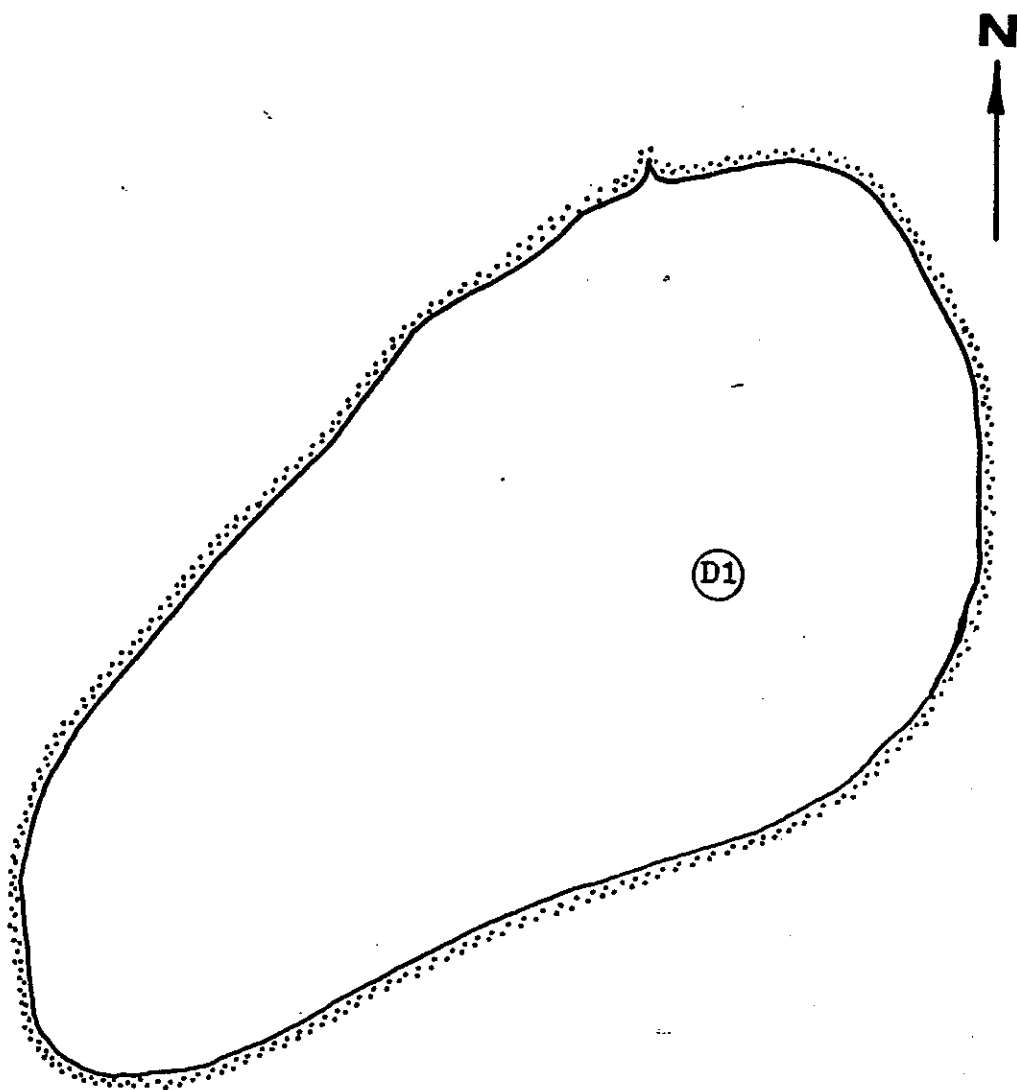
Dredge samples- total number collected from two drops of the dredge
Shoreline samples- total number collected in 30 minutes

Trawl sample- number collected in near-shore trawl,
Kick sample- number collected by kicking a 0.2 m^{-2}
section of substrate for 30 seconds.

Phytoplankton- a list of phytoplankton species and
numbers ml^{-1} is given.

Following the data for individual sites a list of fishes
collected and their length, weight and sex is presented
(page N-141).

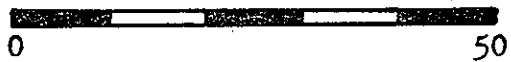
A species list of all phytoplankton, macrophytes, benthic
invertebrates (see section F for Crustacea and Rotifera), and
fish is presented beginning on page N-146.



OTTERTAIL FLATS LAKE

LAKE NO. 6

SCALE METRES



Ⓓ1 = COLLECTION SITE

Locality OTTERTAIL FLATS LAKE (Unofficial name)

Site number 6
 Grid reference 11U/NG289827
 Elevation (metres/feet) 1118/3668
 Altitudinal belt montane
 Maximum depth (m) 1.5
 Surface area (hectares) 4.0

Sampling date 6/VIII/74
 Collection number (999-) 153

Time 1400
 Air temperature (°C) 21.0
 Sky cloudy
 Snow cover (m) -
 Ice cover (m) -
 Secchi disk (m) 1.5+
 pH -
 Conductivity (@25°C) 282

Samples collected

Kick -
 Dredge X
 Phytoplankton X
 Macrophytes X
 Zooplankton X
 Shoreline -
 Shore trawl -
 Fish -
 Primary production -
 Water chemistry -
 Stream flow -

Water temperature m °C
 0 21.5
 1 21.5
 1.5 21.5

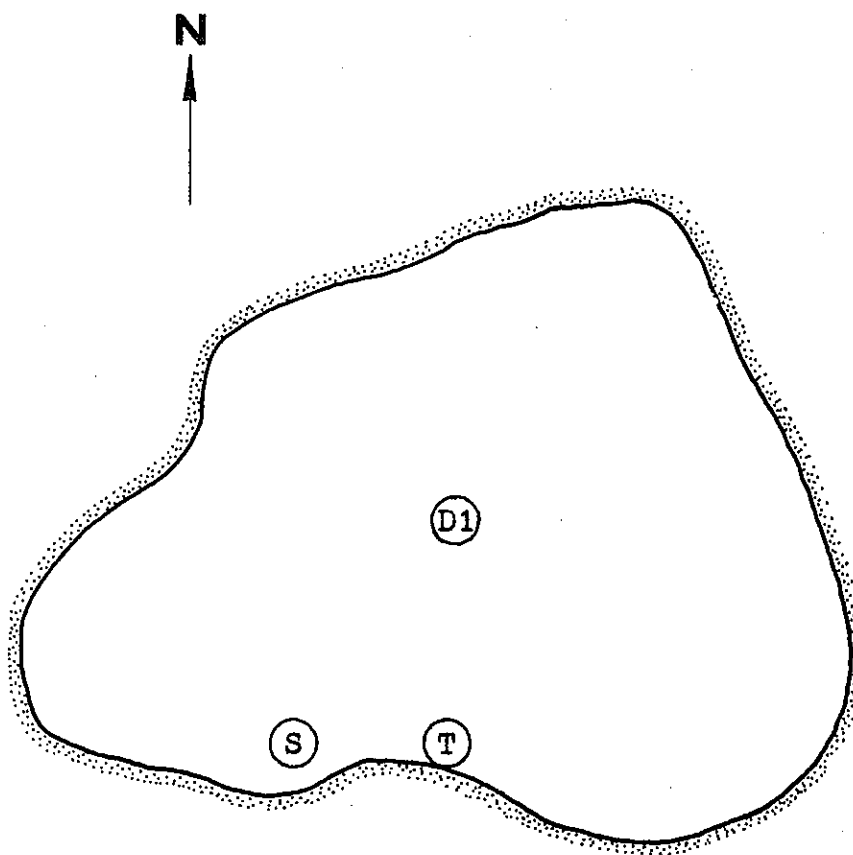
Ottertail Flats Lake (Site 6)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	153
Sample type	D1
Depth (m)	1.5
Total wet weight (g)	0.2
Oligochaeta	
Tubifex sp.	2
Hirundinea	
Helobdella stagnalis	2
Amphipoda	
Hyalolella azteca	2
Trichoptera	
Phryganea sp.	3
Diptera	
Chironomidae	
Procladius sp.	1
Tanytarsus sp.	1
Phaenopsectra sp.	6
Acarina	
Limnesia sp.	2
Total number of invertebrates	19

OTTERTAIL FLATS LAKE (No. 6)
Phytoplankton counts (cells/ml)

Species	Coll. No. (999) Depth (m)	153 0.5
Chlorophyta		
Cosmarium (near bioculatum)		3.1
Cosmarium (near sexnotatum)		3.1
Cosmarium tetragonum var. lundelli		3.1
Mougeotia sp.		15.5
Scenedesmus quadricauda		18.5
Cyanophyta		
Anabaena sp.		12.4
Chroococcus prescottii		37.2
Gomphosphaeria lacustris		124.0
Merismopedia elegans		99.2
Nostoc paludosum		124.0
Oscillatoria (near amphibia)		68.2
Oscillatoria sp.		99.2
Chrysophyta		
Achnanthes flexella		3.1
Achnanthes spp.		9.3
Amphipleura pellucida		3.1
Bitrichia chodatii		3.1
Chrysococcus sp.		24.8
Cyclotella sp.		9.3
Dinobryon sertularia		6.2
Dinobryon sociale var. americanum		6.2
Gomphonema acuminatum var. coronatum		3.1
Kephyrion spp.		21.7
Navicula radiosa		3.1
Navicula tripunctata		24.8
Navicula sp.		24.8
Neidium globiceps		3.1
Nitzschia thermalis		31.0
Nitzschia suecica		9.3
Pseudokephyrion hyalinum		9.3
Pseudokephyrion undulatissimum		3.1
Rhopalodia gibba		3.1
Stauroneis sp.		3.1
Synedra acus		3.1
Synedra radians		9.3
Synedra sp.		3.1
Tabellaria fenestrata		9.3
Total cells/ml		837.0



SCHAFER LAKE

LAKE NO. 7

SCALE METRES

0 50

(S) = COLLECTION SITE

Locality SCHAFER LAKE

Site number 7
 Grid reference 11U/NG454885
 Elevation (metres/feet) 2170/7125
 Altitudinal belt subalpine
 Maximum depth (m) 2.5
 Surface area (hectares) 0.4

Sampling date 23/VIII/73
 Collection number (999-) 129

Time 1430
 Air temperature (°C) 13.5
 Sky cloudy
 Snow cover (m) -
 Ice cover (m) -
 Secchi disk (m) 2.5+
 pH -
 Conductivity (@25°C) -

Samples collected

Kick -
 Dredge X
 Phytoplankton -
 Macrophytes -
 Zooplankton X
 Shoreline X
 Shore trawl X
 Fish -
 Primary production -
 Water chemistry -
 Stream flow -

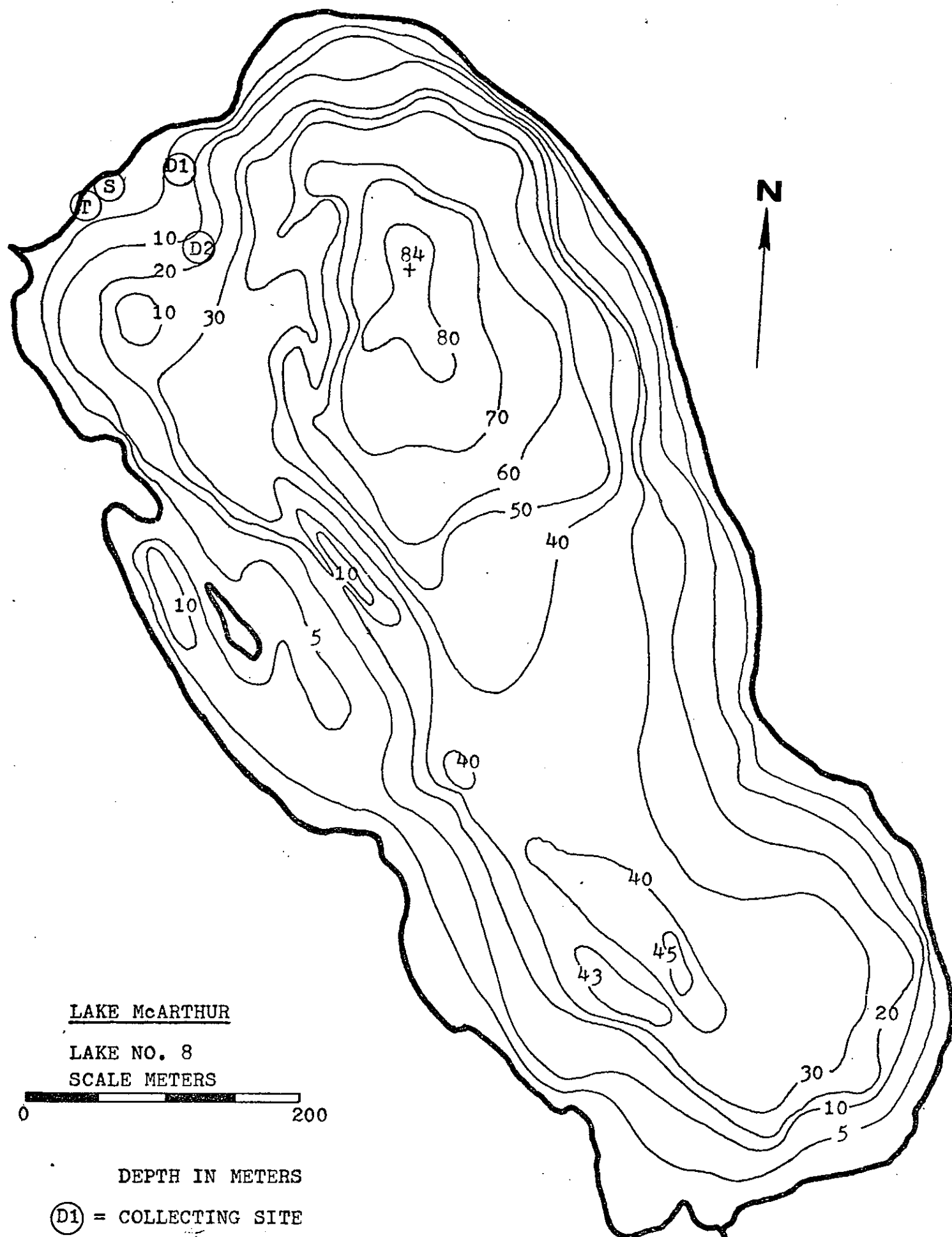
Water temperature

m °C
 0 8.6
 1 8.5
 2 8.2

Schaffer Lake (Site 7)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	129	129	129
Sample type	D1	S	T
Depth (m)	2	-	-
Total wet weight (g)	0.28	0.34	-
Oligochaeta			
Rhynchelmis sp.	2	-	3
Trichoptera			
Limnephilidae	-	2	-
Diptera			
Chironomidae			
Procladius sp.	17	1	11
Eukiefferiella sp.	17	-	-
Tanytarsus sp.	23	17	-
Coleoptera			
Agabus tristis	-	2	-
Hydroporus compertus	-	-	1
Misc. Insecta	1	2	-
Nematoda			
Unidentified	6	-	-
Total number of invertebrates	66	24	15



Locality

LAKE MCARTHUR

Site number 8
 Grid reference 11U/NG460870
 Elevation (metres/feet) 2240/7369
 Altitudinal belt alpine
 Maximum depth (m) 84.4
 Surface area (hectares) 77

Sampling date	23/VIII/73	7/VIII/74
Collection number (999-)	128	154
Time	1015	1400
Air temperature (°C)	11.5	-
Sky	cloudy	cloudy
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	6.1	12.5
pH	8.2	-
Conductivity (@25°C)	109	132
Samples collected		
Kick	-	-
Dredge	X	-
Phytoplankton	X	X
Macrophytes	-	-
Zooplankton	X	X
Shoreline	X	-
Shore trawl	X	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-
Water temperature	m °C	m °C
	0 8.5	0 4.2
	1 8.4	1 4.0
	2 8.4	2 4.0
	5 8.3	4 3.8
	10 5.4	6 3.6
	15 4.5	8 3.4
	20 4.4	10 3.4
	25 4.2	12 3.3
	30 4.2	14 3.3
		16 3.3
		18 3.3
		20 3.3

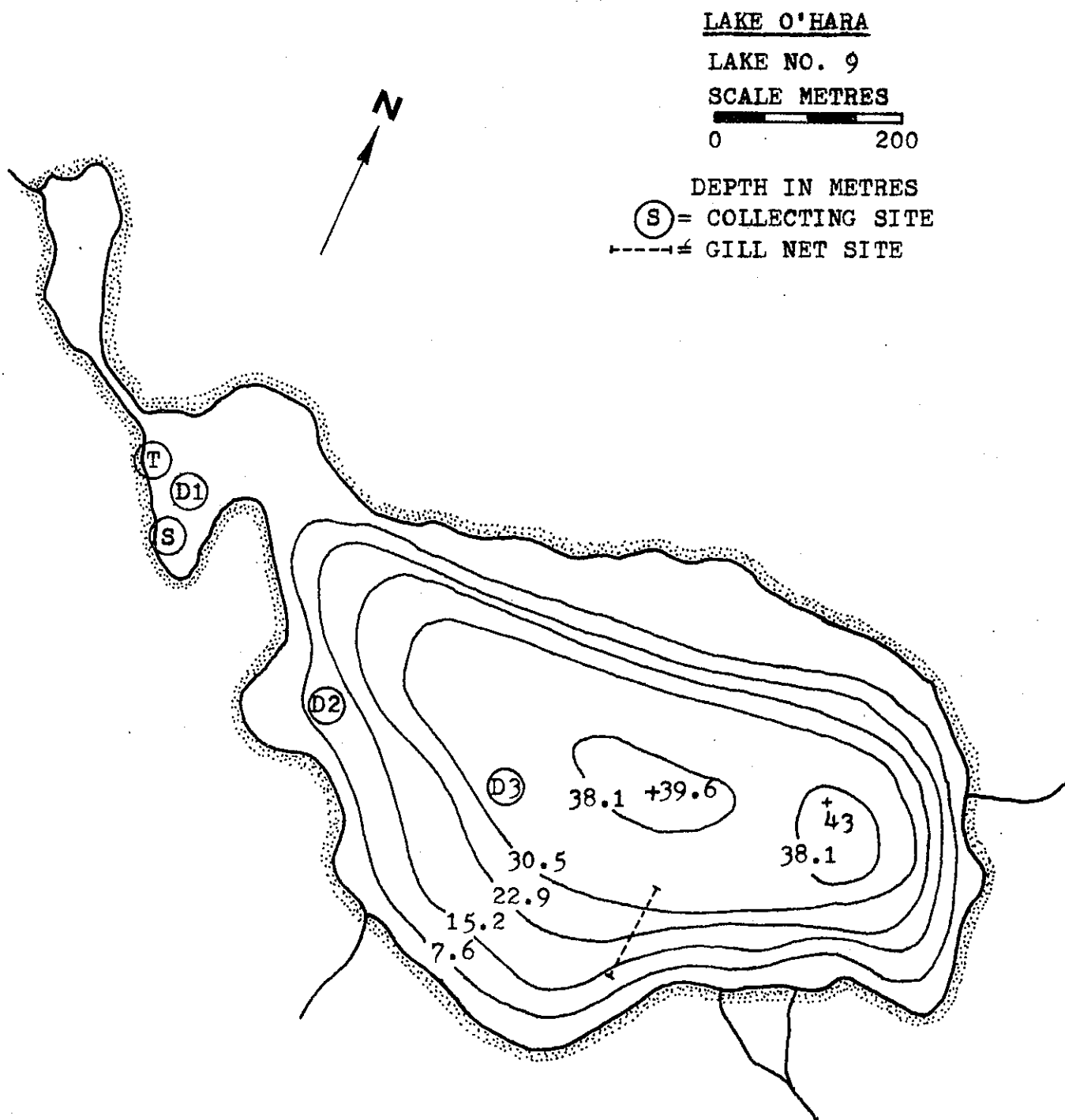
Lake McArthur (Site 8)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	128	128	128	128
Sample type	D1	D2	S	T
Depth (m)	8	10	-	-
Total wet weight (g)	0.23	0.12	0.01	-
Turbellaria				
Mesostoma (arcticum ?)	-	-	6	-
Ephemeroptera				
Parameletus sp.	-	-	2	-
Diptera				
Chironomidae				
Unidentified	82	8	1	-
Tanytarsus sp.	8	-	-	-
Diptera pupae	2	-	-	-
Misc Insecta	-	-	1	-
Acarina				
Lebertia sp.	2	-	-	-
Pelecypoda				
Pisidium conventus	19	25	-	-
Nematoda				
Unidentified	5	-	-	-
Total number of invertebrates	118	33	10	-

Phytoplankton counts (cells/ml)

Species	Coll. No. Depth (m)	999-128 0.5	154 0.5
Chrysophyta			
Cyclotella minuta (?)		163.3	48.0
Kephyrion sp.		7.3	4.5
Navicula sp.			1.5
Melosira italica var. subarctica			4.5
Pyrrophyta			
Unid. Dinoflagellate sp.		3.6	
Total cells/ml		174.2	58.5



Locality LAKE O'HARA

Site number 9
 Grid reference 11U/NG466895
 Elevation (metres/feet) 2014/6620
 Altitudinal belt subalpine
 Maximum depth (m) 38.1
 Surface area (hectares) 34.4

Sampling date	5/VII/73	11/VII/73	28/VIII/73	25/I/74
Collection number (999-)	90	100	132	148

Time	1400	0900	0830	0930
Air temperature (°C)	-	-	6.8	-3.5
Sky	rain	cloudy	cloudy	snow
Snow cover (m)	-	-	-	0.55
Ice cover (m)	-	-	-	0.50
Secchi disk (m)	-	6.8	4.2	-
pH	-	7.4	7.6	-
Conductivity (@25°C)	-	88	90	-

Samples collected

Kick	-	-	-	-
Dredge	X	-	X	X
Phytoplankton	-	X	X	X
Macrophytes	-	-	-	-
Zooplankton	-	X	X	X
Shoreline	X	-	X	-
Shore trawl	X	-	X	-
Fish	-	(9/VIII/73)	-	-
Primary production	-	X	X	-
Water chemistry	-	X	X	-
Stream flow	-	-	-	-

Water temperature	m	°C	m	°C	m	°C	m	°C
	0	7.0	0	7.6	0	7.9	0	0.5
			4	7.2	1	7.9	1	1.8
			10	5.2	2	7.9	2	3.1
			20	4.2	4	7.7	4	3.4
			30	4.0	7	7.0	6	3.5
					10	5.9	8	3.6
					16	3.9	10	3.7
					20	3.7	12	3.8
					25	3.6		
					30	3.3		

Lake O'Hara (Site 9)

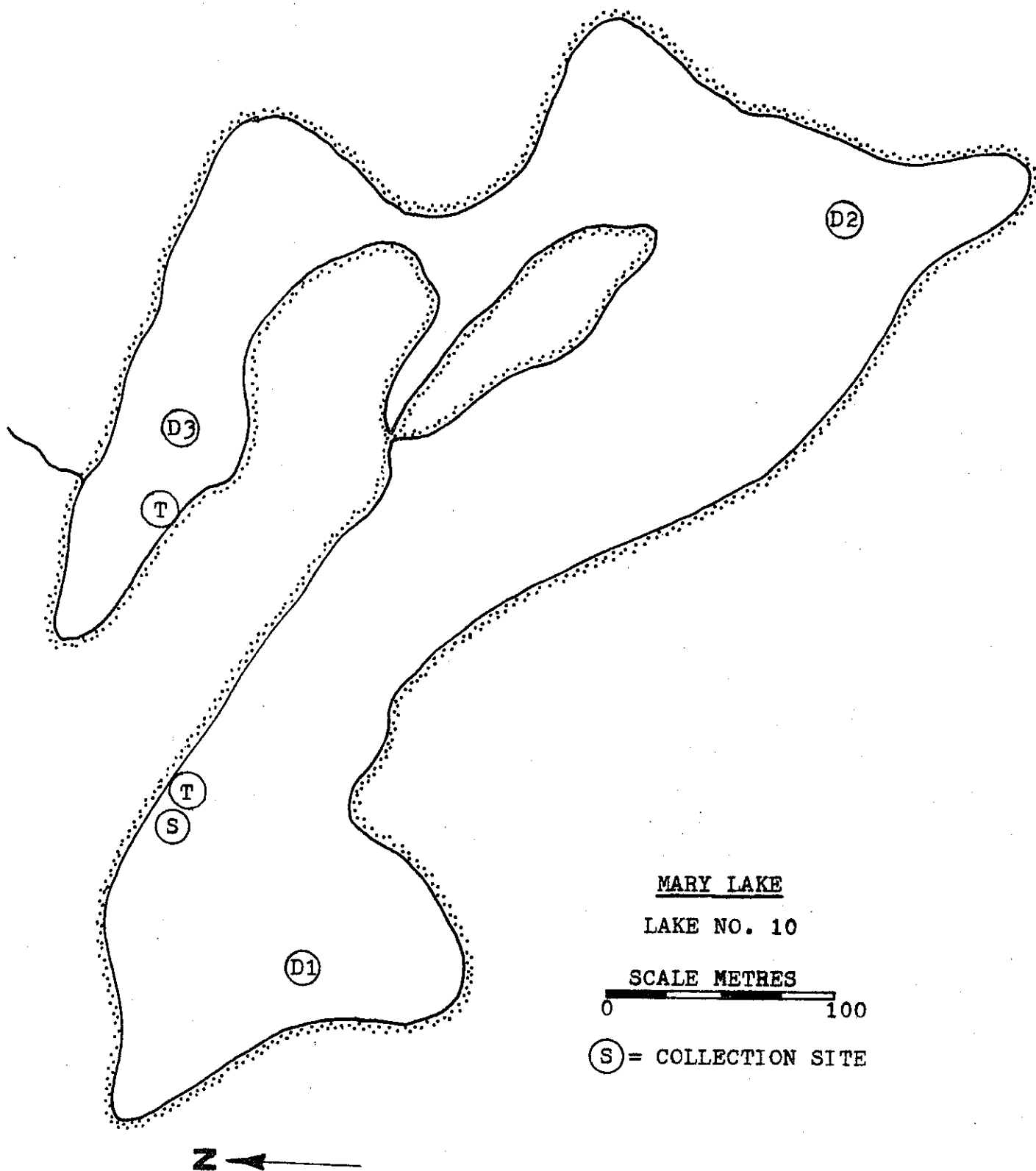
Summary of benthic invertebrate samples (numbers collected)

Coll. number	90	90	90	90	90	132	132	132	132	132	148
Sample type	D1	D2	D3	S	T	D1	D2	D3	S	T	D2
Depth (m)	5	5	20	-	-	5	5	35	-	-	12
Total wet weight (g)	0.3	0.6	0.3	3.8	-	0.4	1.0	0.2	0.7	-	0.5
Oligochaeta											
Limnodrilus sp.	-	-	-	3	-	-	-	-	-	-	-
Tubifex sp.	-	1	-	-	-	2	-	1	-	2	1
Rhenchelmis sp.	-	2	-	-	-	-	-	-	-	5	-
Amphipoda											
Gammarus lacustris	-	1	-	-	-	-	6	-	-	-	-
Ephemeroptera											
Rithrogena robusta (?)	-	-	-	-	-	1	-	-	-	-	-
Trichoptera											
Limnephilidae	-	1	-	12	-	-	-	-	-	-	-
Limnephilus sp.	-	-	-	-	-	-	2	-	13	-	-
Diptera											
Chironomidae											
Procladius sp.	2	-	-	-	-	-	-	-	-	-	-
Pentaneura sp.	-	2	-	3	-	-	-	-	1	4	11
Diamesa sp.	-	-	1	-	-	-	-	-	-	-	-
Brillia spp.	-	2	2	-	-	-	-	-	-	2	8
Corynoneura sp.	-	-	1	-	-	2	-	-	3	1	-
Cricotopus spp.	-	-	-	3	2	-	-	1	7	-	-
Eukiefferiella sp.	1	-	-	-	1	-	-	-	-	-	-
Pseudochironomus sp.	-	-	15	-	-	-	-	-	-	-	-
Tanytarsus sp.	9	84	10	-	-	5	117	3	-	12	105
Psectrocladius sp.	-	-	-	-	-	-	-	-	9	40	-
Chironomus (Limnochironomus)	-	-	-	-	-	72	-	-	-	-	-
Phaenopsectra sp.	7	86	14	-	-	-	32	1	-	-	6
Diptera pupae	-	-	-	-	-	-	-	-	-	1	-
Coleoptera											
Hydroporus compertus	-	-	-	2	-	-	-	-	-	-	-
Agabus tristis	-	-	-	-	-	-	-	-	1	-	-
Dyticid larvae	-	-	-	-	-	-	-	-	1	-	-
Misc. Insecta	-	-	-	-	1	-	-	-	-	-	-
Acarina											
Lebertia sp.	-	-	-	-	-	-	-	-	-	1	-
Pionidae	-	-	-	-	-	-	-	-	-	-	1
Pelecypoda											
Pisidium conventus	41	54	-	-	-	-	14	16	-	-	2
Pisidium ventricosum	1	-	-	-	-	-	-	-	-	-	-
Pisidium lilljeborgi	-	-	-	-	-	-	1	-	-	-	-
Total number of invertebrates	61	233	43	23	4	82	172	22	35	68	134

LAKE O'HARA

Phytoplankton counts (cells/ml)

Species	Coll. No. (999)	100	100	100	132	132	132	132	148	148
	Depth (m)	0.5	4.0	10.0	0.5	4.0	10.0	16.0	1.0	10.0
Chlorophyta										
Ankistrodesmus sp.		94.4	71.0	71.0	29.0	18.2	123.4	410.7	-	-
Ankistrodesmus falcatus		-	-	-	-	-	-	-	1.1	2.2
Carteria sp.		-	-	-	-	-	-	-	-	2.2
Chlamydomonas sp.		-	-	-	-	-	14.5	26.5	6.6	-
Chrysophyta										
Achnanthes sp.		-	-	3.3	-	5.0	-	-	-	1.1
Bitrichia chodatii		3.4	-	-	7.3	3.3	7.3	-	-	-
Chrysoikos skujae		-	6.6	1.7	-	1.7	-	-	2.2	-
Cyclotella minuta		1698.	1438.	1762.	1966.	1859.	2474.	5527.	83.6	660.0
Cymbella affinis		-	-	-	-	1.2	3.6	-	-	-
Diatoma hiemale var. mesodon		-	-	-	-	2.7	-	-	-	-
Dinobryon cylindricum		-	-	3.3	-	-	-	-	-	-
Dinobryon sociale		-	1.7	-	-	-	-	-	-	-
Fragilaria pinnata		-	-	1.7	-	-	-	-	-	-
Hannea arcus		-	-	-	3.6	-	-	-	-	-
Kephyrion sp.		-	31.4	1.7	112.5	82.4	348.4	3.3	2.2	-
Kephyrion obliquum (?)		54.4	-	-	-	-	-	-	-	-
Kephyriopsis sp.		-	-	-	39.9	18.2	94.4	-	-	-
Navicula sp.		-	3.3	-	-	-	-	-	-	-
Pseudokephyrion hiemale		-	-	-	3.6	5.0	-	-	-	-
Pseudokephyrion parvum		-	-	-	3.6	-	-	-	-	-
Pyrrophyta										
Gymnodinium sp.		-	-	-	-	-	-	3.3	-	-
Gymnodinium helveticum		-	-	-	-	-	-	-	-	1.1
Woloszynkia sp.		-	5.0	1.7	3.6	3.3	-	-	-	-
Cryptophyta										
Cryptomonas sp.		-	-	-	-	-	3.6	29.8	1.1	6.6
Rhodomonas minuta		-	-	46.2	7.3	14.9	108.9	79.5	4.4	31.9
Total cells/ml		1850.	1557.	1892.	2177.	2016.	3179.	6080.	101.2	705.1



Locality MARY LAKE

Site number 10
 Grid reference 11U/NG465888
 Elevation (metres/feet) 2034/6670
 Altitudinal belt subalpine
 Maximum depth (m) 3.8
 Surface area (hectares) 6.5

Sampling date	6/VII/73	11/VII/73
Collection number (999-)	91	101

Time	0800	1000
Air temperature (°C)	6.8	-
Sky	cloudy	cloudy
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	3.8+	3.8+
pH	-	7.9
Conductivity (@25°C)	-	99

Samples collected

Kick	-	-
Dredge	X	-
Phytoplankton	X	X
Macrophytes	-	X
Zooplankton	X	-
Shoreline	X	-
Shore trawl	X	-
Fish	-	-
Primary production	-	X
Water chemistry	-	X
Stream flow	-	-

Water temperature	m	°C	m	°C
	0	8.7	0	8.9
	1	8.5	2	8.9
	3	7.3		
	3.8	7.0		

Mary Lake (Site 10)

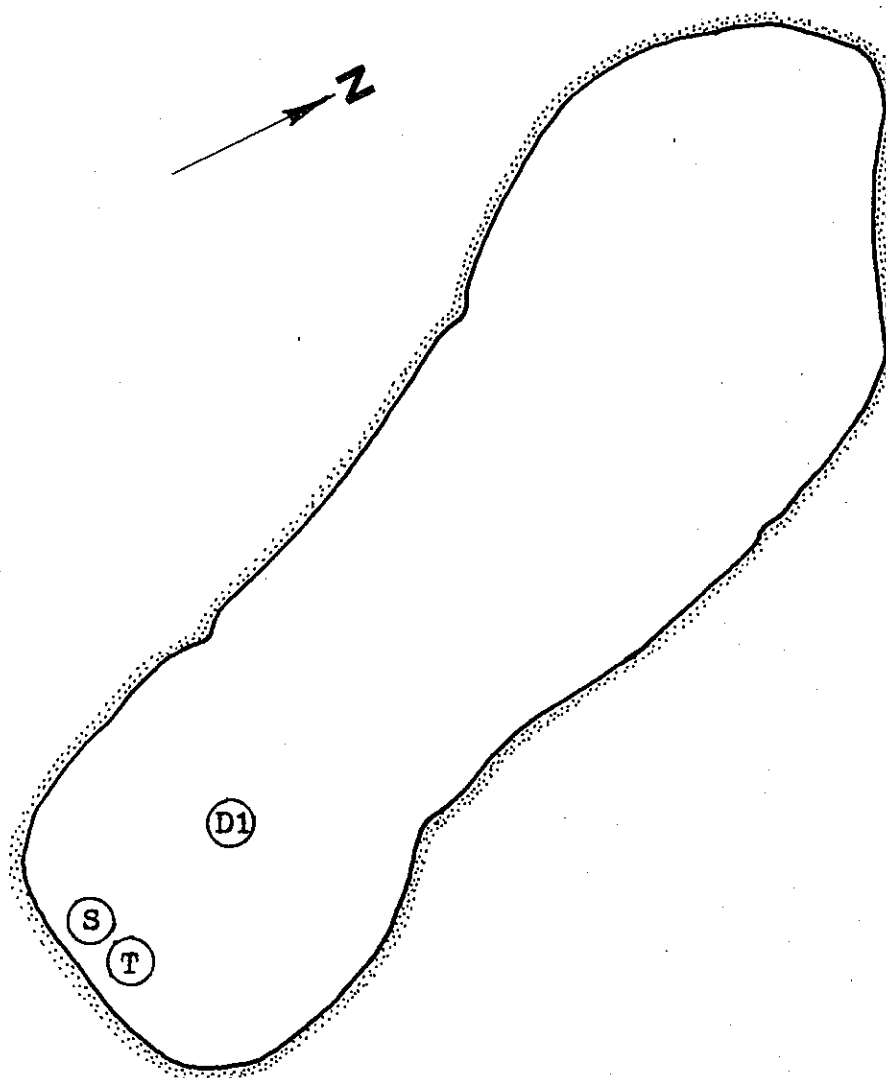
Summary of benthic invertebrate samples (numbers collected)

Coll. number	91	91	91	91	91
Sample type	D1	D2	D3	S	T
Depth (m)	3.3	2.5	1.5	-	-
Total wet weight (g)	0.01	0.08	0.21	3.87	-
Oligochaeta					
Limnodrilus sp.	-	-	1	-	-
Rhynchelmis sp.	-	-	3	-	2
Hirudindidea					
Glossophonia complanata	-	-	-	1	-
Trichoptera					
Limnephilidae	-	-	-	50	7
Diptera					
Culicidae					
Aedes sp.	-	-	-	50	-
Heleidae					
Alluaudomyia sp.	-	-	3	-	-
Chironomidae					
Procladius sp.	-	-	4	-	2
Pentaneura sp.	-	-	-	1	-
Circotopus sp. A.	-	-	-	2	2
Psectrocladius sp.	-	-	1	-	-
Phaenopsectra sp.	6	2	-	2	-
Tanytarsus sp.	-	2	3	5	-
Chironomus (limnochironomus) sp.	-	-	-	-	5
Diptera pupae	-	-	-	17	19
Coleoptera					
Hydroporus occidentalis	-	-	-	1	9
Misc. Insecta	-	-	-	5	3
Acarina					
Lebertia sp.	-	-	1	-	5
Limnesia sp.	-	-	-	3	-
Pionidae	-	-	1	-	-
Pelecypoda					
Pisidium ventricosum	-	-	-	-	7
Total number of invertebrates	6	4	17	137	61

MARY LAKE

Phytoplankton counts (cells/ml)

Species	Coll. No. (999)	91	101	101
	Depth (m)	0.5	0.5	2
Chlorophyta				
Chlamydomonas sp.		7.3	-	-
Dictyosphaerium pulchellum		-	43.6	-
Tetraedon minimum		1.7	-	-
Chrysophyta				
Achnanthes sp.		8.3	7.3	6.6
Achnanthes microcephala		3.3	-	-
Bitrichia chodatii		-	3.6	3.3
Cymbella sp.		8.3	-	6.6
Cymbella affinis		3.3	-	-
Dinobryon cylindricum		1.7	3.6	3.3
Dinobryon sp.		-	3.6	-
Dinobryon sociale		74.3	293.9	476.9
Fragilaria sp.		5.0	-	-
Fragilaria pinnata		5.0	-	-
Kephyrion sp.		79.8	-	-
Navicula sp.		5.0	7.3	6.6
Nitzschia sigma		1.7	-	3.3
Synedra sp		5.0	14.5	9.9
Synedra radians		9.9	-	-
Pyrrophyta and Cryptophyta				
Cryptomonas erosa		-	36.3	19.9
Glenodinium sp.		5.0	-	-
Peridinium sp.		3.3	-	-
Rhodomonas minuta		-	14.5	6.6
Total cells/ml		221.7	428.2	543.0



LOWER OPABIN LAKE

LAKE NO. 13

SCALE METRES

0 50

Ⓢ = COLLECTION SITE

Locality LOWER OPABIN LAKE

Site number 13
 Grid reference 11U/NG474881
 Elevation (metres/feet) 2234/7328
 Altitudinal belt subalpine
 Maximum depth (m) 1.5
 Surface area (hectares) 0.3

Sampling date 10/VII/73
 Collection number (999-) 98

Time 1400
 Air temperature (°C) 15.0
 Sky clear
 Snow cover (m) -
 Ice cover (m) -
 Secchi disk (m) 1.5+
 pH 7.1
 Conductivity (@25°C) 15

Samples collected

Kick -
 Dredge X
 Phytoplankton X
 Macrophytes -
 Zooplankton X
 Shoreline X
 Shore trawl X
 Fish -
 Primary production -
 Water chemistry X
 Stream flow -

Water temperature

m	°C
0	11.0
0.5	11.0
1.2	11.0

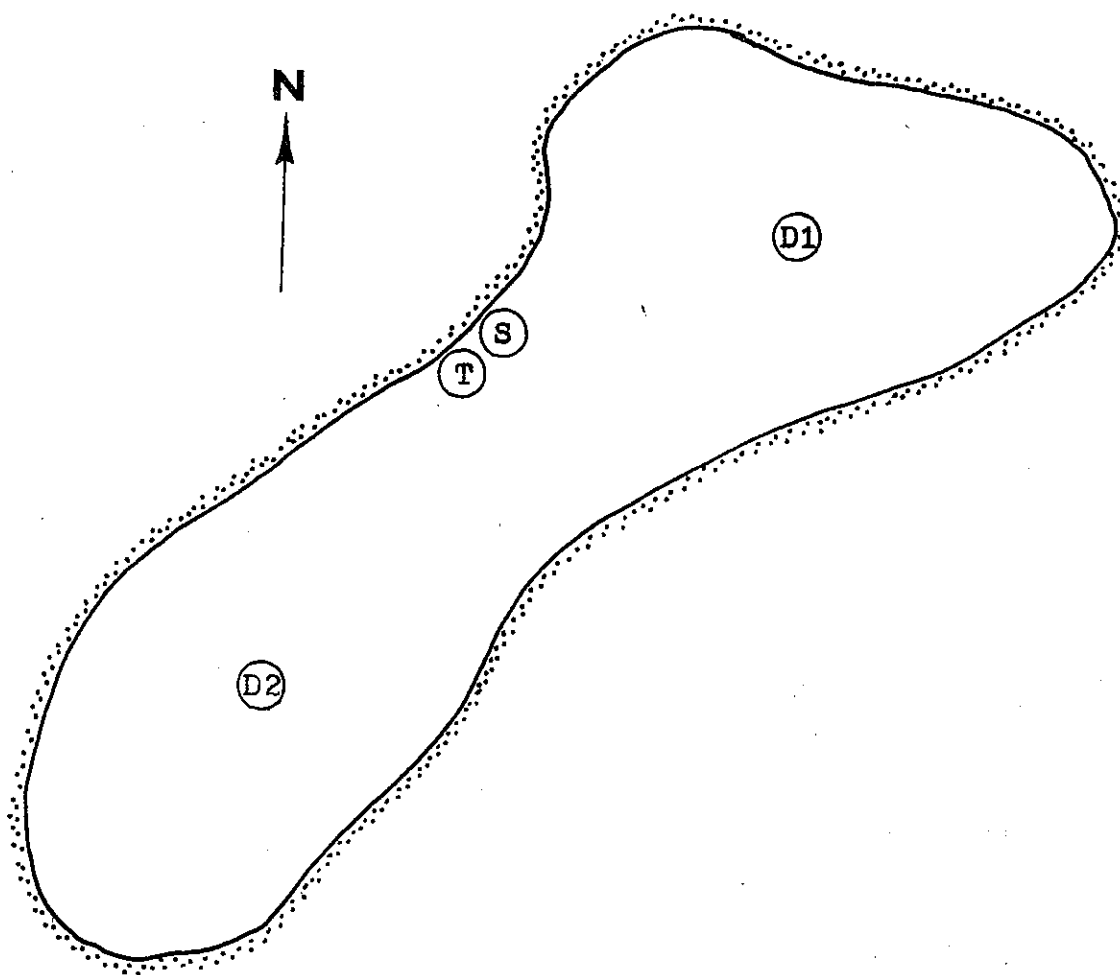
Opabin Lake (Site 13)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	98	98	98
Sample type	D1	S	T
Depth (m)	1.2	-	-
Total wet weight (g)	0.63	2.11	-
Oligochaeta			
Rhynchelmis sp.	2	-	4
Trichoptera			
Hesperophylax sp.	-	1	-
Limnephilidae	-	15	-
Diptera			
Culicidae			
Chaoborus sp.	1	35	5
Chironomidae			
Procladius sp.	6	4	4
Phaenopsectra	26	1	7
Tanytarsus sp.	-	2	6
Diptera pupae	-	13	1
Aerial diptera	-	2	-
Coleoptera			
Agabus tristis	-	1	-
Hydroporus occidentalis	-	2	-
Hydroporus compertus	-	1	-
Unidentified	-	1	-
Total number of invertebrates	35	78	27

Phytoplankton counts (cells/ml)

Species	Coll. No. Depth (m)	999-98 0.5
Chlorophyta		
Tetraedon minimum		3.3
Cyanophyta		
Spirulina nr. major		1.7
Chrysophyta		
Dinobryon attenuatum		160.1
Kephyrion spp.		21.5
Pseudokephyrion sp.		3.3
Navicula sp.		9.9
Pyrrophyta		
Peridinium sp.		117.2
Woloszynkia sp. (?)		13.2
Total cells/ml		330.2



MIDDLE OPABIN LAKE

LAKE NO. 14

SCALE METRES

0 50

Ⓢ = COLLECTION SITE

Locality

MIDDLE OPABIN LAKE

Site number	14
Grid reference	11U/NG475880
Elevation (metres/feet)	2245/7320
Altitudinal belt	treeline
Maximum depth (m)	2.7
Surface area (hectares)	1.7

Sampling date	10/VII/73
Collection number (999-)	97

Time	1200
Air temperature (°C)	14.6
Sky	clear
Snow cover (m)	-
Ice cover (m)	-
Secchi disk (m)	2.7+
pH	6.9
Conductivity (@25°C)	16

Samples collected

Kick	-
Dredge	X
Phytoplankton	X
Macrophytes	-
Zooplankton	X
Shoreline	X
Shore trawl	X
Fish	-
Primary production	-
Water chemistry	X
Stream flow	-

Water temperature

m	°C
0	8.0
1	7.9
2.2	4.7

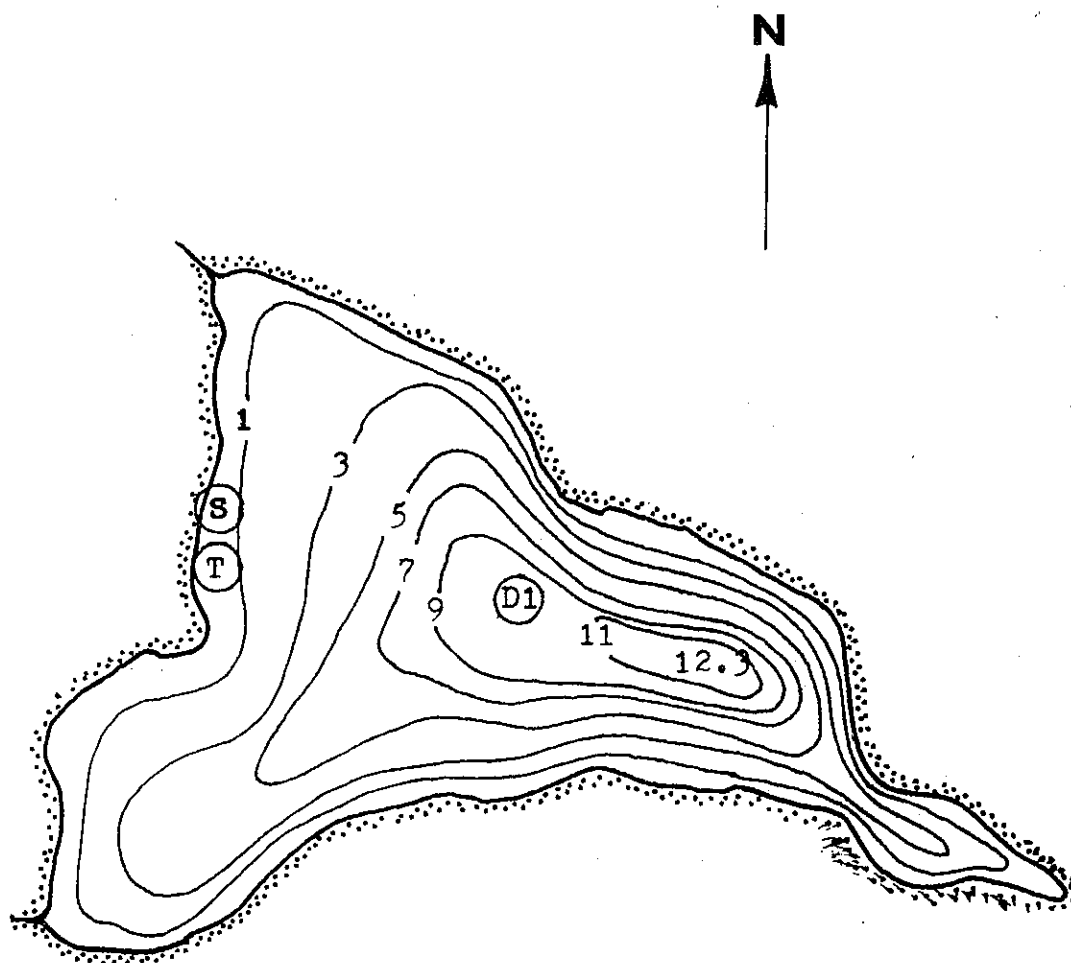
Middle Opabin Lake (Site 14)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	97	97	97	97
Sample type	D1	D2	S	T
Depth (m)	2.7	2.0	-	-
Total wet weight (g)	0.14	0.02	2.04	-
Oligochaeta				
Tubifex sp.	1	-	-	-
Rhynchelmis sp.	2	1	-	-
Trichoptera				
Limnephilidae	-	-	38	-
Diptera				
Chironomidae				
Procladius sp.	27	-	-	-
Corynoneura sp.	3	-	6	-
Cricotopus sp.	-	-	1	-
Tanytarsus sp.	7	-	6	1
Coleoptera				
Agabus tristis	-	-	6	-
Hydroporus occidentalis	-	-	27	2
Hydroporus griseostriatus	-	-	1	-
Acarina				
Lebertia sp.	-	-	6	-
Araneae	-	1	-	-
Total number of invertebrates	40	2	91	3

Phytoplankton counts (cells/ml)

Species	Coll. No. Depth (m)	999-97 0.5
Chrysophyta		
Acananthes sp.		2.7
Acananthes sp.		13.6
Dinobryon attenuatum		2.7
Dinobryon cylindricum		57.1
Kephyrion sp.		19.1
Euglenophyta		
Trachelomonas nr. pulchella		2.7
Total cells/ml		97.9



UPPER OPABIN LAKE

LAKE NO. 15

SCALE METRES

0 50 100

DEPTH IN METRES:

(S) = COLLECTION SITE

Locality

UPPER OPABIN LAKE

Site number	15
Grid reference	11U/NG480877
Elevation (metres/feet)	2270/7450
Altitudinal belt	alpine
Maximum depth (m)	12.3
Surface area (hectares)	3.1

Sampling date	10/VII/73
Collection number (999-)	96

Time	1000
Air temperature (°C)	11.2
Sky	clear
Snow cover (m)	-
Ice cover (m)	60% soft ice
Secchi disk (m)	3.0
pH	7.6
Conductivity (@25°C)	42

Samples collected

Kick	-
Dredge	X
Phytoplankton	X
Macrophytes	-
Zooplankton	X
Shoreline	X
Shore trawl	X
Fish	-
Primary production	-
Water chemistry	X
Stream flow	-

Water temperature

m	°C
0	1.1
1	1.3
2	1.4
4	1.4
6	1.4
8	1.5
9.5	1.8

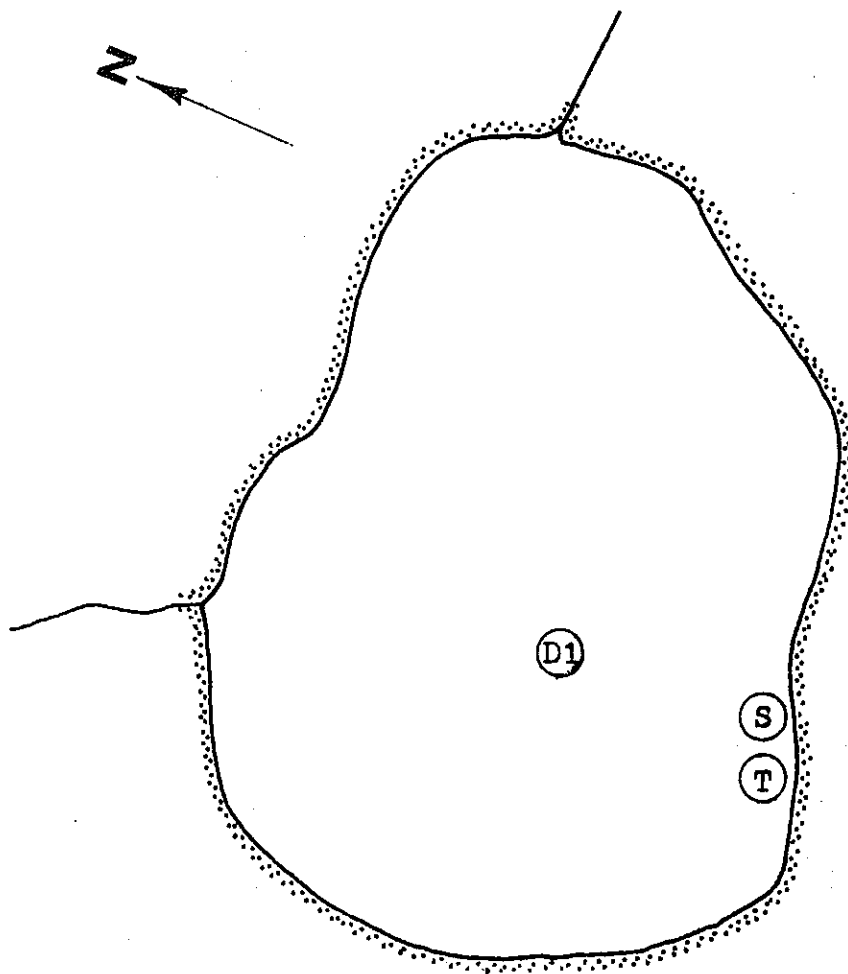
Upper Opabin Lake (Site 15)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	96	96	96
Sample type	D1	S	T
Depth (m)	10	-	-
Total wet weight (g)	0.01	2.04	-
Oligochaeta			
Limnodrilus sp.	-	2	-
Ephemeroptera			
Parameletus sp.	-	87	10
Plecoptera			
Alloperla (fidelis ?)	-	15	3
Diptera			
Chironomidae			
Procladius sp.	-	2	-
Tanytarsus sp.	3	-	-
Coleoptera			
Dyticid larva	-	1	-
Total number of invertebrates	3	107	13

Phytoplankton counts (cells/ml)

Species	Coll. No.	999-96
	Depth (m)	0.5
Chrysophyta		
Navicula sp.		1.7
Total cells/ml		1.7



LOWER OPABIN POND

LAKE NO. 15A

SCALE METRES

0 50

Ⓢ = COLLECTION SITE

Locality LOWER OPABIN POND

Site number 15A
 Grid reference 11U/NG471885
 Elevation (metres/feet) 2204/7250
 Altitudinal belt subalpine
 Maximum depth (m) 1.2
 Surface area (hectares) 0.1

Sampling date 10/VII/73
 Collection number (999-) 99

Time 1300
 Air temperature (°C) 15.0
 Sky clear
 Snow cover (m) -
 Ice cover (m) -
 Secchi disk (m) 1.2+
 pH 7.8
 Conductivity (@25°C) 73

Samples collected

Kick -
 Dredge X
 Phytoplankton -
 Macrophytes -
 Zooplankton X
 Shoreline X
 Shore trawl X
 Fish -
 Primary production -
 Water chemistry X
 Stream flow -

Water temperature 11.5

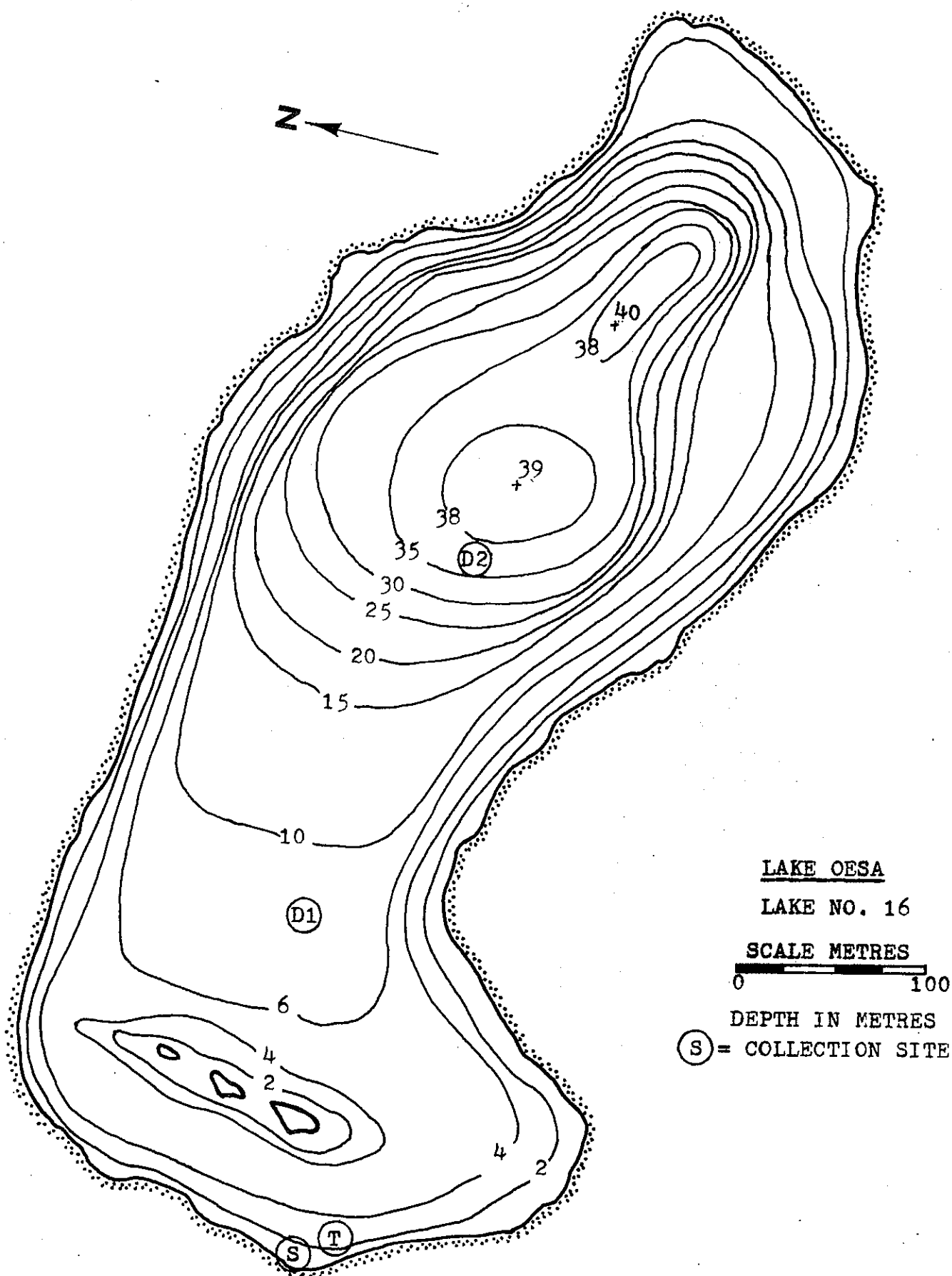
Lower Opabin Pond (Site 15A)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	99	99	99
Sample type	D1	S	T
Depth (m)	0.6	-	-
Total wet weight (g)	0.09	0.16	-
Oligochaeta			
Tubifex sp.	-	-	1
Rhynchelmis sp.	1	-	-
Ephemeroptera			
Parameletus sp.	-	5	-
Ameletus sp.	6	5	1
Diptera			
Chironomidae			
Eukiefferiella sp.	-	1	-
Total number of invertebrates	7	11	2

Phytoplankton counts (cells/ml)

Species	Coll. No. Depth (m)	999-99 0.5
Chlorophyta		
Cosmarium sp.		5.0
Chrysophyta		
Achnanthes sp.		34.7
Cocconeis sp.		1.7
Cymbella sp.		19.8
Dinobryon cylindricum		1.7
Fragilaria pinnata		13.2
Hannea arcus		3.3
Kephyrion sp.		1.7
Navicula sp.		26.4
Pinnularia sp.		1.7
Stauroneis sp.		1.7
Total cells/ml		110.9



Locality	LAKE OESA
Site number	16
Grid reference	11U/NG485893
Elevation (metres/feet)	2285/7505
Altitudinal belt	alpine
Maximum depth (m)	39
Surface area (hectares)	16.1

Sampling date	21/VIII/73
Collection number (999-)	126

Time	1100
Air temperature (°C)	10.5
Sky	clear
Snow cover (m)	-
Ice cover (m)	-
Secchi disk (m)	3.5
pH	7.8
Conductivity (@25°C)	93

Samples collected	
Kick	-
Dredge	X
Phytoplankton	X
Macrophytes	-
Zooplankton	X
Shoreline	X
Shore trawl	X
Fish	-
Primary production	-
Water chemistry	X
Stream flow	-

Water temperature	m	°C
	0	6.3
	1	6.4
	2	6.3
	5	5.8
	10	5.2
	15	3.9
	20	3.6
	25	3.6
	30	3.5

Lake Oesa (Site 16)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	126	126	126	126
Sample type	D1	D2	S	T
Depth (m)	10	35	-	-
Total wet weight (g)	0.62	0.10	0.16	-
Turbellaria				
Mesostoma (arcticum ?)	-	-	7	-
Ephemeroptera				
Parameletus sp.	-	-	2	1
Plecoptera				
Alloperla (fidelis ?)	-	-	9	-
Trichoptera				
Limnephilidae	-	-	1	-
Diptera				
Chironomidae				
Cricotopus sp.	-	7	-	-
Phaenopsectra sp.	63	-	-	-
Tanytarsus sp.	116	6	-	-
Unidentified	-	1	-	-
Diptera pupae	4	-	1	-
Aerial diptera	-	-	3	5
Misc. Insecta	-	-	4	3
Total number of invertebrates	183	14	27	9

Phytoplankton counts (cells/ml)

Species	Coll.No.	999-126
	Depth (m)	0.5
Chrysophyta		
Achnanthes sp.		6.2
Achnanthes microcephala		2.5
Cocconeis sp.		1.2
Cyclotella minuta (?)		671.2
Cymbella sp.		2.5
Pseudokephyrion hiemale		7.4
Total cells/ml 691.0		

ROSS LAKE
LAKE NO. 17

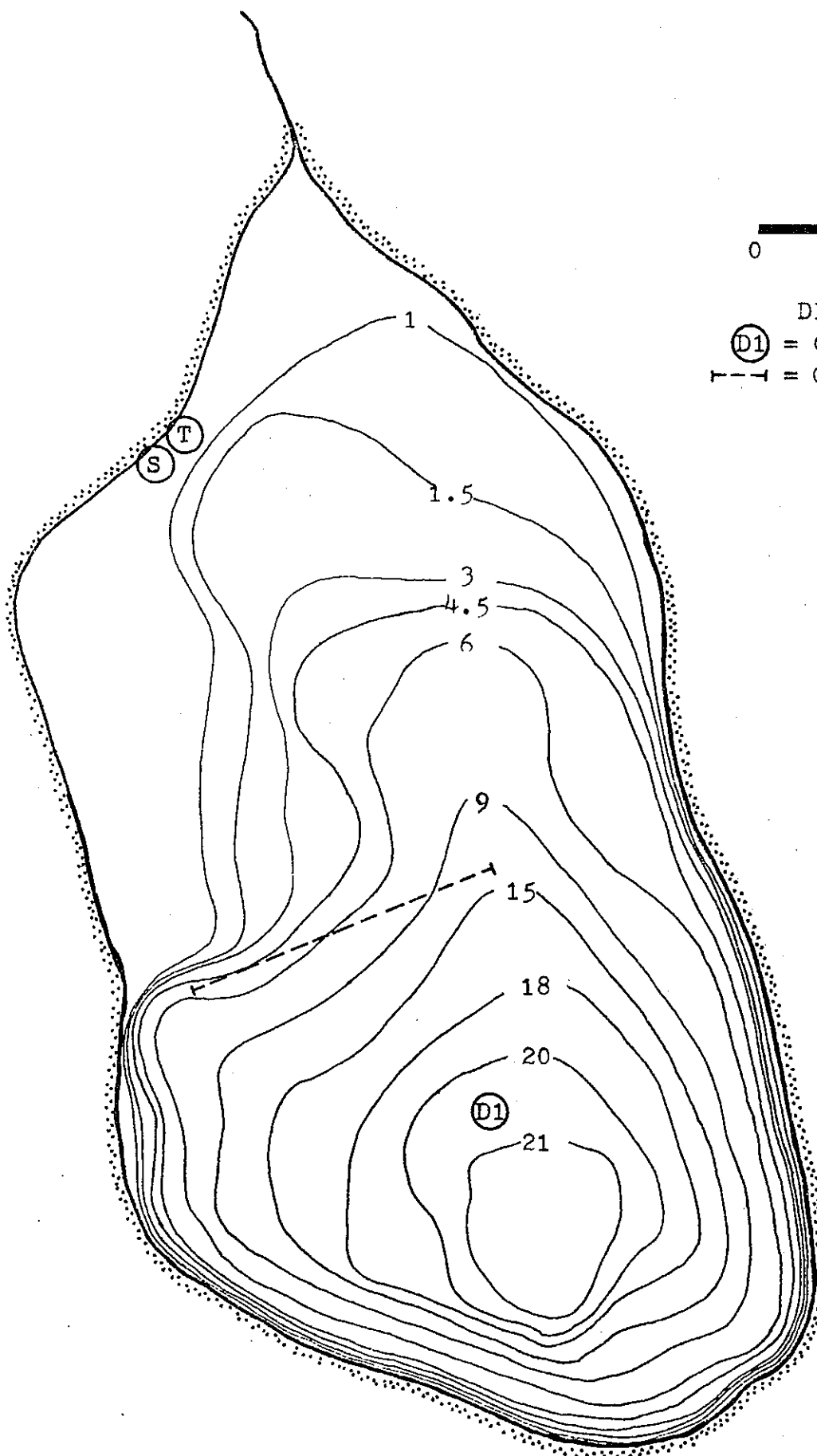
SCALE METRES

0 50 100

DEPTH IN METRES

⊙D1 = COLLECTING SITE

--- = GILL NET SITE



Locality ROSS LAKE

Site number 17
 Grid reference 11U/NG486984
 Elevation (metres/feet) 1729/5670
 Altitudinal belt subalpine
 Maximum depth (m) 21.5
 Surface area (hectares) 6.0

Sampling date	18/VI/71	5/VIII/71	13/VI/73	11/IX/73	28/II/74
Collection number (999-)	7	17	71	144	152
Time	1000	0900	1030	1000	1600
Air temperature (°C)	10.5	22	8.2	7.4	16
Sky	cloudy	clear	rain	clear	cloudy
Snow cover (m)	-	-	-	-	0.25
Ice cover (m)	-	-	-	-	0.76
Secchi disk (m)	12	12.5	10	8.0	-
pH	8.1	8.1	7.7	8.0	-
Conductivity (@25°C)	198	209	319	175	-
Samples collected					
Kick	-	-	-	-	-
Dredge	X	X	-	-	-
Phytoplankton	-	-	X	X	X
Macrophytes	-	-	-	-	-
Zooplankton	X	X	X	X	X
Shoreline	X	X	X	-	-
Shore trawl	-	X	-	-	-
Fish	-	(8/VIII/73)	-	-	-
Primary production	-	-	X	X	-
Water chemistry	X	-	X	X	-
Stream flow	-	-	-	-	-
Water temperature	m °C	m °C	m °C	m °C	m °C
	0 6.5	0 15.0	0 6.7	0 8.8	0 0
	2 6.5	1 15.0	1 6.6	1 8.8	1 1.4
	4 6.2	2 13.0	2 6.3	2 8.8	2 2.5
	6 6.0	4 11.0	4 5.7	4 8.6	4 3.0
	8 5.5	6 8.0	8 5.2	7 7.2	8 3.1
	10 5.5	8 7.0	10 5.1	10 5.1	12 3.3
	15 5.5	10 6.0	14 5.0	15 4.3	14 3.0
	20 5.0	12 6.0	18 5.0	19 4.3	16 2.7
		14 6.0		20 4.2	17 2.6
		16 6.0			
		18 6.0			
		20 6.0			

Ross Lake (Site 17)

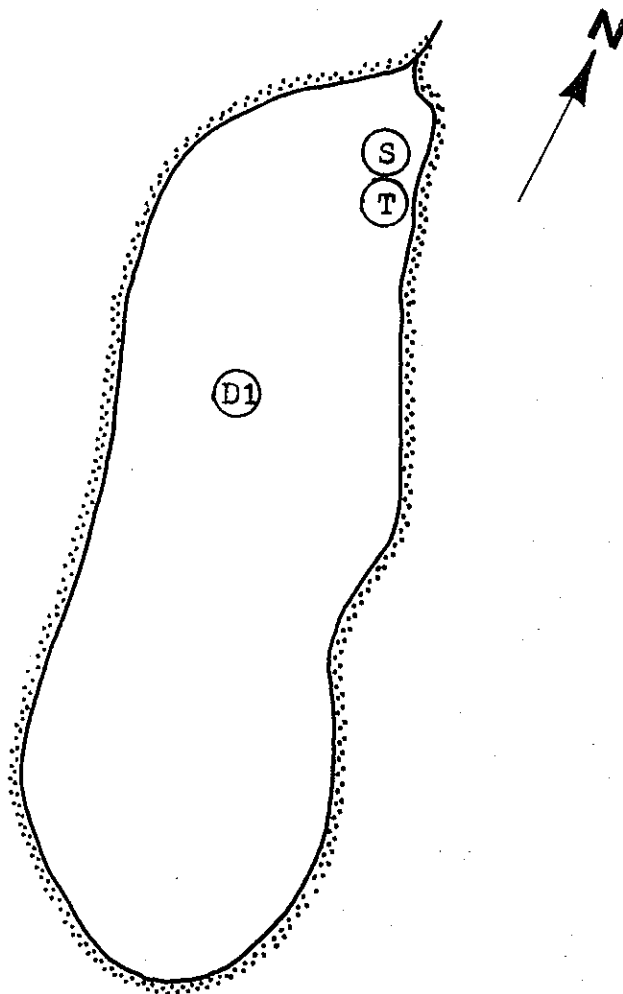
Summary of benthic invertebrate samples (numbers collected)

Coll. number	7	7	17	17	17	71
Sample type	K1	S	D1	S	T	S
Depth (m)	18.0	-	20.0	-	-	-
Total wet weight (g)	-	-	-	-	-	0.72
Oligochaeta						
Rhynchelmis sp.	1	-	1	14	-	4
Amphipoda						
Gammarus lacustris	-	7	-	19	-	-
Ephemeroptera						
Baetis sp.	-	-	-	1	-	-
Ameletus sp.	-	2	-	-	-	1
Habrophlebiodes sp.	-	-	-	-	-	1
Plecoptera						
Alloperla (fidelis ?)	-	-	-	2	-	-
Trichoptera						
Limnephilidae	-	11	-	7	-	-
Diptera						
Tipulidae	-	-	1	-	-	-
Chironomidae						
Eukiefferiella sp.	-	-	-	-	-	1
Procladius sp.	-	-	4	5	-	-
Pentaneura sp.	3	-	2	-	-	-
Chironomus sp.	91	-	95	-	-	-
Tanytarsus sp.	60	-	24	-	-	-
Unidentified	-	-	9	7	6	-
Coleoptera						
Ametor scabrosus	-	1	-	-	-	-
Hydrophilidae	-	-	-	1	-	-
Gastropoda						
Gyalus parvus	-	17	-	33	-	20
Gyalus circumstriatus	-	20	-	6	-	-
Gyalus sp.	-	-	-	5	-	-
Pelecypoda						
Pisidium lilljeborgi	4	-	-	41	-	6
pisidium conventus	1	-	6	-	-	-
Total number of invertebrates	160	58	142	141	6	33

ROSS LAKE

Phytoplankton counts (cells/ml)

Species	Coll. No. (999)	71 Depth (m) 0.5	71 4.0	71 10.0	144 0.5	144 4.0	144 10.0	152 0.5
Chlorophyta								
Ankistrodesmus sp.	-	-	-	14.9	9.9	65.3	-	-
Chlamydomonas sp.	-	-	-	1.7	5.0	3.6	-	8.8
Cosmarium sp. A	13.6	8.3	23.1	5.0	5.0	3.6	-	-
Cosmarium sp. B	8.2	6.6	9.9	-	-	-	-	-
Tetraedon minimum	5.4	6.6	3.3	-	3.3	43.6	-	-
Chrysophyta								
Acnanthos sp.	-	-	6.6	8.3	13.3	-	-	-
Acnanthos microcephala	5.4	-	-	-	-	-	-	-
Chromulina sp.	-	-	-	-	-	-	-	5.5
Chrysoikos gracilis	8.2	18.2	29.7	-	-	-	-	5.5
Chrysolykos planctonicus	-	-	-	14.9	9.9	39.9	-	1.1
Cyclotella sp.	10.9	9.9	11.5	500.1	483.6	1647.5	-	3.3
Cyclotella ocellata	-	13.2	11.5	9.9	21.5	61.7	-	-
Cymbella sp.	-	1.7	-	-	1.7	7.3	-	-
Dinobryon sociale	304.8	338.3	562.7	1.7	3.3	-	-	-
Diploneis elliptica	-	-	-	-	-	3.3	-	-
Fragilaria construens	-	-	-	-	1.7	-	-	-
Gomphonema sp.	-	-	-	1.7	-	-	-	-
Kephyrion sp.	35.4	75.9	56.0	117.6	163.9	199.6	-	-
Lagnyon sp (?)	-	-	-	-	-	-	-	2.2
Navicula sp.	-	5.0	-	5.0	26.5	3.6	-	-
Ochromonas sp.	-	-	-	-	-	-	-	11.1
Pseudokephyrion hiemale	-	-	-	39.7	64.6	43.6	-	-
Synedra radians	16.3	11.6	5.0	1.7	-	7.3	-	-
Pyrrophyta and Cryptophyta								
Glenodinium sp.	-	-	1.7	3.3	3.3	-	-	-
Gymnodinium sp.	-	-	-	-	-	-	-	1.1
Peridinium inconspicuum	-	-	-	-	-	14.5	-	-
Peridinium sp.	-	-	-	3.3	-	18.1	-	-
Rhodomonas minuta	2.7	8.3	33.0	-	-	-	-	5.5
Unidentified	-	-	-	-	-	-	-	31.9
Total cells/ml		410.9	503.6	754.0	728.8	796.5	2162.8	76.0



SOUTH NARAO LAKE

LAKE NO. 18

SCALE METRES

0 100

(S) = COLLECTION SITE

Locality SOUTH NARAO LAKE

Site number 18
 Grid reference 11U/NG455967
 Elevation (metres/feet) 1715/5625
 Altitudinal belt subalpine
 Maximum depth (m) 6.3
 Surface area (hectares) 0.7

Sampling date	14/VI/73	29/VIII/73	28/II/74
Collection number (999-)	56	135	150
Time	1115	0915	1000
Air temperature (°C)	10.5	-	14.5
Sky	rain	clear	snow
Snow cover (m)	-	-	0.26
Ice cover (m)	-	-	0.71
Secchi disk (m)	2.5+	2.0+	-
pH	8.0	7.9	-
Conductivity (@25°C)	237	258	-
Samples collected			
Kick	-	-	-
Dredge	X	X	-
Phytoplankton	X	X	X
Macrophytes	-	X	-
Zooplankton	X	X	X
Shoreline	X	X	-
Shore trawl	X	X	-
Fish	-	-	-
Primary production	-	-	-
Water chemistry	X	X	-
Stream flow	-	-	-
Water temperature	m °C	m °C	m °C
	0 10.2	0 10.7	0 0
	1.0 10.1	1.0 10.4	1.0 0.6
	2.0 9.2	2.0 10.6	2.0 2.6
	2.5 9.2		

South Narao (Site 18)

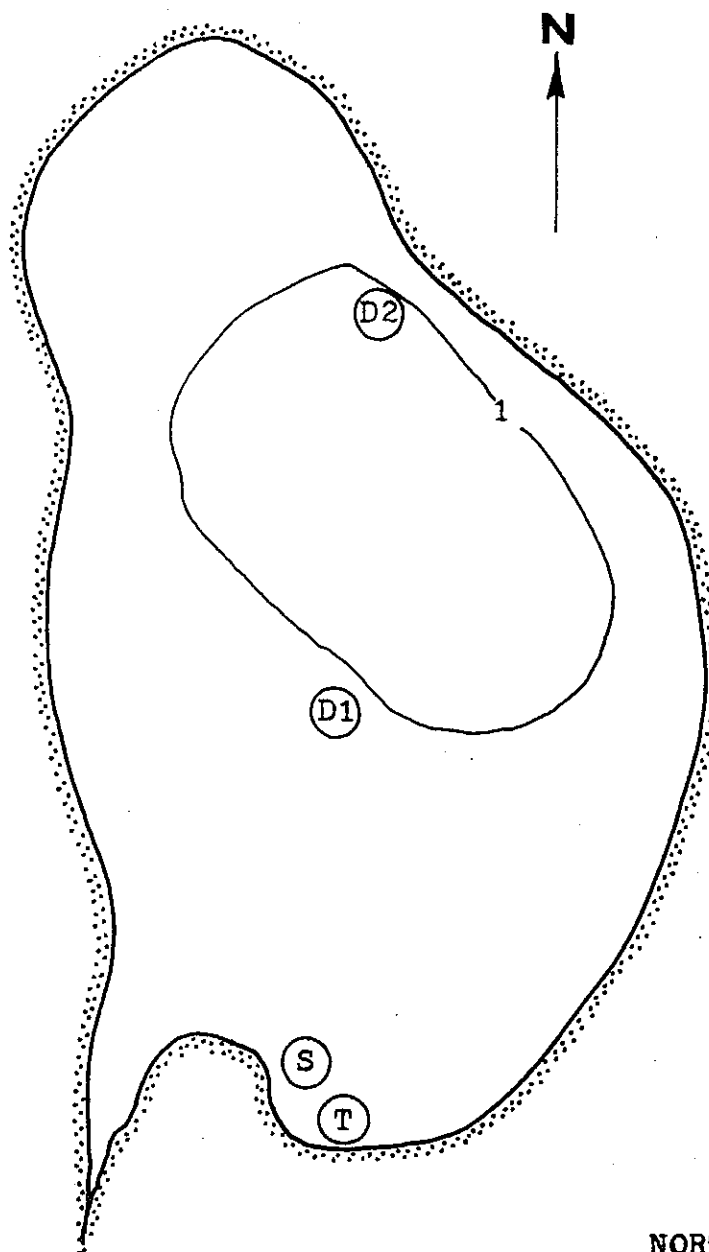
Summary of benthic invertebrate samples (numbers collected)

Coll. number	56	56	56	135	135	135
Sample type	D1	S	T	D1	S	T
Depth (m)	2.5	-	-	2.5	-	-
Total wet weight (g)	1.83	1.60	-	3.41	1.57	-
Oligochaeta						
Tubifex sp.	6	-	1	-	-	-
Rhynchelmis sp.	2	-	-	-	-	3
Hirudinoidea						
Helobdella stagnalis	-	-	-	-	-	2
Amphipoda						
Hyaella azteca	-	-	-	-	-	4
Ephemeroptera						
Centroptilum sp.	-	1	1	-	-	-
Trichoptera						
Glyptotaelius sp.	-	25	12	-	-	-
Limnephilidae	-	13	3	-	-	5
Diptera						
Heleidae						
Alluaudomyia sp.	1	-	11	2	2	3
Chironomidae						
Procladius sp.	10	-	1	-	-	5
Corynoneura sp.	-	-	-	-	2	1
Cricotopus sp.	-	1	7	4	-	-
Psectrocladius sp.	-	-	3	-	-	-
Chironomus sp.	246	-	-	270	1	-
Phaenopsectra sp.	-	-	-	-	6	5
Tanytarsus sp.	10	-	1	11	4	1
Odonata						
Aeshna interrupta	-	1	2	-	-	-
Ischnura perparva	-	-	1	-	-	-
Sympetrum sp.	-	2	1	-	-	-
Heteroptera						
Gerris comatus	-	3	-	-	-	-
Coleoptera						
Agabus tristis	-	1	-	-	-	-
Haliphus sp.	-	-	-	-	-	1
Dyticid larva	-	-	-	-	-	2
Acarina						
Arrenurus sp.	2	-	-	-	-	-
Lebertia sp.	4	-	2	12	-	1
Limnesia sp.	1	-	6	1	-	-
Araneae	1	-	-	-	-	1
Pelecypoda						
Pisidium conventus	1	6	-	6	-	-
Pisidium lilljeborgi	8	-	-	-	-	-
Pisidium ventricosum	-	2	-	-	-	-
Total number of invertebrates	292	51	52	306	15	34

SOUTH NARAO LAKE

Phytoplankton counts (cells/ml)

Species	Coll. No. (999) Depth (m)	56 0.5	135 0.5	135 2.0	150 0.5
Chlorophyta					
Ankistrodesmus sp.		3.6	29.0	290.3	-
Ankistrodesmus falcatus		-	-	-	1.8
Chlamydomonas sp.		7.3	-	7.3	54.3
Coelastrum microporum		-	-	87.1	-
Cosmarium sp.		3.6	-	-	-
Crucigenia quadrata		-	4790.0	3570.7	-
Lagerheimia ciliata		-	7.3	7.3	-
Lagerheimia longista		-	-	21.8	-
Oocystis borgei		-	36.3	79.8	-
Oocystis parva		-	1268.4	849.1	-
Scenedesmus bijuga		5.8	-	29.0	-
Scenedesmus obliquus		-	101.9	551.6	-
Sphaerocystis Schroeteri		-	58.1	-	-
Tetraedon minimum		-	7.3	14.5	1.8
Cyanophyta					
Anabaena sp.		-	-	7.3	-
Arthrospira jenneri		-	-	-	1.8
Oscillatoria sp.		36.3	-	-	-
Oscillatoria geminata		-	-	-	7.2
Oscillatoria limnetica		-	-	-	18.0
Oscillatoria rubescens		-	145.2	203.2	-
Chrysophyta					
Achnanthes sp.		-	14.5	-	-
Achnanthes exigua var. heterovalvata		-	-	-	1.8
Achnanthes microcephala		25.4	-	36.3	-
Chrysolykos planctonicus		10.9	-	-	-
Cyclotella sp.		10.9	166.9	355.6	-
Cymbella sp.		3.6	7.3	-	-
Dinobryon sertularia		-	7.3	-	-
Dinobryon sociale		36.7	-	7.3	-
Dinobryon sociale var. americanum		36.3	-	-	-
Kephyrion sp.		-	7.3	14.5	2.6
Kephyrion sp. A		144.1	14.5	21.8	-
Kephyrion sp. B		7.3	-	-	-
Kephyrion littorale		391.3	-	-	1.8
Navicula sp.		39.9	21.8	58.1	5.4
Nitzschia sp.		-	7.3	7.3	-
Ochromonas sp.		-	-	-	222.6
Pseudokephyrion parvum		10.9	-	7.3	-
Pyrrophyta and Cryptophyta					
Cryptomonas sp.		-	-	-	1.8
Cryptomonas erosa		7.3	21.8	72.6	-
Glenodinium sp.		3.6	-	-	-
Rhodomonas minuta		-	326.6	645.9	16.3
Total cells/ml		784.2	7038.8	6945.7	337.2



NORTH NARAO LAKE

LAKE NO. 19

SCALE METRES

0 50 100

DEPTH IN METRES

⊙ = COLLECTION SITE

Locality NORTH NARAO LAKE

Site number 19
 Grid reference 11U/NG455971
 Elevation (metres/feet) 1715/5625
 Altitudinal belt subalpine
 Maximum depth (m) 2.0
 Surface area (hectares) 3.0

Sampling date	14/VI/73	29/VIII/73	28/II/74
Collection number (999-)	57	134	151

Time	0900	0845	1200
Air temperature (°C)	8.8	8.5	14.5
Sky	cloudy	clear	snow
Snow cover (m)	-	-	0.3
Ice cover (m)	-	-	0.76
Secchi disk (m)	1.0+	1.0+	-
pH	8.39	7.9	-
Conductivity (@25°C)	209	209	-

Samples collected

Kick	-	-	-
Dredge	X	X	-
Phytoplankton	X	X	-
Macrophytes	-	X	-
Zooplankton	X	X	-
Shoreline	X	X	-
Shore trawl	X	X	-
Fish	-	-	-
Primary production	-	X	-
Water chemistry	X	X	-
Stream flow	-	-	-

Water temperature	m	°C	m	°C	m	°C
	0	10.8	0	8.1	0	0
	0.5	10.7	0.8	7.3		
	1.0	9.6				

North Narao (Site 19)

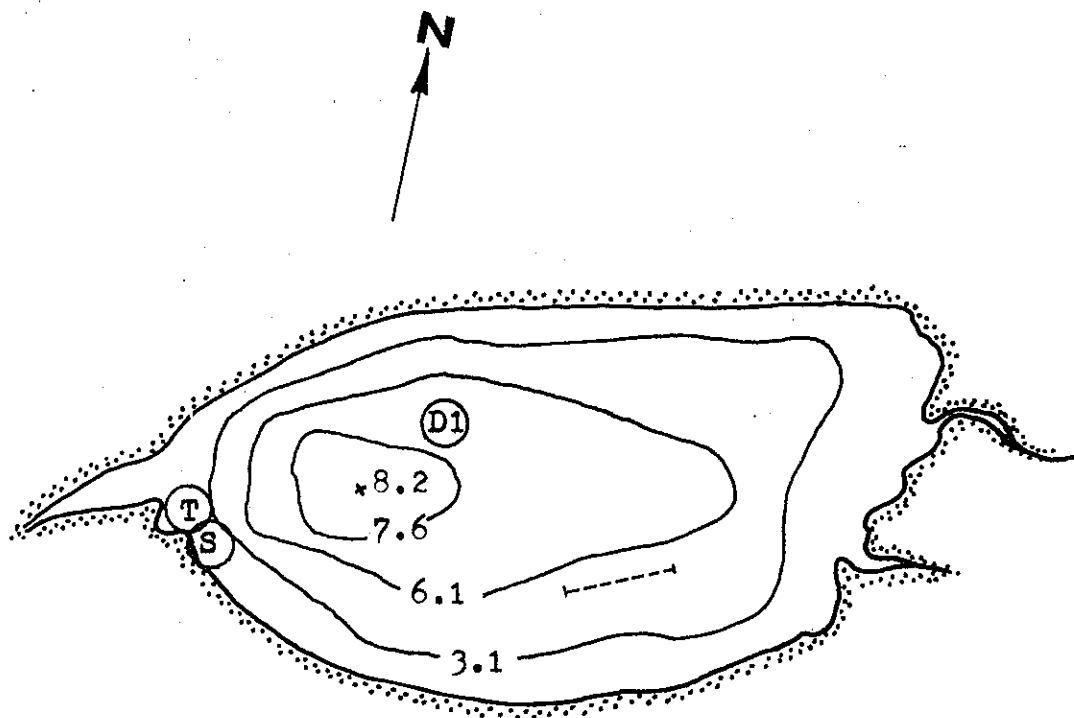
Summary of benthic invertebrate samples (numbers collected)

Coll. number	57	57	57	57	134	134	134	134
Sample type	D1	D2	S	T	D1	D2	S	T
Depth (m)	0.6	0.9	-	-	0.6	0.9	-	-
Total wet weight (g)	1.24	2.24	5.64	-	1.47	3.25	1.22	-
Oligochaeta								
Limnodrilus sp.	7	-	-	-	1	-	-	-
Rhynchelmis sp.	4	-	-	-	4	18	-	-
Turbellaria								
Mesostoma (arcticum ?)	-	-	4	1	-	-	-	-
Hirudinoidea								
Helobdella stagnalis	-	-	1	-	4	1	-	-
Ephemeroptera								
Centroptilum sp.	-	-	1	-	-	-	1	-
Parameletus sp.	-	-	19	5	-	-	-	-
Siphonurus (occidentalis ?)	-	-	20	14	-	-	1	-
Trichoptera								
Limnephilidae	-	-	13	3	-	-	15	9
Glyptotaelius sp.	-	-	26	12	-	-	-	-
Diptera								
Heleidae								
Alluaudomyia sp.	-	-	1	-	-	-	-	-
Chironomidae								
Procladius sp.	29	32	-	-	8	12	-	1
Cricotopus sp. A.	-	-	-	-	-	1	-	-
Psectrocladius sp.	14	9	-	-	-	-	-	-
Chironomus sp.	-	4	-	-	-	35	-	-
Cryptochironomus sp.	8	1	-	-	-	1	-	-
Pseudochironomus sp.	6	-	-	-	-	-	-	-
Phaenopsectra sp.	24	12	13	-	3	-	-	-
Tanytarsus sp.	26	10	6	-	1	-	-	-
Collembola								
Podura aquatica	-	-	17	-	-	-	-	-
Odonata								
Aeshna palmata	-	-	-	-	-	-	2	-
Coleoptera Unk.	1	-	-	-	-	-	-	-
Misc. Insecta	-	-	-	-	-	-	-	1
Acarina								
Arrenurus sp.	3	1	3	2	5	3	-	-
Hygrobatas sp.	-	-	7	5	-	-	-	-
Lebertia sp.	-	2	-	-	-	-	-	-
Limnesia sp.	1	2	4	-	1	-	-	-
Araneae	-	-	-	-	-	-	1	-
Gastropoda								
Lymnaea stagnalis	-	-	5	-	-	-	-	-
Lymnaea arctica	-	7	15	4	1	8	4	1
Lymnaea elodes	5	2	4	-	5	15	2	-
Gyalus parvus	-	2	-	-	-	2	-	-
Gyalus sp.	-	2	-	-	-	-	-	-
Pelecypoda								
Pisidium conventus	-	3	5	-	-	-	-	-
Pisidium casternatum	-	3	2	1	-	-	-	-
Pisidium ventricosum	-	3	-	-	-	4	-	-
Total number of invertebrates	128	95	166	47	33	100	26	12

NORTH NARAO LAKE

Phytoplankton counts (cells/ml)

Species	Coll. No. (999)	57	134
	Depth (m)	0.5	0.5
Chlorophyta			
Chlamydomonas	19.8	8.3	
Cosmarium sp.	3.3	-	
Crucigenia quadrata	6.6	105.6	
Oocystis parva	1.7	47.9	
Scenedesmus bijuga	9.9	6.6	
Scenedesmus quadricaudata	6.6	-	
Tetraedon minimum	-	1.7	
Cyanophyta			
Merismopedia punctata	343.2	-	
Merismopedia tenuissima	26.4	-	
Oscillatoria sp.	29.7	-	
Chrysophyta			
Acanthos sp.	28.1	19.8	
Acanthos microcephala	99.0	18.2	
Chrysolykos planctonicus	3.3	-	
Bitrichia chodatii	3.3	1.7	
Cyclotella sp.	-	1.7	
Cymbella sp.	16.5	11.6	
Diatoma hiemale	-	24.8	
Diatoma hiemale			
var. mesodon	1.7	-	
Dinobryon sociale	16.5	-	
Dinobryon sociale			
var. americanum	64.4	-	
Fragilaria crotonensis	14.9	-	
Fragilaria pinnata	-	3.3	
Gomphonema acuminatum	1.7	-	
Hannea arcus	3.3	-	
Kephyrion sp.	-	49.5	
Kephyrion sp. A	141.9	9.9	
Kephyrion sp. B	5.0	-	
Kephyrion littorale	250.8	-	
Navicula sp.	79.2	47.9	
Neidium binode	-	1.7	
Nitzschia sp.	5.0	5.0	
Opephora sp.	-	1.7	
Pseudokephyrion parvum	-	1.7	
Pyrrophyta and Cryptophyta			
Cryptomonas erosa	-	94.1	
Cryptomonas ovata	-	1.7	
Glenodinium sp.	5.0	-	
Rhodomonas minuta	-	282.2	
Total cells/ml		1320.9	876.9

**WAPTA LAKE**

LAKE NO. 20

SCALE METRES

0 200

DEPTH IN METRES

⊙ = COLLECTION SITE
----- = GILL NET SITE

Locality WAPTA LAKE

Site number 20
 Grid reference 11U/NG454987
 Elevation (metres/feet) 1590/5203
 Altitudinal belt subalpine
 Maximum depth (m) 8.2
 Surface area (hectares) 24.1

Sampling date	17/VI/71	4/VIII/71	12/VI/73	30/VIII/73	3/I/74
Collection number (999-)	5	16	59	136	145
Time	1230	1800	1045	1200	1200
Air temperature (°C)	9.5	26	11	7.4	-16
Sky	cloudy	clear	cloudy	cloudy	clear
Snow cover (m)	-	-	-	-	0.30
Ice cover (m)	-	-	-	-	0.57
Secchi disk (m)	8.0	4.0	8.0+	7.5	-
pH	8.0	8.2	7.9	7.9	-
Conductivity (@25°C)	143	137	198	150	-

Samples collected

Kick	-	-	-	-	-
Dredge	-	X	-	-	X
Phytoplankton	X	X	X	X	X
Macrophytes	-	-	X	-	-
Zooplankton	X	X	X	X	X
Shoreline	X	X	X	-	-
Shore trawl	X	X	X	-	-
Fish	-	-	(13/VI/73)	-	-
Primary production	-	-	X	X	-
Water chemistry	X	-	X	-	-
Stream flow	-	-	-	-	-

Water temperature	m	°C	m	°C	m	°C	m	°C	m	°C
	0	5.5	0	11.0	0	6.8	0	7.2	0	0
	1	5.5	1	11.0	1	6.8	1	7.2	1	0.4
	2	5.5	2	10.5	2	6.8	2	7.1	2	0.9
	4	5.5	4	10.0	4	6.0	4	7.1	3	1.4
	6	5.5	6	10.0	6	6.0	6	7.1	5	1.7
	8	5.5	8	10.0	8	6.3	8	6.8	7	3.6

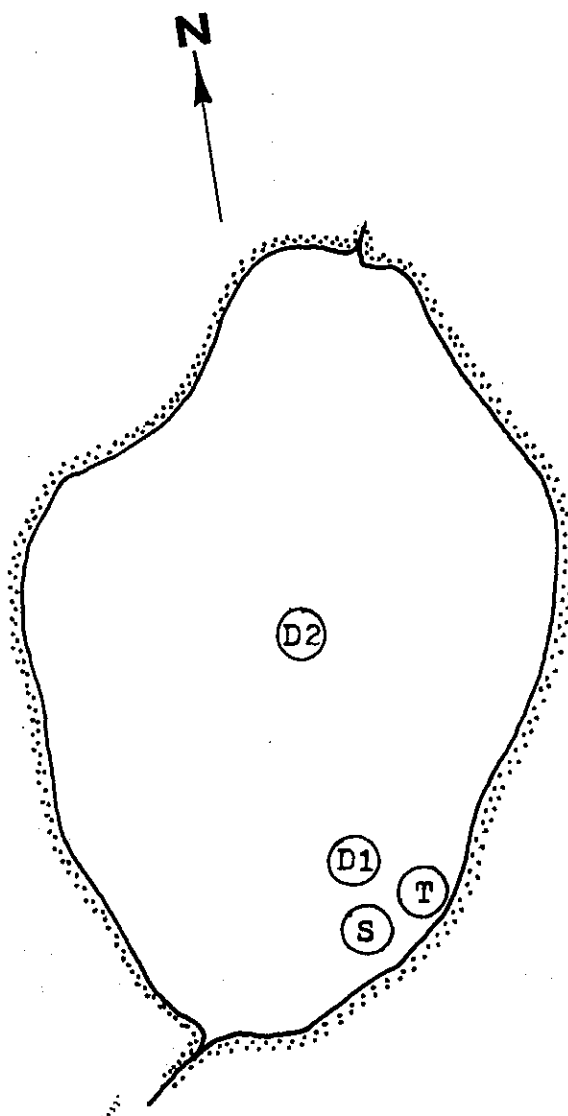
Wapta Lake (Site 20)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	5	5	16	16	16	59	59	145
Sample type	S	T	D1	S	T	S	T	D1
Depth (m)	6.0	-	6.0	-	-	-	-	7.0
Total wet weight (g)	-	-	-	-	-	2.17	-	-
Oligochaeta								
Rhynchelmis sp.	-	-	11	-	23	4	2	8
Amphipoda								
Gammarus lacustris	-	-	-	1	-	2	1	-
Ephemeroptera								
Ameletus sp.	26	-	-	2	-	11	-	-
Siphonurus sp.	6	-	-	21	-	2	6	-
Parametetus sp.	5	-	-	-	-	-	-	-
Plecoptera								
Alloperla (fidelis ?)	2	-	-	4	-	1	-	-
Isoperla ebria	-	-	-	-	-	8	-	-
Acroneuria pacifica	-	-	-	-	-	1	-	-
Trichoptera								
Hesperophylax sp.	-	-	-	-	-	1	-	-
Limnophilidae sp.	18	-	-	1	-	3	3	-
Diptera								
Tipulidae	-	-	-	9	-	-	1	-
Empididae	-	-	-	-	-	-	1	-
Chironomidae								
Procladius sp.	-	521	298	-	-	-	4	305
Psectrocladius sp.	-	-	-	-	-	-	45	-
Cryptochironomus sp.	-	-	-	-	-	-	5	-
Tanytarsus sp.	-	423	408	-	-	-	33	344
Pentaneura sp.	2	-	-	-	-	-	-	-
Unidentified	-	2	21	2	-	-	-	-
Diptera pupae	-	2	-	-	-	42	-	-
Misc. Insecta	-	-	1	-	-	-	-	-
Acarina							11	
Lebertia sp.	-	-	-	-	-	-	11	-
Pelecypoda								
Pisidium nitidum	-	-	7	-	-	1	-	-
Pisidium conventus	-	-	12	-	-	-	-	14
Pisidium subtruncatum	-	-	4	-	-	-	-	-
Total number of invertebrates	58	948	762	40	23	16	123	671

Phytoplankton counts (cells/ml)

Species	Coll. No. (999)	59	59	59	136	136	136	146	146	146
	Depth (m)	0.5	2.0	6.0	0.5	2.0	6.0	1.0	3.0	6.0
Chlorophyta										
Chlamydomonas sp.	-	-	-	-	-	-	-	-	0.7	-
Crucigenia quadrata	-	-	5.0	-	-	-	-	-	-	-
Oocystis parva	-	-	2.5	-	-	-	-	-	-	-
Scenedesmus bijuga	-	10.9	-	-	-	-	-	-	-	-
Ulothrix sp.	-	-	-	-	-	-	-	11.9	-	-
Ulothrix subconstricta	-	-	-	-	-	-	-	-	-	11.9
Cyanophyta										
Merismopedia punctata	-	-	-	-	171.6	-	-	-	-	-
Merismopedia glauca	-	-	-	-	-	-	-	-	-	15.4
Chrysophyta										
Achnanthes sp.	26.0	38.1	38.4	64.4	74.3	82.5	6.3	8.4	19.6	-
Achnanthes exigua	-	-	-	-	-	-	0.7	-	-	-
Achnanthes flexella	-	-	-	-	-	-	-	-	-	0.7
Achnanthes lanceolata	-	-	-	-	-	-	-	-	-	-
var. dubia	5.0	19.1	-	-	-	-	-	-	-	-
Achnanthes linearis	-	-	-	-	-	-	-	-	-	-
(near curta)	-	-	-	-	-	-	-	-	-	0.7
Achnanthes microcephala	2.3	-	-	-	-	-	-	-	-	-
Achnanthes minutissima	-	-	-	-	-	-	-	-	-	2.1
Amphipleura pellucida	-	-	-	-	-	1.7	-	-	-	-
Chrysoikos skujae	-	2.7	-	-	-	-	-	-	-	-
Cocconeis placentula	-	-	-	1.7	1.7	1.7	-	-	-	-
Cyclotella sp.	-	-	-	9.9	-	-	-	-	-	-
Cymbella sp.	6.2	2.7	2.5	5.0	8.3	-	-	-	-	-
Cymbella ventricosa	-	-	-	-	-	-	-	0.7	1.4	-
Diatoma sp.	-	-	-	-	21.5	1.7	-	-	-	-
Diatoma hiemale var.	-	-	-	-	-	-	-	-	-	-
mesodon	3.7	-	18.6	-	-	-	-	-	-	0.7
Dinobryon cylindricum	-	2.7	-	-	-	-	-	-	-	-
Dinobryon sociale	-	-	-	-	-	-	0.7	-	-	-
Dinobryon sociale var.	-	-	-	-	-	-	-	-	-	-
americanum	-	-	-	1.7	-	-	-	-	-	-
Diploneis puella	-	-	-	-	-	-	-	-	-	0.7
Eunotia sp.	2.5	-	-	-	-	-	-	-	-	-
Fragilaria brevistriata	-	-	-	-	-	-	-	-	-	1.4
Fragilaria brevistriata	-	-	-	-	-	-	-	-	-	-
var. capitata	-	-	-	-	-	-	-	-	-	1.4
Fragilaria construens	-	-	-	-	-	-	-	-	-	0.7
Fragilaria crotonensis	-	-	-	-	-	-	0.7	-	-	-
Gomphonema sp.	1.2	-	1.2	1.7	-	-	-	-	-	-
Gomphonema olivaceum	-	-	-	-	-	-	-	-	-	0.7
Hannea arcus	5.0	5.4	5.0	1.7	-	5.0	-	-	-	-
Kephyrion sp.	2.5	5.4	-	90.8	78.3	47.9	-	1.4	2.1	-
Kephyrion littorale	-	-	-	13.2	16.5	28.1	-	-	-	-
Monosiga varians	-	-	-	-	-	-	-	9.8	-	-
Navicula sp.	17.3	32.2	32.2	21.5	19.8	14.9	0.7	3.5	7.0	-
Navicula elginensis	-	-	-	-	-	-	-	-	-	0.7
Navicula meniscula var.	-	-	-	-	-	-	-	-	-	-
upsaliensis	1.2	-	-	-	-	-	-	-	-	-
Nitzschia sp.	2.5	-	-	-	-	-	-	-	-	-
Pseudokephyrion sp.	-	-	-	-	-	-	0.7	4.2	4.2	-
Pseudokephyrion hiemale	-	-	-	38.0	26.4	6.6	-	-	-	0.7
Pseudokephyrion parvum	-	-	-	3.3	19.8	8.3	-	-	-	-
Synedra sp.	2.5	-	1.2	-	-	-	-	-	-	-
Synedra ulna	1.2	-	-	-	-	-	-	-	-	-
Cryptophyta										
Cryptomonas sp.	-	-	-	-	-	-	0.7	-	-	-
Rhodomonas minuta	-	-	2.5	-	-	-	-	0.7	-	-
Unidentified	-	-	-	-	-	-	-	6.3	11.9	-
Total cells/ml										
		79.1	119.7	109.1	252.9	439.2	198.4	22.4	35.7	83.3



MIDDLE MORNING GLORY LAKE

LAKE NO. 22

SCALE METRES

0 50

⊙ = COLLECTION SITE

Locality MIDDLE MORNING GLORY LAKE

Site number 22
 Grid reference 11U/NG444903
 Elevation (metres/feet) 1997/6550
 Altitudinal belt subalpine
 Maximum depth (m) 3.0
 Surface area (hectares) 1.0

Sampling date	12/VII/73	8/VIII/74
Collection number (999-)	104	157
Time	1400	1300
Air temperature (°C)	-	-
Sky	clear	clear
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	3.0+	-
pH	8.2	-
Conductivity (@25°C)	125	-
Samples collected		
Kick	-	-
Dredge	X	-
Phytoplankton	X	-
Macrophytes	-	-
Zooplankton	X	-
Shoreline	X	-
Shore trawl	X	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-
Water temperature	-	m °C 0 7.2

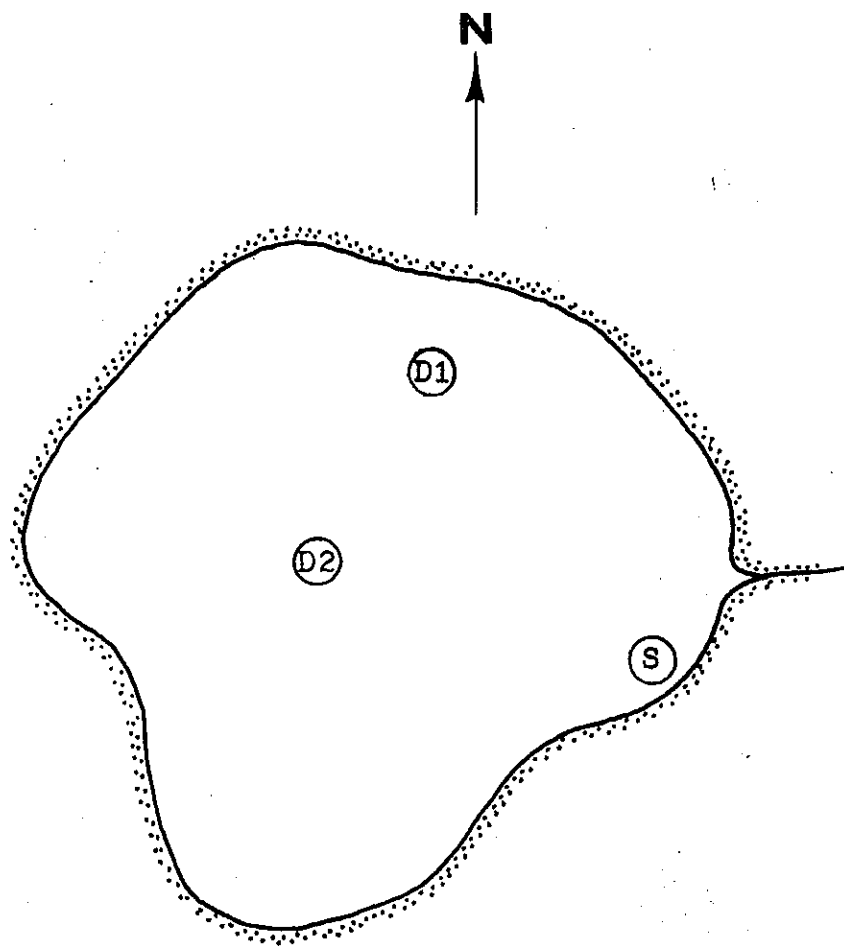
Mid Morning Glory Lake (Site 22)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	104	104	104	104
Sample type	D1	D2	S	T
Depth (m)	2	2.5	-	-
Total wet weight (g)	0.12	0.11	0.11	-
Oligochaeta				
Tubifex sp.	-	-	-	1
Rhynchelmis sp.	1	2	-	-
Ephemeroptera				
Siphonurus (occidentalis ?)	-	-	3	-
Ameletus sp.	-	-	3	-
Epeorus (iron) sp. A.	-	-	2	-
Diptera				
Chironomidae				
Procladius sp.	7	6	-	-
Corynoneura sp.	-	-	9	-
Cricotopus sp. A.	1	-	-	-
Eukiefferiella sp.	-	-	9	-
Tanytarsus sp.	5	15	3	-
Unidentified	-	1	3	-
Aerial diptera	-	-	-	7
Misc. Insecta	-	2	7	7
Acarina				
Lebertia sp.	-	-	1	-
Total number of invertebrates	14	26	40	15

Phytoplankton counts (cells/ml)

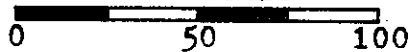
Species	Coll. No.	999-104
	Depth (m)	0.5
Chlorophyta		
Chlamydomonas sp.		10.9
Chrysophyta		
Acanthos sp.		32.7
Cymbella sp.		5.4
Cymbella ventricosa		8.2
Diatoma vulgare		10.9
Gomphonema olivaceum		2.7
Hannea arcus		2.7
Kephyrion sp.		2.7
Navicula sp.		16.3
Synedra ulna		2.7
Cryptophyta		
Rhodomonas minuta		87.1
Total cells/ml		182.3



UPPER MORNING GLORY LAKE

LAKE NO. 23

SCALE METRES



Ⓢ = COLLECTION SITE

Locality UPPER MORNING GLORY LAKE

Site number 23
 Grid reference 11U/NG440902
 Elevation (metres/feet) 2006/6580
 Altitudinal belt subalpine
 Maximum depth (m) 4.5
 Surface area (hectares) 1.7

Sampling date	12/VII/73	8/VIII/74
Collection number (999-)	103	156
Time	1200	1200
Air temperature (°C)	-	-
Sky	clear	clear
Snow cover (m)	-	-
Ice cover (m)	30%	-
Secchi disk (m)	4.5+	-
pH	8.2	-
Conductivity (@25°C)	127	-
Samples collected		
Kick	-	-
Dredge	X	-
Phytoplankton	X	-
Macrophytes	-	-
Zooplankton	X	-
Shoreline	X	-
Shore trawl	-	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-
Water temperature	-	m °C 0 5.7

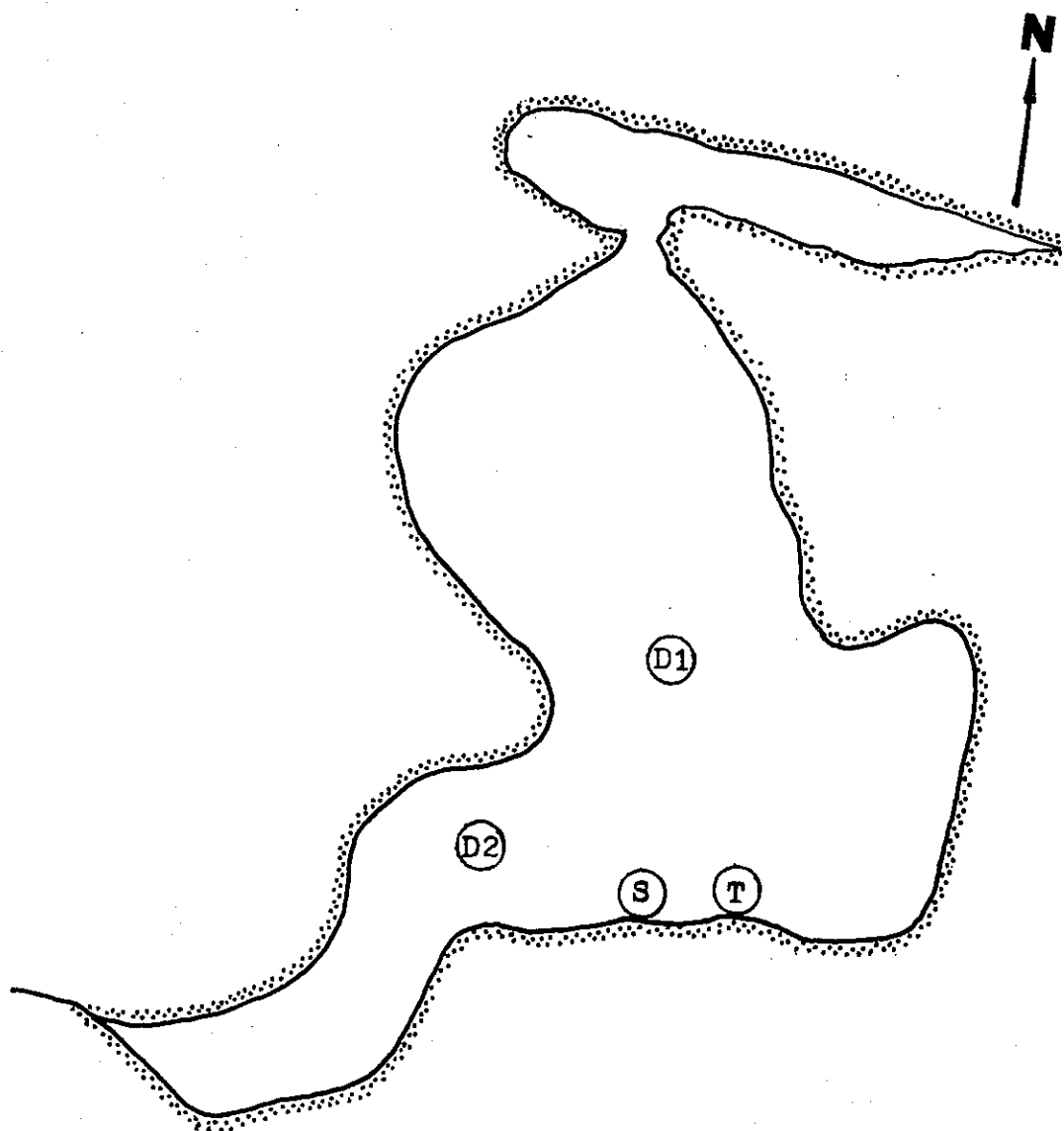
Upper Morning Glory (Site 23)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	103	103	103
Sample type	D1	D2	S
Depth (m)	2	7	-
Total wet weight (g)	0.18	0.11	0.34
Ephemeroptera			
Siphonurus (occidentalis ?)	-	-	18
Ameletus sp.	-	-	2
Plecoptera			
Arcynopteryx aurea	-	-	1
Diptera			
Chironomidae			
Eukiefferiella sp.	2	1	-
Phaenopsectra sp.	14	-	2
Tanytarsus sp.	12	-	2
Unidentified	-	-	2
Diptera pupae	6	-	-
Coleoptera			
Hydroporus compertus	-	-	3
Acarina			
Lebertia sp.	-	-	1
Total number of invertebrates	34	1	31

Phytoplankton counts (cells/ml)

Species	Coll. No.	999-1.3
	Depth (m)	0.5
Chrysophyta		
Acanthos sp.		23.5
Cymbella sp.		8.7
Diatoma hiemale var. mesodon		1.2
Fragilaria pinnata		8.7
Navicula sp.		12.4
Nitzschia sp.		1.2
Pyrrophyta		
Dinoflagellate sp.		9.9
Cryptophyta		
Rhodomonas minuta		8.7
Total cells/ml		74.3

LINDA LAKE

LAKE NO. 24

SCALE METRES

0 50 100

DEPTH IN METRES

Ⓢ = COLLECTING SITE

Locality	LINDA LAKE
Site number	24
Grid reference	11U/NG437909
Elevation (metres/feet)	2098/6880
Altitudinal belt	subalpine
Maximum depth (m)	12.0
Surface area (hectares)	4.0

Sampling date	12/VII/73	8/VIII/74
Collection number (999-)	102	155
Time	1000	1000
Air temperature (°C)	-	-
Sky	clear	clear
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	11.0+	-
pH	8.1	-
Conductivity (@25°C)	172	-
Samples collected		
Kick	-	-
Dredge	X	-
Phytoplankton	X	-
Macrophytes	-	-
Zooplankton	X	-
Shoreline	X	-
Shore trawl	X	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-
Water temperature	m °C	m °C
	0 7.4	0 7.7
	2 7.2	
	5 6.6	
	7 5.8	
	10 5.9	

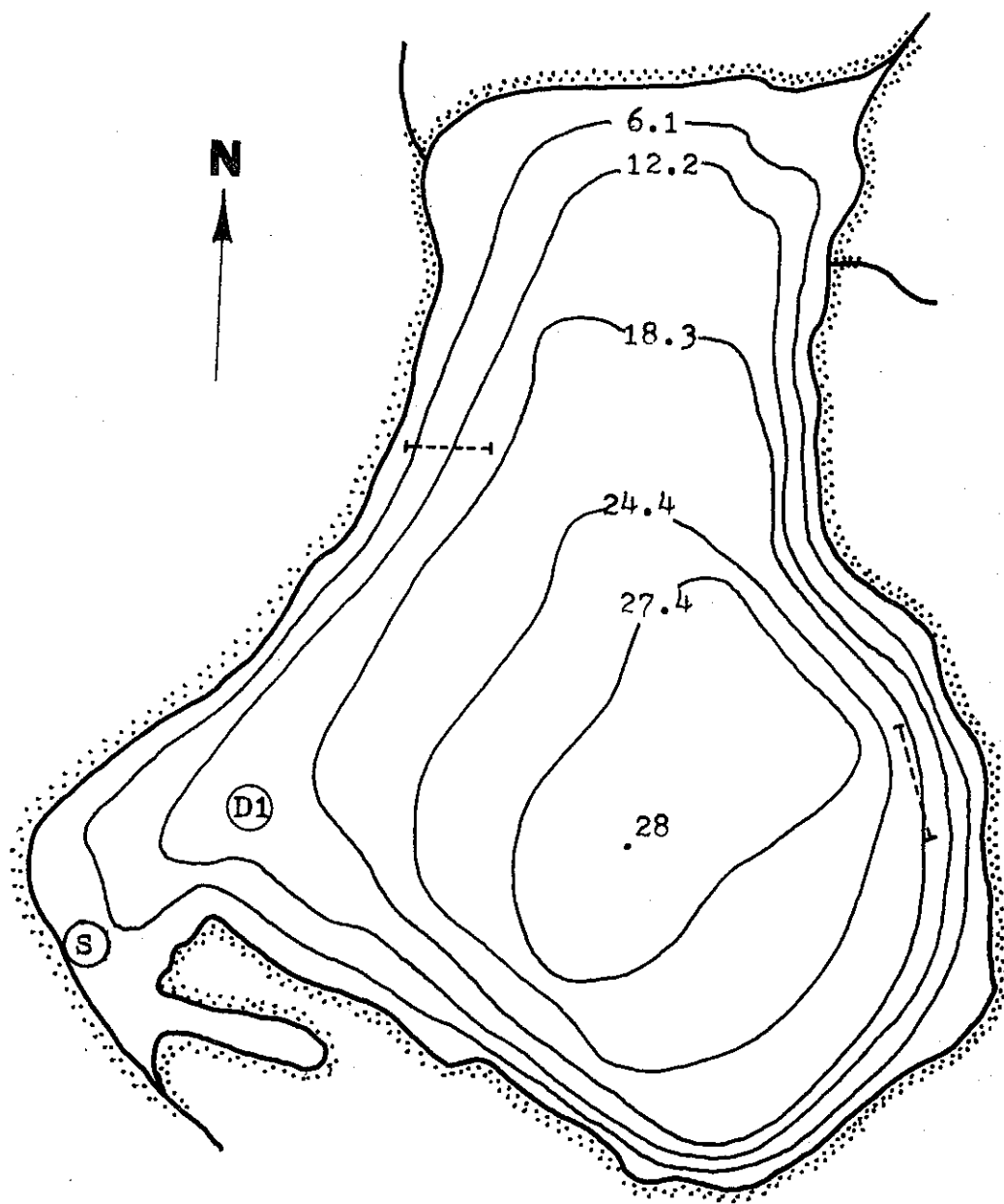
Linda Lake (Site 24)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	102	102	102	102
Sample type	D1	D2	S	T
Depth (m)	11	3.2	-	-
Total wet weight (g)	0.01	0.01	1.30	-
Oligochaeta				
Limnodrilus sp.	-	-	-	2
Amphipoda				
Gammarus lacustris	-	-	6	4
Trichoptera				
Hesperophylax sp.	-	-	1	-
Limnephilidae	-	-	5	-
Diptera				
Chironomidae				
Pentaneura sp.	-	-	1	-
Corynoneura sp.	12	16	122	-
Cricotopus sp.	-	-	-	1
Tanytarsus sp.	6	-	-	-
Unidentified	2	1	-	-
Diptera pupae	1	-	1	-
Misc. Insecta	-	-	3	-
Acarina				
Lebertia sp.	-	-	-	2
Total number of invertebrates	21	17	139	9

Phytoplankton counts (cells/ml)

Species	Coll. No. Depth (m)	999-102 0.5
Chlorophyta		
Ankistrodesmus sp.		3.3
Chlamydomonas sp.		6.6
Chrysophyta		
Acananthes sp.		1.7
Cyclotella minuta		95.7
Cymbella sp.		1.7
Kephyrion sp.		47.9
Navicula sp.		3.3
Synedra sp.		47.9
Synedra acus		5.0
Synedra ulna		3.3
Pyrrophyta		
Woloszynkia sp. (?)		1.7
Cryptophyta		
Rhodomonas minuta		8.3
Total cells/ml		226.4



EMERALD LAKE

LAKE NO. 26

SCALE METRES

0 500

DEPTH IN METRES

(S) = COLLECTING SITE

--- = GILL NET SITE

Locality EMERALD LAKE

Site number 26
 Grid reference 11U/NG327990
 Elevation (metres/feet) 1300/4272
 Altitudinal belt subalpine
 Maximum depth (m) 28.0
 Surface area (hectares) 116

Sampling date	17/VI/71	4/VIII/71	10/IX/73	24/I/74
Collection number (999-)	4	15	139	146

Time	0830	1300	1200	1200
Air temperature (°C)	12	26	17	-1
Sky	rain	clear	clear	cloudy
Snow cover (m)	-	-	-	0.35
Ice cover (m)	-	-	-	0.44
Secchi disk (m)	2.0	1.0	5.2	-
pH	8.1	8.2	8.2	-
Conductivity (@25°C)	242	198	220	-

Samples collected

Kick	-	-	-	-
Dredge	X	-	-	X
Phytoplankton	-	-	X	X
Macrophytes	-	-	X	-
Zooplankton	X	X	X	X
Shoreline	X	X	X	-
Shore trawl	X	X	-	-
Fish	(14/VI/73)			
Primary production	-	-	X	-
Water chemistry	X	-	X	-
Stream flow	-	-	-	-

Water temperature		m	°C	m	°C	m	°C	m	°C
0	9.2	0	17.0	0	12.8	0	0.5		
1	9.0	1	16.0	1	12.6	1	2.0		
2	7.5	2	13.5	2	12.4	2	4.0		
4	7.0	4	11.0	4	11.8	4	4.0		
6	7.0	6	10.0	7	10.8	8	4.1		
8	6.5	8	9.0	10	9.5	12	4.6		
10	5.5	10	7.5	15	5.1	16	4.1		
15	5.0	12	6.0	20	4.6				
20	5.0	14	6.0	26	4.5				
22	5.0	16	5.5						
		18	5.0						
		20	5.0						
		22	5.0						

Emerald Lake (Site 26)

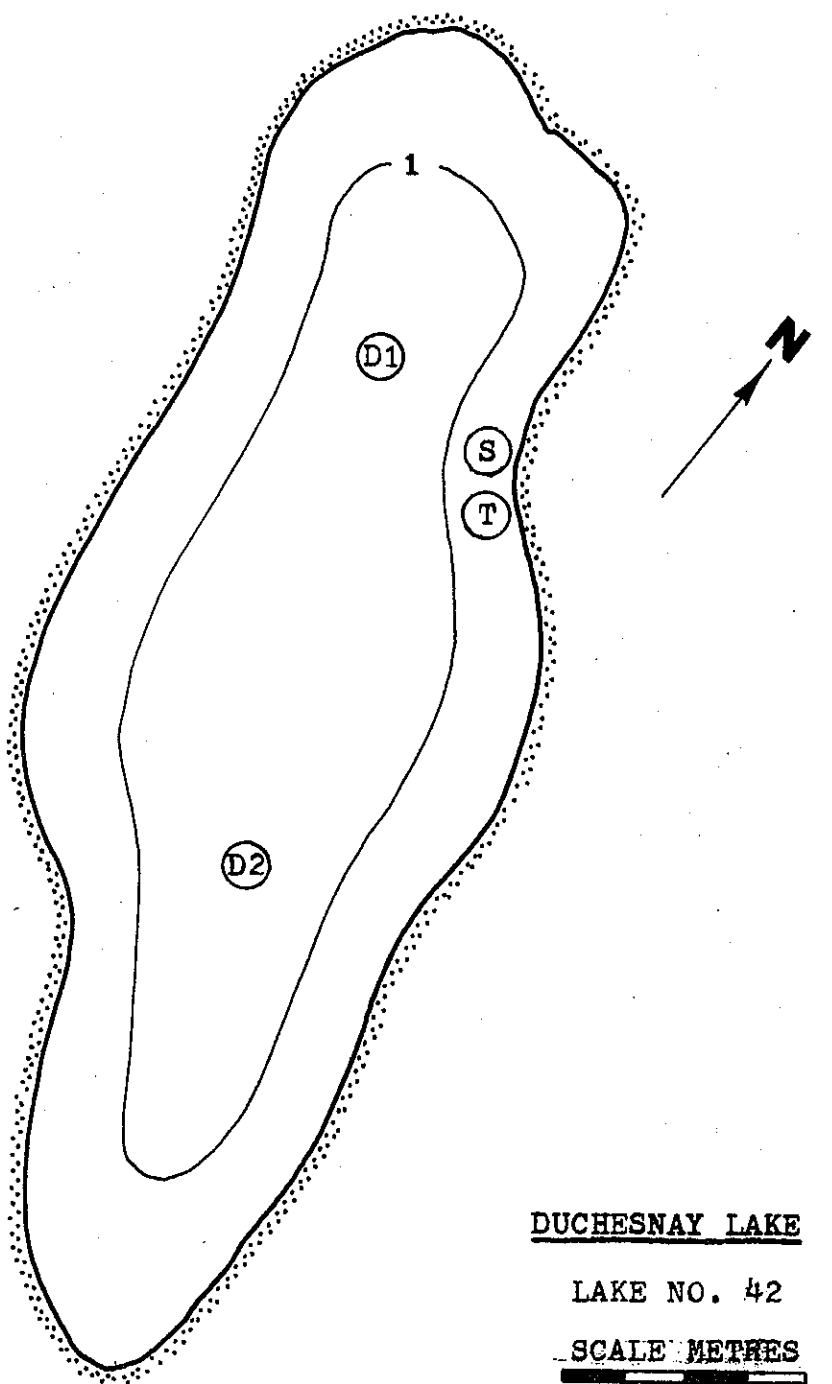
Summary of benthic invertebrate samples (numbers collected)

Coll. number	4	4	4	15	15	139	146
Sample type	D1	S	T	S	T	S	D1
Depth (m)	15	-	-	-	-	-	16
Total wet weight (g)	-	-	-	-	-	9.92	0.01
Oligochaeta							
Limnodrilus	-	-	-	-	6	-	9
Hirudinoidea							
Helobdella stagnalis	-	-	-	-	1	-	1
Amphipoda							
Hyalella azteca	-	122	-	27	-	6	-
Ephemeroptera							
Baetis sp. A.	-	-	-	3	-	-	-
Siphonurus (occidentalis ?)	-	-	-	1	-	-	-
Paraleptophelbia bicornuta	-	-	-	44	-	6	-
Centroptilum sp.	-	1	-	11	2	21	-
Trichoptera							
Hesperophylax sp.	-	-	-	-	-	1	-
Limnephilidae	-	12	-	5	-	-	-
Diptera							
Tipulidae	-	-	-	2	-	-	-
Chironomidae							
Pentaneura sp.	3	1	2	2	6	1	-
Procladius sp.	-	-	-	-	1	-	-
Tanytarsus sp.	-	-	-	4	1	-	-
Chironomus sp.	20	1	-	-	-	-	-
Chironomus (limnochironomus) sp.	28	-	-	-	60	-	-
Odonata							
Aeshna palmata	-	-	-	-	-	5	-
Aeshna interrupta	-	11	-	1	-	-	-
Gastropoda							
Lymnaea arctica	-	46	-	14	-	25	-
Gyrinus parvus	-	1	-	-	-	1	-
Physia gyrina	-	6	-	-	-	2	-
Gyrinus circumstriatus	-	1	-	6	-	-	-
Pelecypoda							
Pisidium casternatum	1	-	-	-	1	-	-
Total number of invertebrates	52	202	2	120	78	67	10

EMERALD LAKE

Phytoplankton counts (cells/ml)

Species	Coll. No. (999)	139	139	139	146	146
	Depth (m)	0.5	4.0	10.0	1.0	10.0
Chlorophyta						
Chlamydomonas sp.		-	8.3	14.9	-	1.5
Crucigenia quadrata		-	-	-	6.0	-
Dictyosphaerium pulchellum		-	-	-	-	45.0
Chrysophyta						
Acnanthes sp.		1.7	8.3	8.3	-	-
Acnanthes flexella		-	1.7	-	-	-
Acnanthes microcephala		1.7	-	-	-	-
Bitrichia chodatii		1.7	6.6	5.0	-	-
Chrysoikos gracilis		-	-	-	1.5	-
Cyclotella minuta		-	9.9	3.3	13.5	136.5
Cymbella sp.		-	-	1.7	-	-
Dinobryon sp.		-	-	-	1.5	-
Dinobryon attenuatum		-	-	-	1.5	-
Dinobryon cylindricum		-	-	-	1.5	15.0
Dinobryon sociale		134.0	371.3	372.9	1.5	-
Dinobryon sociale var. americanum		-	3.3	3.3	-	-
Kephyrion spp.		13.3	47.9	33.0	7.3	7.5
Kephyrion littorale		-	5.0	5.0	13.5	15.0
Kephyriopsis sp.		-	-	-	12.0	6.0
Navicula sp.		3.3	6.6	5.0	-	-
Pseudokephyrion sp.		-	-	-	4.5	-
Synedra sp.		-	-	3.3	-	-
Synedra radians		-	-	-	3.0	36.0
Pyrrophyta						
Ceratium hirundinella		-	3.3	1.7	-	-
Woloszynkia sp.		-	-	-	1.5	-
Gymnodinium helveticum		-	-	-	-	1.5
Cryptophyta						
Rhodomonas minuta		-	-	1.7	10.5	22.5
Zooflagellate (?)		-	-	500.4	-	-
Cryptomonas sp.		3.3	6.6	41.3	7.3	1.5
Total cells/ml		159.0	478.8	1000.5	320.6	303.0

**DUCHESNAY LAKE**

LAKE NO. 42

SCALE METRES

0 100

(S) = COLLECTION SITE
DEPTH IN METRES

Locality DUCHESNAY LAKE

Site number 42
 Grid reference 11U/NH347080
 Elevation (metres/feet) 1595/5230
 Altitudinal belt subalpine
 Maximum depth (m) 1.0
 Surface area (hectares) 3.5

Sampling date 14/VIII/73
 Collection number (999-) 124

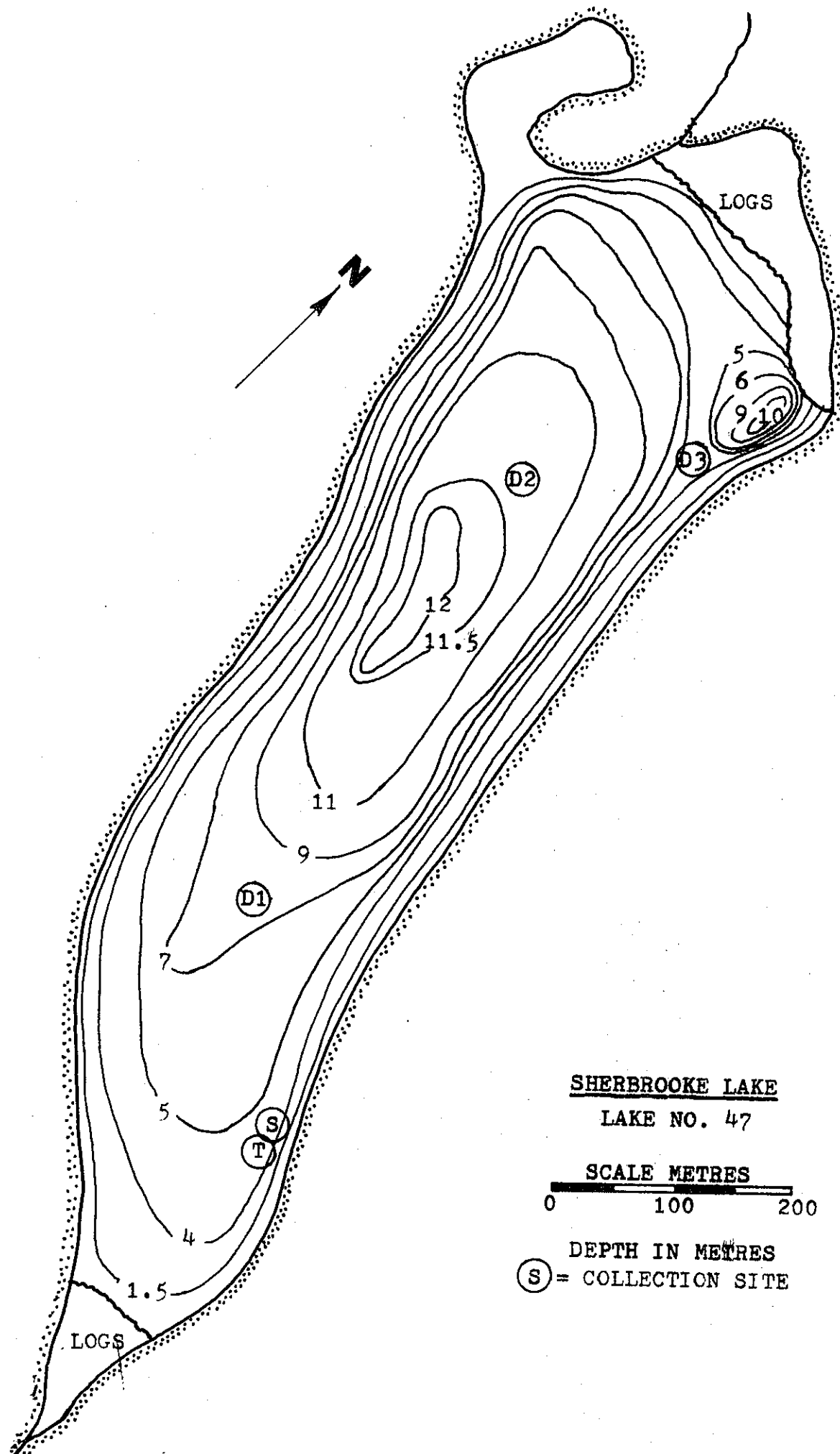
Time 1300
 Air temperature (°C) 20.6
 Sky clear
 Snow cover (m) -
 Ice cover (m) -
 Secchi disk (m) 1.1+
 pH 9.2
 Conductivity (@25°C) 138

Samples collected

Kick -
 Dredge X
 Phytoplankton X
 Macrophytes -
 Zooplankton X
 Shoreline X
 Shore trawl X
 Fish -
 Primary production -
 Water chemistry X
 Stream flow -

Water temperature

m °C
 0 17.9
 0.5 17.9
 1.1 17.8

**SHERBROOKE LAKE**

LAKE NO. 47

SCALE METRES

0 100 200

DEPTH IN METRES

Ⓢ = COLLECTION SITE

Locality	SHERBROCKE LAKE
Site number	47
Grid reference	11U/NH428005
Elevation (metres/feet)	1800/5918
Altitudinal belt	subalpine
Maximum depth (m)	12
Surface area (hectares)	35.0

Sampling date	11/VII/71	6/VII/73	13/VII/73
Collection number (999-)	11	92	105
Time	1020	1400	1000
Air temperature (°C)	19.0	-	-
Sky	clear	rain	clear
Snow cover (m)	-	-	-
Ice cover (m)	-	-	-
Secchi disk (m)	3.5	-	2.2
pH	8.2	-	7.75
Conductivity (@25°C)	176	-	165
Samples collected			
Kick	-	-	-
Dredge	X	X	-
Phytoplankton	X	-	X
Macrophytes	-	-	-
Zooplankton	-	-	X
Shoreline	X	X	-
Shore trawl	X	X	-
Fish	-	-	-
Primary production	-	-	X
Water chemistry	X	-	-
Stream flow	-	-	-
Water temperature	m °C	-	m °C
	0 8.5		0 6.5
	2 7.0		2 6.5
	4 6.5		8 6.2
	6 6.0		
	8 5.7		
	10 5.5		
	12 5.5		

Sherbrook Lake (Site 47)

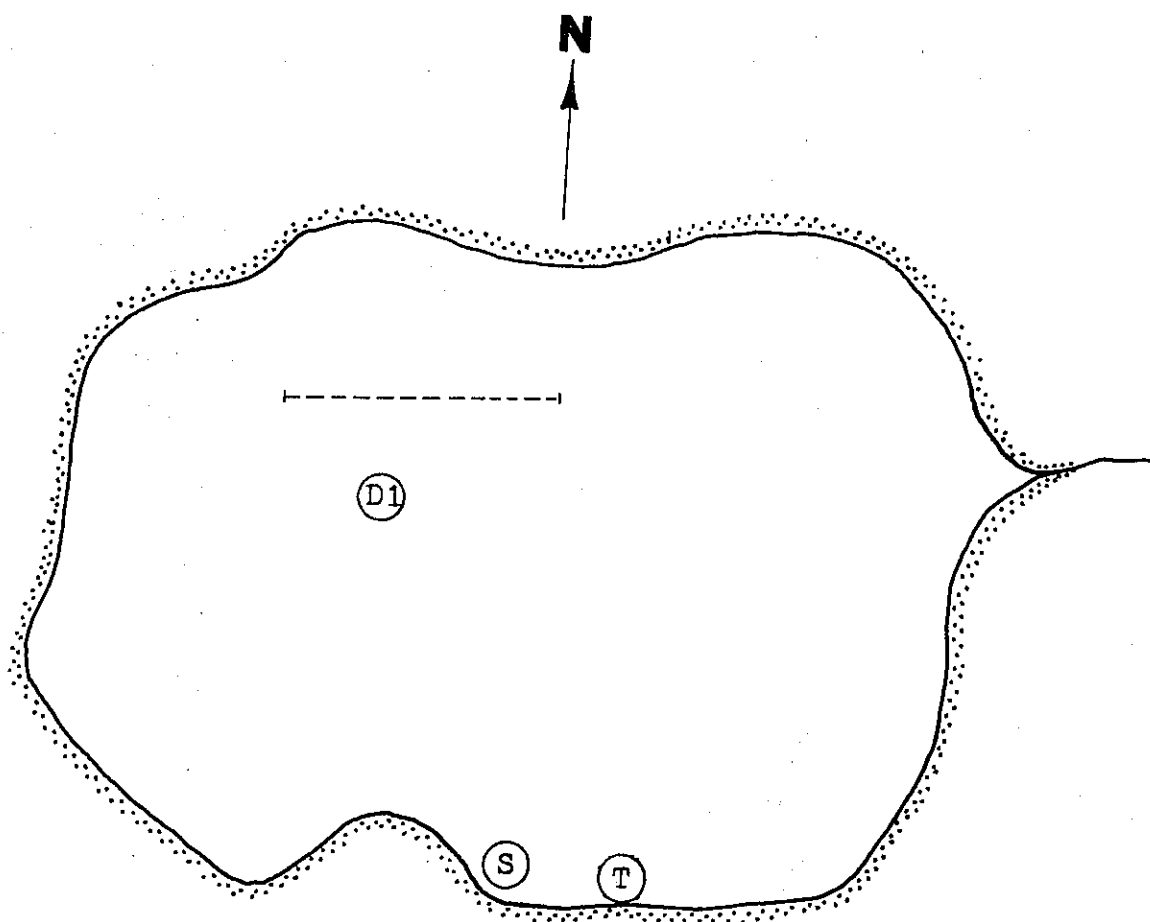
Summary of benthic invertebrate samples (numbers collected)

Coll. number	11	11	92	92	92	92	92
Sample type	D1	S	D1	D2	D3	S	T
Depth (m)	12	-	4	10	8	-	-
Total wet weight (g)	-	-	0.93	0.30	0.40	2.1 ^P	-
Oligochaeta							
Limnodrilus sp.	-	3	-	-	6	1	-
Tubifex sp.	-	-	1	-	1	-	-
Rhynchelmis sp.	-	-	1	-	-	1	-
Amphipoda							
Gammarus lacustris	-	7	1	-	-	-	2
Ephemeroptera							
Paramelotus sp.	-	-	-	-	1	3	2
Ameletus sp.	-	2	-	-	-	-	-
Siphonourus sp.	-	2	-	-	-	-	-
Plecoptera							
Alloperla (fidelis ?)	-	1	-	-	-	1	1
Isoperla ebria	-	-	-	-	-	9	1
Trichoptera							
Psephenophylax sp.	-	-	-	-	-	2	-
Limnephilidae	-	14	-	-	-	16	10
Diptera							
Tipulidae	-	8	-	-	-	-	-
Chironomidae							
Procladius sp.	3	-	2	-	1	-	-
Corynoneura sp.	-	-	-	-	-	1	-
Phaenopsectra sp.	-	-	72	35	41	5	-
Tanytarsus sp.	-	-	-	-	1	6	1
Chironomus sp.	1	-	-	-	-	-	-
Chironomus (limnochironomus) sp.	-	-	7	5	8	-	-
Unidentified	-	1	-	-	-	-	-
Diptera pupae	-	-	-	-	4	-	-
Hymenoptera	-	1	-	-	-	-	-
Coleoptera							
Agabus tristis	-	1	-	-	-	-	-
Misc. Insecta	-	-	-	-	1	1	1
Pelecypoda							
Pisidium ventricosum	-	-	5	5	-	-	3
Pisidium illejeborgei	15	-	-	-	-	-	-
Pisidium subtruncatum	6	-	-	-	-	-	-
Nematoda							
Unidentified	-	-	-	-	-	1	-
Total number of invertebrates	25	40	89	45	64	47	21

SHERBROOKE LAKE

Phytoplankton counts (cells/ml)

Species	Coll. No. Depth (m)	999-105 0.5	999-105 2.0	999-105 8.0
Chrysophyta				
Achnanthes sp.	-	-	10.9	3.3
Achnanthes microcephala	5.0	-	-	3.3
Dinobryon cylindricum	740.9	841.9	789.2	-
Gomphonema sp.	-	-	-	1.7
Kephyrion sp.	6.6	3.6	-	-
Navicula sp.	-	-	-	1.7
Pinnularia sp.	1.7	-	-	-
Synedra sp.	-	-	-	6.6
Synedra acus	1.7	7.3	-	-
Total cells/ml	755.9	863.7	805.8	-

SINK LAKE

LAKE NO. 48

SCALE METRES

0 50 100

(S) = COLLECTION SITE
----- = GILL NET SITE

Sink Lake (Site 48)

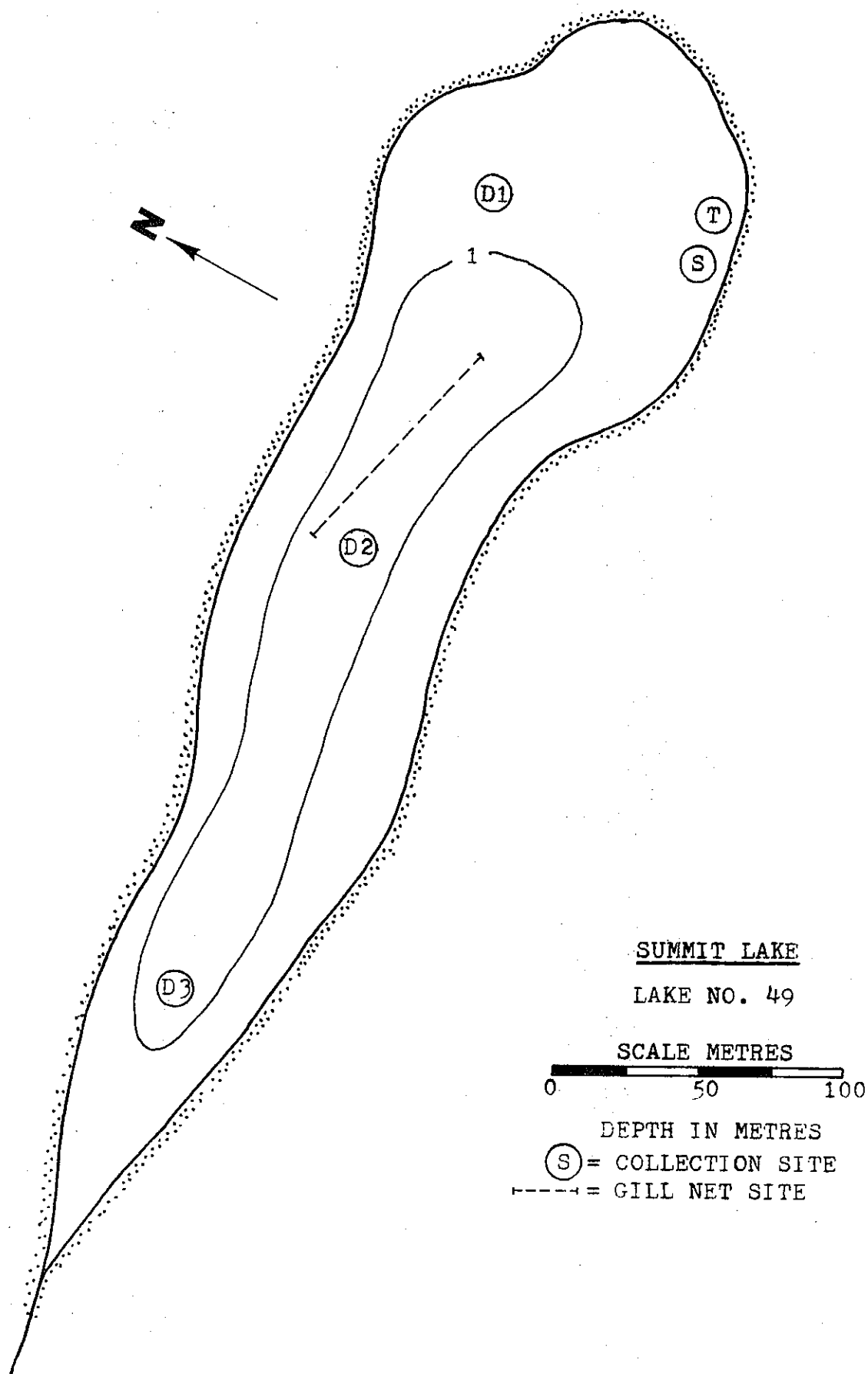
Summary of benthic invertebrate samples (numbers collected)

Coll. number	6	6	6	18	18	58	58	147
Sample type	D1	S	T	D1	T	S	T	D1
Depth (m)	2.0	-	-	2.0	-	-	-	1.0
Total wet weight (g)	-	-	-	-	-	5.47	-	0.79
Oligochaeta								
Tubifex sp.	5	-	-	3	-	-	-	5
Rhynchelmis sp.	-	-	-	-	-	-	2	-
Hirundinoidea								
Helobdella stannalis	-	-	1	19	-	-	-	3
Erpobdella punctata	-	-	-	-	-	3	-	-
Amphipoda								
Hyalella azteca	2	147	21	1	-	-	14	-
Gammarus lacustris	-	-	-	-	-	-	-	1
Cladocera								
Eurycerus lamellatus	-	-	-	-	11	-	-	-
Daphnia pulicaria	-	-	2	-	-	-	-	-
Simnocephalus vetulus	-	-	124	-	2	-	-	-
Ephemeroptera								
Siphonurus								
(occidentalis ?)	-	1	-	-	-	-	-	-
Centroptilum sp.	-	23	-	-	-	26	23	-
Trichoptera								
Glyphotaelius sp. A.	-	-	-	-	-	-	2	-
Limnephilidae	-	-	-	-	-	11	3	-
Nystacides sp.	3	-	6	2	-	-	5	-
Diptera								
Heleidae								
Alluaudomyia sp.	2	-	-	-	-	-	-	-
Chironomidae								
Procladius sp.	14	2	-	-	-	1	4	12
Pentaneura sp.	-	-	-	-	-	1	1	5
Tanytarsus sp.	-	-	-	-	11	-	6	35
Phaenopsectra	-	-	-	-	-	-	-	11
Chironomus								
(limnochironomus)	-	-	-	-	47	-	-	40
Brillia sp. A.	28	-	-	-	-	-	-	13
Diamesa sp. A.	2	-	-	-	2	-	-	-
Unidentified	21	-	7	-	45	-	1	-
Diptera pupae						2		
Odonata								
Aeshna palmata	-	-	-	-	-	1	-	-
Enallagma boreale	-	5	-	-	-	-	-	-
Hymenoptera								
Formicinae	-	-	-	-	-	-	1	-
Coleoptera								
Halipus sp.	-	-	-	-	-	2	-	-
Hydroporus								
grisiostratus	-	-	-	-	-	4	1	-
Acarina								
Limnesia sp.	-	-	-	-	-	-	1	-
Piona sp.	-	-	-	-	-	-	1	-
Unionicola sp.	-	-	-	-	-	-	1	-
Libertia sp.	-	-	-	-	-	-	-	2
Pionidae	-	-	-	-	-	-	-	2
Unidentified	1	-	4	-	8	-	-	-
Gastropoda								
Physa gyrina	1	-	-	-	-	4	-	-
Polycypoda								
Fisidina nitidum	-	-	-	1	-	-	-	-
Total number of invertebrates	70	178	165	26	126	55	66	129

SINK LAKE

Phytoplankton counts (cells/ml)

Species	Coll. No. (999)	58	58	137	137	147
	Depth (m)	0.5	1.5	0.5	1.5	0.5
Chlorophyta						
Carteria sp.	-	-	3.3	-	-	-
Chlamydomonas sp.	9.9	-	1.7	-	-	-
Oocystis elliptica	-	-	-	-	6.0	-
Oocystis gigas	-	-	-	1.5	-	-
Oocystis parva	-	-	-	4.5	7.5	-
Mougeotia sp.	-	-	-	-	12.0	-
Quadrigula lacustus	-	-	-	7.5	-	-
Cyanophyta						
Oscillatoria	-	-	11.6	-	-	-
Chrysophyta						
Achnanthes sp.	9.9	-	1.7	-	6.0	-
Achnanthes flexella	-	-	-	1.5	-	-
Achnanthes microcephala	49.5	-	36.3	-	-	-
Cyclotella sp.	-	-	-	-	3.0	-
Cymbella sp.	6.6	-	-	4.5	3.0	-
Cymbella amphicephala	-	-	-	1.5	-	-
Dinobryon sertularia	14.9	-	11.6	-	-	-
Fragilaria crotonensis	1.7	-	8.3	-	-	-
Gomphonema sp.	-	-	1.7	-	-	-
Gomphonema intricatum	-	-	-	1.5	1.5	-
Kephyrion sp.	33.0	-	49.5	-	1.5	-
Navicula sp.	18.2	-	28.1	7.5	10.5	-
Nitzschia sp.	1.7	-	3.3	1.5	3.0	-
Pinnularia sp.	-	-	1.7	-	-	-
Salpingocea sp.	-	-	-	-	-	6.2
Synedra ulna	-	-	1.7	-	-	-
Synedra sp.	-	-	-	-	1.5	-
Cryptophyta						
Cryptophyta sp.	5.0	-	1.7	12.0	9.0	-
Rhodomonas minuta	-	-	-	24.0	7.5	-
Total cells/ml		150.4	162.2	67.5	72.0	6.2



Locality	SUMMIT LAKE
Site number	49
Grid reference	11U/NG492999
Elevation (metres/feet)	1628/5340
Altitudinal belt	subalpine
Maximum depth (m)	1.2
Surface area (hectares)	2.0

Sampling date	1/VI/73	12/VI/73	30/VIII/73
Collection number (999-)	54	54B	138
Time	1015	0900	1015
Air temperature (°C)	8.5	9.0	8.2
Sky	cloudy	cloudy	cloudy
Snow cover (m)	-	-	-
Ice cover (m)	-	-	-
Secchi disk (m)	1.2+	1.2+	1.2+
pH	8.3	8.1	8.1
Conductivity (@25°C)	190	270	260
Samples collected			
Kick	-	-	-
Dredge	X	-	X
Phytoplankton	X	X	X
Macrophytes	-	-	X
Zooplankton	X	-	X
Shoreline	X	-	-
Shore trawl	X	-	-
Fish	-	(Aug. 9, 1973)	-
Primary production	-	X	X
Water chemistry	X	-	-
Stream flow	-	-	-
Water temperature	m °C	-	m °C
	0 10.6		0 9.3
	0.5 10.6		0.5 9.4
	1.0 10.6		1.0 10.1

Summit Lake (Site 49)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	54	54	54	54	54	138	138
Sample type	D1	D2	D3	S	T	D1	D2
Depth (m)	0.7	1.0	1.2	-	-	0.7	1.0
Total wet weight (g)	0.34	3.32	2.15	2.85	-	1.52	2.48
<i>Oligochaeta</i>							
<i>Limnodrilus</i> sp.	22	-	-	2	-	-	-
<i>Rhynchelmis</i> sp.	-	-	-	-	-	13	-
<i>Hirudinoidea</i>							
<i>Helobdella stagnalis</i>	-	25	-	-	-	4	-
<i>Erpobdella punctata</i>	-	2	-	-	-	-	-
<i>Nepheleopsis</i> (obscura ?)	-	2	-	-	-	-	-
<i>Glossophonia complanata</i>	-	-	-	-	-	-	1
<i>Mooreobdella furvida</i>	-	-	-	-	-	-	2
<i>Ephemeroptera</i>							
<i>Centroptilum</i> sp.	-	-	-	14	11	-	10
<i>Plecoptera</i>							
<i>Nemoura oregonensis</i>	-	-	-	-	1	-	-
<i>Trichoptera</i>							
<i>Banksiola</i> sp.	1	-	-	-	1	-	1
<i>Limnephilidae</i>	-	-	-	4	8	-	-
<i>Nystacodes</i> sp.	-	-	-	-	-	-	1
<i>Diptera</i>							
<i>Culicidae</i>							
<i>Aedes</i>	-	-	-	1	1	-	-
<i>Heleidae</i>							
<i>Alluaudomyia</i> sp.	2	5	2	1	7	-	2
<i>Chironomidae</i>							
<i>Procladius</i> sp.	1	3	13	-	4	20	-
<i>Pentaneura</i> sp.	1	9	12	1	-	-	1
<i>Cricotopus</i> sp.	-	4	8	2	-	-	-
<i>Psectrocladius</i> sp.	-	-	-	-	13	-	35
<i>Chironomus</i> sp.	-	-	-	-	-	1	-
<i>Sergentia</i> sp.	21	64	27	-	2	1	32
<i>Tanytarsus</i> sp.	-	-	-	-	4	2	-
Unidentified	-	-	6	-	-	-	-
Diptera pupae	7	16	4	2	7	-	-
<i>Heteroptera</i>							
<i>Sigara (vermicorixa) alternata</i>	-	-	-	-	1	-	-
<i>Odonata</i>							
<i>Sympetrum</i> sp.	-	-	-	1	-	-	-
<i>Ischnura perparva</i>	-	-	-	1	-	-	-
<i>Hymenoptera</i>							
<i>Myrmicinae</i>	1	-	-	-	-	-	-
<i>Acarina</i>							
<i>Arrenurus</i> sp.	-	-	-	-	9	-	-
<i>Lebertia</i> sp.	2	-	-	2	-	-	-
Araneae (unidentified)	-	-	-	1	-	-	-
<i>Pelecypoda</i>							
<i>Pisidium conventus</i>	2	-	-	-	-	-	-
<i>Pisidium subtruncatum</i>	1	-	-	-	-	-	-
<i>Pisidium casternatum</i>	-	15	-	-	-	6	-
<i>Gastropoda</i>							
<i>Lymnaea stagnalis</i>	-	-	-	1	-	-	-
<i>Lymnaea</i> sp.	2	-	-	-	-	-	-
Total number of invertebrates	63	145	72	33	69	47	85

SUMMIT LAKE

Phytoplankton counts (cells/ml)

Species	Coll. No. (999) Depth (m)	54 0.5	54 0.5	138 0.5
Chlorophyta				
Ankistrodesmus spiralis	-	-	-	6.6
Carteria sp.	3.6	1.7	-	-
Chlamydomonas sp.	-	-	-	1.7
Cosmarium sp.	-	1.7	-	1.7
Lagerheimia quadriseta	-	-	-	1.7
Mougeotia sp.	-	-	-	1.2
Nephrocystium agardhianum	14.5	13.4	-	-
Oocystis parva	3.6	1.7	-	-
Pediastrum tetras	-	1.7	-	-
Scenedesmus bijuga	-	9.9	-	6.6
Scenedesmus brasiliensis	-	-	-	6.6
Scenedesmus quadricauda	7.3	-	-	-
Schroederia setigera	-	-	-	1.7
Tetraedon minimum	-	5.0	-	-
Cyanophyta				
Lynxbya sp.	50.8	-	-	-
Merismopedia glauca	-	26.4	-	-
Oscillatoria sp.	65.3	-	-	-
Chrysophyta				
Acnanthes sp.	29.0	34.7	-	-
Acnanthes microcephala	76.2	72.6	-	5.0
Cymbella sp.	14.5	6.6	-	1.7
Denticula sp.	-	1.7	-	-
Diatoma hiemale var. hiemale	7.3	-	-	-
Dinobryon sertularia	7.3	9.9	-	-
Epithemia sp.	-	1.7	-	3.3
Fragilaria crotonensis	25.4	18.2	-	-
Gomphonema sp.	3.6	3.3	-	-
Gomphonema acuminatum	3.6	-	-	-
Kephyrion sp.	870.9	94.1	-	8.3
Navicula sp.	79.8	44.6	-	21.5
Navicula radiosa	14.5	-	-	-
Nitzschia sp.	7.3	16.5	-	1.7
Nitzschia palea	2.6	1.7	-	-
Pinnularia sp.	3.6	-	-	-
Pseudokephyrion parvum	254.0	5.0	-	-
Stenocalyx sp.	-	-	-	1.7
Synedra sp.	-	8.3	-	-
Synedra ulna	3.6	1.7	-	-
Pyrrophyta and Cryptophyta				
Cryptomonas sp.	14.5	-	-	21.5
Glenodinium sp.	-	3.3	-	-
Rhodomonas minuta	14.5	16.5	-	133.7
Total cells/ml				
		1571.0	401.7	226.2

Locality ICT RIVER
 Site number 102
 Grid reference 11U/NG405988
 Elevation (metres/feet) 1295/4260
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	19/VI/73	28/VIII/73
Collection number (999-)	76	133
Time	0900	1530
Air temperature (°C)	-	15.0
Sky	cloudy	cloudy
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	0.5+	0.5+
pH	7.9	-
Conductivity (@25°C)	264	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	(24/VII/73)	
Water temperature	5.4	7.8

Ice River (Site 102)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	76	76	76	133	133	133
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.98	0.95	0.79	0.40	1.03	0.51
Oligochaeta						
Rhynchelmis	-	1	-	-	-	-
Tricladida						
Polycelis coronata	-	-	-	-	-	1
Ephemeroptera						
Baetis sp. A.	16	8	21	3	5	3
Rithrogena (robusta ?)	54	54	29	25	51	34
Cinygmula sp.	2	10	7	2	1	4
Ameletus sp.	-	-	-	1	-	-
Epeorus (ironopsis)						
grandis	3	7	5	-	-	-
Ephemerella coloradensis	1	2	2	1	4	1
Epeorus (iron) sp.	1	10	36	5	14	9
Ephemerella doddsi	2	-	1	-	1	-
Ephemerella (invaria)						
(inermis ?)	-	-	-	-	1	-
Plecoptera						
Arcynopteryx aurea	1	1	-	-	-	2
Alloperla fidelis	1	3	-	1	1	5
Capnia sp.	-	-	2	2	-	-
Nemoura oregonensis	3	2	7	6	12	11
Nemoura columbiana	-	-	-	6	3	8
Trichoptera						
Glossosoma sp.	5	1	3	-	-	-
Parapsyche sp.	1	-	1	1	2	-
Rhyacophila sp.	2	-	2	4	2	2
Diptera						
Elephariceridae						
Bibiocephala sp.	1	-	-	-	-	-
Simuliidae	3	-	-	-	-	-
Tetanoceridae	1	-	1	-	-	-
Ephydriidae	1	-	-	-	-	-
Empididae	-	-	-	-	1	-
Chironomidae						
Eukiefferiella sp.	7	16	9	-	2	-
Metriocnemus sp.	-	1	-	-	-	-
Tanytarsus sp.	2	5	-	-	-	-
Unidentified	-	-	1	-	-	1
Diptera pupae	-	-	-	-	1	1
Aerial diptera	-	-	1	-	1	-
Misc. Insecta	-	-	1	-	3	-
Araneae	-	-	-	-	2	-
Total number of invertebrates	107	121	129	57	107	82

Locality BEAVERFOOT RIVER

Site number 104
 Grid reference 11U/NG299706
 Elevation (metres/feet) 1094/3600
 Altitudinal belt subalpine
 Maximum depth (m) 1.0
 Surface area (hectares) -

Sampling date	19/VI/73	10/IX/73
Collection number (999-)	77	141

Time	1400	1200
Air temperature (°C)	-	-
Sky	cloudy	clear
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	1.0	0.7
pH	7.0	-
Conductivity (@25°C)	34	-

Samples collected

Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-

Water temperature	7.2	8.8
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Beaverfoot River (Site 104)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	77	77	77	141	141	141
Sample type	K1	K2	K3	K2	K2	K3
Total wet weight (g)	0.23	0.01	0.21	0.05	0.10	0.64
Ephemeroptera						
Baetis sp. A.	2	-	-	-	-	-
Baetis sp. B.	4	1	1	-	-	-
Rithrogena (robusta ?)	-	2	4	1	-	-
Cinygmula sp.	8	2	1	-	1	-
Ameletus sp.	1	-	-	-	1	-
Parameletus sp.	-	-	-	-	3	-
Epeorus (iron)						
(deceptivus ?)	-	-	1	-	-	-
Ephemerella (invaria)						
(inermis ?)	3	-	1	-	-	-
Ephemerella proserpina	1	1	-	-	5	17
Plecoptera						
Unidentified	1	-	-	-	-	-
Alloperla (fidelis ?)	-	-	-	-	3	4
Nemoura oregonensis	-	-	-	-	1	-
Nemoura cataractae	-	-	-	-	-	1
Trichoptera						
Brachycentrus sp.	5	1	1	-	-	-
Diptera						
Tetanoceridae	-	-	1	1	-	-
Ephydriidae	-	-	2	-	-	-
Tabanidae	-	-	-	1	-	-
Empididae	-	-	-	-	1	2
Chironomidae						
Brillia sp. A	2	-	-	-	-	-
Eukiefferiella sp.	-	1	-	-	-	-
Sergentia sp. A.	3	-	-	-	-	-
Psectrocladius sp.	-	-	-	1	1	2
Diptera pupae	-	-	-	-	1	-
Aerial Diptera	-	2	-	-	-	-
Heteroptera						
Mesovelgia sp.	-	-	-	-	2	-
Collembola	-	-	-	-	-	1
Misc. Insecta	-	-	-	-	1	-
Acarina						
Araneae	-	-	-	-	1	1
Gastropoda						
Lymnaea sp.	-	-	1	-	-	-
Valvata sp.	-	-	2	-	-	-
Gyrulus crista	1	-	-	-	-	-
Gyrulus sp.	1	-	-	-	-	-
Planorbula sp.	-	-	1	-	-	-
Total number of invertebrates	32	10	16	4	21	28

Locality KICKING HORSE RIVER

Site number 106
 Grid reference 11U/NC204762
 Elevation (metres/feet) 1140/3750
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	14/VII/71	20/VIII/71	20/VII/73	7/VIII/73
Collection number (999-)	9	23	70	110
Time	1430	0930	1100	1600
Air temperature (°C)	21	18.5	-	-
Sky	clear	clear	cloudy	cloudy
Snow cover (m)	-	-	-	-
Ice cover (m)	-	-	-	-
Secchi disk (m)	0.5	0.1	0.5	-
pH	8.2	8.2	7.9	-
Conductivity (25°C)	198	176	198	-
Samples collected				
Kick	X	X	X	X
Dredge	-	-	-	-
Phytoplankton	-	-	-	-
Macrophytes	-	-	-	-
Zooplankton	-	-	-	-
Shoreline	-	-	-	-
Shore trawl	-	-	-	-
Fish	-	-	-	-
Primary production	-	-	-	-
Water chemistry	X	X	X	-
Stream flow	-	-	-	-
Water temperature	12.5	7.5	7.0	-

Kicking Horse River (Site 106)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	70	70	70	110	110	110	9
Sample type	K1	K2	K3	K1	K2	K3	K1
Total wet weight (g)	-	-	0.33	0.61	0.26	0.38	0.15
Ephemeroptera							
Gaetis sp.	1	3	-	8	5	-	-
Rithrogena (robusta)	14	1	1	1	-	-	-
Cinygmula sp.	1	-	3	14	14	14	-
Parameletus sp.	-	-	-	1	-	-	-
Epeorus (inonopsis)	-	-	-	-	-	-	-
grandis	1	8	-	2	2	-	6
Epeorus (iron) sp. A.	-	16	16	132	38	25	11
Ephemerella doddsi	2	1	-	1	1	4	-
Ephemerella (invaris)	-	-	-	-	-	-	-
inermis ?	-	1	2	2	-	-	-
Ephemerella coloradensis	-	-	-	1	-	-	-
Ephemerella margarita	-	-	-	3	1	-	-
Plecoptera							
Arcynopteryx aurea	-	1	-	-	-	-	-
Alloperla (fidelis ?)	3	-	1	10	7	4	1
Isoperla fulva	3	-	-	-	-	-	-
Trichoptera							
Glossosoma sp.	21	-	7	-	-	-	-
Parapsyche sp.	2	-	-	-	1	-	-
Diptera							
Blephariceridae							
Eibiocephala sp.	-	3	-	1	-	-	-
Chironomidae							
Eukiefferiella sp.	2	3	2	-	-	-	-
Metriocnemus sp.	-	6	27	1	-	5	-
Unidentified	-	-	-	-	1	-	3
Total number of invertebrates	50	43	59	177	70	52	21

Locality PORCUPINE CREEK

Site number 107
 Grid reference 11U/NC279797
 Elevation (metres/feet) 1124/3700
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date 20/VI/73
 Collection number (999-) 79

Time 0810
 Air temperature (°C) -
 Sky cloudy
 Snow cover (m) -
 Ice cover (m) -
 Secchi disk (m) 0.5+
 pH 7.9
 Conductivity (@25°C) 203

Samples collected:

Kick	X
Dredge	-
Phytoplankton	-
Macrophytes	-
Zooplankton	-
Shoreline	-
Shore trawl	-
Fish	-
Primary production	-
Water chemistry	X
Stream flow	(24/VII and 22/VIII/73)

Water temperature 4.0

Forcupine Creek (Site 107)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	79	79	79
Sample type	K1	K2	K3
Total wet weight (g)	0.21	0.14	0.09
Ephemeroptera			
Baetis sp. A.	-	6	7
Rithrogena (robusta)	19	20	27
Epeorus (ironopsis) grandis	1	-	-
Plecoptera			
Alloperla (fidelis ?)	2	1	4
Capnia sp.	1	2	1
Nemoura cinctipes	1	-	-
Trichoptera			
Glossosoma sp.	1	-	-
Rhyacophila sp.	-	-	1
Diptera			
Chironomidae			
Diamesa sp.	1	1	-
Erillia sp.	-	1	2
Eukiefferiella sp.	1	4	1
Total number of invertebrates	27	35	43

Locality OTTERTAIL RIVER

Site number 108
 Grid reference 11U/NG310870
 Elevation (metres/feet) 1155/3800
 Altitudinal belt subalpine
 Maximum depth (m) 1.0
 Surface area (hectares) -

Sampling date	19/VI/73	9/VII/73
Collection number (999-)	78	95
Time	1600	1400
Air temperature (°C)	-	-
Sky	-	clear
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	-	-
pH	8.1	-
Conductivity (@25°C)	302	-
Samples collected		
Kick	-	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	(31/VII/73)	-
Primary production	-	-
Water chemistry	X	-
Stream flow	(24/VII and 20/VIII/73)	-
Water temperature	7.2	-

Ottertail River (Site 108)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	95	95	95
Sample type	K1	K2	K3
Total wet weight (g)	0.30	0.25	0.19
Oligochaeta			
Limnodrilus	1	-	-
Tricladida			
Polycelis coronata	1	-	-
Ephemeroptera			
Eaetis sp. A.	6	6	3
Rithrogena (robusta ?)	16	12	8
Cinygmula sp.	1	1	-
Parameletus sp.	-	1	-
Epeorus (ironopsis)			
grandis	-	1	-
Epeorus (iron) sp.	6	4	-
Ephemerella doddsi	-	-	1
Plecoptera			
Nemoura oregonensis	2	1	-
Nemoura sp.	-	1	-
Trichoptera			
Glossosoma sp.	2	1	1
Parapsyche sp.	1	-	1
Rhyacophila sp.	-	1	-
Diptera			
Empididae	2	-	-
Tetanoceridae	-	1	-
Ephydriidae	7	1	-
Chironomidae			
Eukiefferiella sp.	3	1	1
Misc. Insecta	2	1	1
Total number of invertebrates	50	33	16

Locality	OTTERTAIL RIVER
Site number	109
Grid reference	11U/NG355843
Elevation (metres/feet)	1337/4400
Altitudinal belt	subalpine
Maximum depth (m)	0.7
Surface area (hectares)	-

Sampling date	9/VIII/73
Collection number (999-)	118

Time	1400
Air temperature (°C)	-
Sky	cloudy
Snow cover (m)	-
Ice cover (m)	-
Secchi disk (m)	0.3
pH	-
Conductivity (@25°C)	-

Samples collected

Kick	X
Dredge	-
Phytoplankton	-
Macrophytes	-
Zooplankton	-
Shoreline	-
Shore trawl	-
Fish	-
Primary production	-
Water chemistry	-
Stream flow	-

Water temperature	-
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Ottertail River (Site 109)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	118	118	118
Sample type	K1	K2	K3
Total wet weight (g)	0.29	0.10	0.19
Ephemeroptera			
Baetis sp. A.	9	6	1
Rithrogena (robusta ?)	28	9	10
Cinygmula sp.	3	-	5
Epeorus (ironopsis)			
grandis	-	1	-
Epeorus (iron) sp.	27	10	18
Ephemerella doddsi	2	1	-
Plecoptera			
Arcynopteryx aurea	1	-	-
Nemoura oregonensis	-	1	1
Nemoura columbiana	1	-	-
Trichoptera			
Parapsyche sp.	-	-	1
Rhyacophila sp.	1	1	2
Diptera			
Blenhariceridae			
Bibiocephala sp.	1	-	-
Chironomidae			
Unid.	1	-	-
Eukiefferiella sp.	1	-	-
Metrocnemus sp.	-	1	-
Diptera pupae	-	-	1
Misc. Insecta	-	-	1
Total number of invertebrates	75	30	40

Locality UPPER OTTERTAIL RIVER

Site number	110
Grid reference	11U/NG420808
Elevation (metres/feet)	1459/4800
Altitudinal belt	subalpine
Maximum depth (m)	0.7
Surface area (hectares)	-

Sampling date	9/VIII/73
Collection number (999-)	117

Time	1200
Air temperature (°C)	-
Sky	clear
Snow cover (m)	-
Ice cover (m)	-
Secchi disk (m)	-
pH	-
Conductivity (@25°C)	-

Samples collected

Kick	X
Dredge	-
Phytoplankton	-
Macrophytes	-
Zooplankton	-
Shoreline	-
Shore trawl	-
Fish	-
Primary production	-
Water chemistry	-
Stream flow	-

Water temperature	-
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Ottertail River (Site 110)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	117	117	117
Sample type	K1	K2	K3
Total wet weight (g)	1.39	1.00	1.38
Ephemeroptera			
Baetis sp. A	46	36	36
Rithrogena (robusta ?)	28	31	36
Cinygmula sp.	33	10	22
Epeorus (ironopsis) grandis	2	9	11
Epeorus (iron) sp. A	34	35	46
Ephemerella doddsi	-	2	2
Plecoptera			
Arcynopteryx aurea	4	-	-
Camnia sp.	-	2	2
Nemoura oregonensis	11	4	13
Nemoura columbiana	-	3	-
Nemoura cataractae	1	-	1
Trichoptera			
Glossosoma sp.	-	1	-
Parapsyche sp.	2	-	2
Rhyacophila sp.	6	3	7
Diptera			
Tipulidae	1	-	-
Blephariceridae			
Bibiocephala sp.	-	-	1
Simuliidae	-	-	1
Chironomidae			
Unid. Diamesini	-	1	7
Eukiefferiella sp.	2	2	19
Diptera pupae	2	-	-
Misc. Insecta	-	-	2
Acarina			
Lebertia sp.	-	1	-
Total number of invertebrates	172	140	208

Locality OTTERHEAD RIVER

Site number 111
 Grid reference 11U/NG292893
 Elevation (metres/feet) 1149/3780
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	13/VI/73	9/VIII/73
Collection number (999-)	69	120
Time	1220	1600
Air temperature (°C)	-	-
Sky	cloudy	rain
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	0.5+	-
pH	8.42	-
Conductivity (@25°C)	203	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	(31/VII/73)	-
Primary production	-	-
Water chemistry	X	-
Stream flow	(11/VII and 20/VIII/73)	-
Water temperature	7.8	-

Otterhead River (Site 111)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	69	69	69	120	120	120
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.09	0.33	0.21	0.37	0.18	0.25
<i>Oligochaeta</i>						
<i>Limnodrilus</i> sp.	1	-	-	-	1	-
<i>Ephemeroptera</i>						
<i>Baetis</i> sp. A.	28	15	10	1	2	3
<i>Rithrogena</i> (robusta ?)	6	22	9	26	18	13
<i>Cinygmula</i> sp.	-	5	12	5	1	4
<i>Epeorus</i> (ironopsis)						
<i>grandis</i>	2	11	13	-	-	-
<i>Epeorus</i> (iron) sp.	-	-	-	23	12	22
<i>Parametetus</i> sp.	-	-	-	1	-	-
<i>Ephemerella</i> <i>doddsi</i>	-	-	-	1	-	-
<i>Plecoptera</i>						
<i>Capnia</i> sp.	-	6	-	-	1	-
<i>Nemoura oregonensis</i>	-	2	-	-	-	4
<i>Nemoura</i> sp.	-	1	-	-	2	-
<i>Nemoura columbiana</i>	-	-	-	-	-	5
<i>Alloperla</i> (<i>fidelis</i> ?)	-	-	-	-	1	1
<i>Trichoptera</i>						
<i>Glossosoma</i> sp.	-	1	-	-	-	1
<i>Parapsyche</i> sp.	-	3	1	-	1	-
<i>Rhyacophila</i> sp.	1	2	-	-	1	-
<i>Diptera</i>						
<i>Simuliidae</i>	-	1	-	1	-	1
<i>Tetanoceridae</i>	-	-	2	-	-	-
<i>Ephydriidae</i>	1	-	-	1	-	-
<i>Heleidae</i>						
<i>Alluaudomyia</i> sp.	-	1	-	-	-	-
<i>Chironomidae</i>						
<i>Pentaneura</i> sp.	-	1	-	-	-	-
<i>Eukiefferiella</i> sp.	16	16	3	6	1	11
<i>Metriocnemus</i> sp.	-	3	3	-	-	-
<i>Orthocladus</i> sp.	-	-	-	-	-	11
Unidentified	2	-	-	-	-	-
Aerial diptera	-	-	-	-	1	-
<i>Acarina</i>						
<i>Sperchon</i> sp.	-	-	-	-	1	-
Total number of invertebrates	57	90	53	65	42	76

Locality KICKING HORSE RIVER

Site number 112
 Grid reference 11U/NG310898
 Elevation (metres/feet) 1140/3750
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	13/VI/73	9/VIII/73
Collection number (999-)	68	119
Time	1200	1500
Air temperature (°C)	-	-
Sky	rain	rain
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	-	-
pH	8.42	-
Conductivity (@25°C)	247	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-
Water temperature	10.0	-

Kicking Horse River (Site 112)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	68	68	68	119	119	119
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.46	0.54	0.23	0.18	0.84	0.30
<i>Oligochaeta</i>						
<i>Limnodrilus</i>	-	1	-	-	-	-
<i>Ephemeroptera</i>						
<i>Baetis</i> sp. A.	4	6	1	14	36	20
<i>Baetis</i> sp. B.	-	1	-	-	-	-
<i>Rithrogena</i> (robusta ?)	6	5	1	-	1	1
<i>Cinygmula</i> sp.	9	6	1	12	26	15
<i>Parameletus</i> sp.	-	-	2	1	-	-
<i>Epeorus</i> (ironopsis)						
<i>grandis</i>	7	6	3	-	-	-
<i>Epeorus</i> (iron) sp.	-	-	-	13	62	16
<i>Ephemerella</i> <i>doddsi</i>	1	7	2	-	-	-
<i>Ephemerella</i> (inermis ?)	-	3	-	-	-	-
<i>Ephemerella</i> <i>coloradensis</i>	2	-	-	-	2	-
<i>Ephemerella</i> <i>proserpina</i>	-	1	-	-	1	-
<i>Plecoptera</i>						
<i>Isogenus</i> sp.	-	1	-	-	-	-
<i>Alloperla</i> (fidelis ?)	1	2	1	1	-	1
<i>Nemoura</i> <i>oregonensis</i>	5	1	-	1	1	-
<i>Nemoura</i> sp.	-	3	-	-	-	-
<i>Arcynopteryx</i> <i>aurea</i>	-	-	-	-	-	1
<i>Trichoptera</i>						
<i>Glossosoma</i> sp.	4	2	-	-	1	-
<i>Parapsyche</i> sp.	1	-	2	-	-	-
<i>Rhyacophila</i> sp.	1	1	-	-	-	-
<i>Diptera</i>						
Tipulidae	1	-	1	-	-	-
Plephariceridae						
<i>Bibliocephala</i> sp.	1	-	-	-	1	-
Chironomidae						
Unid. <i>Diamesini</i>	-	-	-	-	10	2
<i>Eukiefferiella</i> sp.	5	7	-	1	-	1
<i>Metriocnemus</i> sp.	4	4	1	-	-	-
<i>Orthocladius</i> sp.	-	-	-	-	58	6
Diptera pupae	1	-	2	-	-	-
Misc. Insecta	-	-	1	-	-	-
Total number of invertebrates	43	57	18	43	199	63

Locality	BOULDER CREEK
Site number	113
Grid reference	11U/NG326904
Elevation (metres/feet)	1246/4100
Altitudinal belt	subalpine
Maximum depth (m)	0.5
Surface area (hectares)	-

Sampling date	16/VII/71	19/VIII/71	18/VI/73
Collection number (999-)	14	21	75
Time	0800	1515	1500
Air temperature (°C)	14	21	-
Sky	clear	cloudy	rain
Snow cover (m)	-	-	-
Ice cover (m)	-	-	-
Secchi disk (m)	0.5+	0.5+	0.5+
pH	8.25	8.3	8.0
Conductivity (@25°C)	209	231	330
Samples collected			
Kick	X	X	X
Dredge	-	-	-
Phytoplankton	-	-	-
Macrophytes	-	-	-
Zooplankton	-	-	-
Shoreline	-	-	-
Shore trawl	-	-	-
Fish	-	-	-
Primary production	-	-	-
Water chemistry	X	-	X
Stream flow	(24/VII and 20/VIII/73)		
Water temperature	5.5	11.0	6.2

Boulder Creek (Site 113)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	14	21	75	75	75
Sample type	K1	K1	K1	K2	K3
Total wet weight (g)	-	-	0.18	0.40	0.06
Ephemeroptera					
Baetis sp.	1	2	4	3	5
Rithrogena (robusta ?)	-	2	8	13	4
Cinygmula sp.	-	-	-	1	2
Epeorus (ironopsis)					
grandis	-	-	1	5	-
Epeorus (iron) sp.	-	-	-	-	2
Plecoptera					
Alloperla (fidelis ?)	1	-	3	5	-
Capnia sp.	-	-	-	-	1
Peltoperla mariana	-	1	-	-	-
Unidentified	-	1	-	-	1
Trichoptera					
Unidentified	-	1	-	-	-
Diptera					
Simuliidae	-	-	1	-	-
Ephydriidae	-	-	-	-	3
Chironomidae					
Diamesa sp.	-	-	11	5	2
Brillia sp.	-	-	1	6	-
Total number of invertebrates	2	7	29	38	20

Locality	AMISKWI RIVER
Site number	114
Grid reference	11U/NQ317922
Elevation (metres/feet)	1149/3780
Altitudinal belt	subalpine
Maximum depth (m)	0.5
Surface area (hectares)	-

Sampling date	13/VI/73	10/VIII/73
Collection number (999-)	72	121
Time	0900	0745
Air temperature (°C)	-	-
Sky	rain	overcast
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	-	-
pH	-	-
Conductivity (@25°C)	-	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	(1/VIII/73)	-
Primary production	-	-
Water chemistry	-	X
Stream flow	(11/VII and 20/VIII/73)	-
Water temperature	-	9.4

Amiskwi River (Site 114)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	72	72	72	121	121	121
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.11	0.09	0.02	0.27	0.11	0.01
Tricladida						
Polycelis coronata	-	-	5	-	-	-
Ephemeroptera						
Baetis sp. A	6	1	1	1	4	-
Rithrogena (robusta ?)	8	12	11	23	4	4
Cinygmula sp.	9	10	9	-	-	1
Epeorus (iron) sp.	19	4	6	19	6	1
Epeorus (ironopsis)						
grandis	-	-	-	1	2	-
Ephemerella doddsi	-	-	-	-	1	-
Plecoptera						
Alloperla (fidelis ?)	5	1	2	-	-	-
Arcynopteryx aurea	-	-	-	-	4	2
Capnia sp.	-	-	-	-	1	-
Nemoura oregonensis	1	-	1	1	1	-
Nemoura columbiana	-	-	-	2	1	-
Trichoptera						
Neothremma sp.	-	-	-	1	-	-
Parapsyche sp.	2	-	-	1	-	-
Diptera						
Ephydriidae	-	-	1	-	-	-
Blephariceridae						
Bibiocephala sp.	-	-	-	1	-	-
Chironomidae						
Damesa sp. A.	1	-	-	-	-	-
Eukiefferiella sp.	16	-	-	1	-	3
Metriocnemus sp.	8	1	4	-	-	-
Misc. Insecta	-	-	-	-	1	-
Nematoda	-	1	-	-	-	-
Total number of invertebrates	75	30	40	51	25	11

Locality UPPER ANISKWI TRIBUTARY

Site number 115
 Grid reference 11U/NH220003
 Elevation (metres/feet) 1580/5200
 Altitudinal belt subalpine
 Maximum depth (m) 0.3
 Surface area (hectares) -

Sampling date 3/VII/73
 Collection number (999-) 81

Time 1400
 Air temperature (°C) -
 Sky clear
 Snow cover (m) -
 Ice cover (m) -
 Secchi disk (m) -
 pH -
 Conductivity (@25°C) -

Samples collected

Kick	X
Dredge	-
Phytoplankton	-
Macrophytes	-
Zooplankton	-
Shoreline	-
Shore trawl	-
Fish	-
Primary production	-
Water chemistry	-
Stream flow	-

Water temperature -

Upper Amiskwi Tributary (Site 115)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	81	81	81
Sample type	K1	K2	K3
Total wet weight (g)	0.60	1.46	1.67
Tricladida			
Polycelis coronata	-	1	-
Ephemeroptera			
Baetis sp. A.	47	18	68
Rithrogena (robusta ?)	11	10	10
Cinygmula sp.	40	42	76
Parametetus sp.	-	-	1
Epeorus (ironopsis)			
grandis	1	-	5
Epeorus (iron) sp.	-	9	21
Ephemerella coloradensis	5	1	9
Plecoptera			
Arcynopteryx aurea	2	1	2
Alloperla (fidelis ?)	-	-	2
Peltoperla mariana	5	-	12
Capnia sp.	-	4	-
Nemoura oregonensis	-	1	-
Nemoura sp.	-	1	-
Trichoptera			
Glossosoma sp.	6	1	2
Neothremma sp.	3	-	2
Rhyacophila sp.	-	2	7
Diptera			
Chironomidae			
Diamesa sp.	21	53	23
Eukiefferiella sp.	55	88	257
Metriocnemus sp.	-	3	19
Misc. Insecta	1	-	4
Total number of invertebrates	197	235	520

Locality	OTTO CREEK
Site number	116
Grid reference	11U/NH236016
Elevation (metres/feet)	1459/4800
Altitudinal belt	subalpine
Maximum depth (m)	0.5
Surface area (hectares)	-

Sampling date	9/VII/73	27/VIII/73
Collection number (999-)	94	131
Time	1300	1530
Air temperature (°C)	-	-
Sky	-	rain
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	0.5+	0.5+
pH	-	-
Conductivity (@25°C)	-	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	(31/VII/73)	-
Primary production	-	-
Water chemistry	-	-
Stream flow	(24/VII/73)	-
Water temperature	-	-

Otto Creek (Site 116)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	94	94	94	131	131	131
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.45	0.16	0.24	0.16	0.80	2.55
<i>Tricladida</i>						
<i>Polycelis coronata</i>	-	2	-	-	1	-
<i>Ephemeroptera</i>						
<i>Paetis</i> sp. A.	17	12	14	1	1	2
<i>Rithrogena</i> (robusta ?)	8	1	1	16	31	20
<i>Cinygmula</i> sp.	15	7	22	-	3	3
<i>Ephemerella</i> goddsi	2	2	-	1	-	-
<i>Epeorus</i> (iron) sp.	6	4	-	4	7	5
<i>Parameletus</i> sp.	-	-	-	2	2	3
<i>Ameletus</i> sp.	-	-	-	-	2	5
<i>Plecoptera</i>						
<i>Capnia</i> sp.	-	2	1	-	5	3
<i>Nemoura oregonensis</i>	1	-	1	-	7	6
<i>Nemoura cataractae</i>	-	-	1	-	-	1
<i>Nemoura</i> sp.	-	-	1	-	-	-
<i>Arcynonyteryx aurea</i>	-	-	-	1	3	-
<i>Alloperla fidelis</i>	-	-	-	-	1	1
<i>Nemoura columbiana</i>	-	-	-	-	1	-
<i>Trichoptera</i>						
<i>Glossosoma</i> sp.	-	-	1	-	3	1
<i>Limnephilidae</i>	-	2	-	-	-	-
<i>Parapsyche</i> sp.	1	-	1	-	2	-
<i>Rhyacophila</i> sp.	1	-	-	2	1	3
<i>Diptera</i>						
<i>Tipulidae</i>	-	2	3	-	-	-
<i>Blephariceridae</i>						
<i>Bibiocephala</i> sp.	-	1	1	-	-	-
<i>Tabanidae</i>	-	1	1	-	2	-
<i>Ephydriidae</i>	-	1	1	-	-	-
<i>Chironomidae</i>						
<i>Eukiefferiella</i> sp.	5	2	2	-	-	-
<i>Metriocnemus</i> sp.	-	8	-	-	-	-
<i>Psectrocladius</i> sp.	-	-	1	-	-	-
<i>Corynoneura</i> sp.	-	-	-	-	-	1
<i>Cricotopus</i> sp.	-	-	-	2	-	-
Unidentified	-	-	1	-	2	-
Diptera pupae	-	-	1	-	1	-
<i>Acarina</i>						
<i>Sperchon</i> sp.	-	-	2	-	-	1
Total number of invertebrates	56	47	56	29	75	55

Locality UPPER AMISKWI RIVER

Site number 117
 Grid reference 11U/NH228055
 Elevation (metres/feet) 1550/5100
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	9/VII/73	27/VIII/73
Collection number (999-)	93	130
Time	1200	1500
Air temperature (°C)	-	-
Sky	-	rain
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	-	-
pH	-	-
Conductivity (@25°C)	-	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	(31/VII/73)	-
Primary production	-	-
Water chemistry	-	-
Stream flow	-	-
Water temperature	-	-

Upper Amiskwi River (Site 117)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	93	93	93	130	130	130
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.73	0.62	1.36	0.27	1.52	2.10
Ephemeroptera						
Baetis sp.	18	33	23	25	4	-
Rithrogena (robusta ?)	16	10	31	1	38	51
Cinygmula sp.	9	17	2	5	6	1
Ephemerella doddsi	-	1	-	-	15	22
Ephemerella coloradensis	1	-	2	-	1	-
Ephemerella proserpina	-	-	-	30	2	-
Epeorus (iron) sp.	15	19	9	-	1	-
Parametetus sp.	-	-	-	-	1	-
Ameletus sp.	-	-	-	1	-	-
Plecoptera						
Alloperla (fidelis ?)	1	1	3	-	7	4
Capnia sp.	2	4	2	-	5	10
Nemoura oregonensis	-	1	-	1	5	3
Nemoura columbiana	-	-	-	-	-	1
Nemoura cinctipes	-	-	-	-	1	-
Nemoura sp.	1	2	-	-	-	-
Trichoptera						
Glossosoma sp.	-	-	3	-	-	-
Limnephilidae	-	-	1	-	-	-
Parapsyche sp.	1	1	-	-	3	2
Rhyacophila sp.	4	4	2	-	7	8
Hesperophylax sp.	-	-	-	1	-	1
Diptera						
Ephydriidae	1	1	-	-	1	1
Tabanidae	-	-	-	-	-	4
Simuliidae	-	-	-	-	1	2
Chironomidae						
Tanytarsus sp.	2	1	3	-	-	-
Brillia sp.	-	-	-	-	-	2
Orthocladus sp.	-	-	-	7	-	-
Unidentified	-	2	-	-	2	-
Diptera pupae	3	-	-	-	-	4
Misc. Insecta	-	2	-	-	-	-
Acarina						
Sperchon sp.	-	-	-	16	2	-
Total number of invertebrates	74	98	81	87	102	116

Locality KICKING HORSE RIVER

Site number 118
 Grid reference 11U/NG343918
 Elevation (metres/feet) 1237/4070
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	12/VII/73	7/VIII/73
Collection number (999-)	67	109
Time	1400	1500
Air temperature (°C)	-	-
Sky	cloudy	cloudy
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	-	-
pH	8.31	-
Conductivity (@25°C)	198	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	(31/VII/73)	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-
Water temperature	9.8	-

Kicking Horse River (Site 118)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	67	67	67	109	109	109
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	1.34	1.85	3.83	0.52	0.53	0.44
Tricladida						
Polycelis coronata	-	3	-	-	-	-
Ephemeroptera						
Baetis sp.	10	13	2	11	14	8
Rithrogena (robusta ?)	12	8	31	2	1	2
Cinygmula sp.	29	20	14	21	32	23
Epeorus (ironopsis)						
grandis	7	9	8	-	3	-
Epeorus (invaria)						
(inermis ?)	-	5	2	1	-	3
Epeorus coloradensis	1	-	-	3	2	1
Epeorus (iron) sp.	-	-	-	9	43	15
Ephemerella prae-serpina	-	-	-	-	1	-
Ephemerella doddsi	9	10	15	1	-	1
Plecoptera						
Arcynopteryx aurea	-	3	3	-	-	-
Alloperla (fidelis ?)	2	2	6	5	2	1
Nemoura oregonensis	3	14	10	3	5	14
Nemoura columbiana	-	-	-	1	-	-
Trichoptera						
Glossosoma sp.	-	1	6	-	-	1
Parapsyche sp.	2	-	1	-	-	1
Rhyacophila sp.	1	-	1	-	1	1
Neothremma sp.	-	-	-	-	-	1
Diptera						
Tipulidae	2	-	1	-	1	1
Blephariceridae						
Eibiocephala sp.	-	2	1	-	1	1
Chironomidae						
Diamesa sp. A.	-	-	-	2	-	-
Eukiefferiella sp.	1	19	4	-	-	-
Metriocnemus sp.	1	6	3	-	-	-
Psectrocladius sp.	5	-	-	-	-	-
Diptera pupae	-	-	1	-	-	1
Acarina						
Lebertia sp.	-	-	1	-	-	-
Sperchon sp.	-	-	-	-	-	1
Total number of invertebrates	85	115	110	59	106	76

Locality	YOHO RIVER
Site number	119
Grid reference	11U/NG405988
Elevation (metres/feet)	1337/4400
Altitudinal belt	subalpine
Maximum depth (m)	0.5
Surface area (hectares)	-

Sampling date	18/VI/73	9/VIII/73
Collection number (999-)	73	119
Time	1200	1500
Air temperature (°C)	-	-
Sky	cloudy	rain
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	-	-
pH	7.8	-
Conductivity (@25°C)	250	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	(24/VII/73)	-
Water temperature	5.7	-

Yoho River (Site 119)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	73	73	73	119	119	119
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.53	0.47	0.91	0.18	0.84	0.30
Ephemeroptera						
Baetis sp. A.	18	14	14	14	36	20
Rithrogena (robusta ?)	12	21	15	-	1	1
Cinygmula sp.	55	11	83	12	26	15
Ephemerella doddsi	2	1	3	-	-	-
Epeorus (iron) sp.	1	-	-	13	62	16
Parameletus sp.	-	-	-	1	-	-
Ephemerella coloradensis	-	-	-	-	2	-
Ephemerella proserpina	-	-	-	-	1	-
Plecoptera						
Arcynopteryx aurea	-	-	1	-	-	1
Alloperla (fidelis ?)	2	-	2	1	-	1
Nemoura oregonensis	4	1	11	1	1	-
Trichoptera						
Glossosoma sp.	-	-	-	-	1	-
Parapsyche sp.	-	-	1	-	-	-
Rhyacophila sp.	1	2	1	-	-	-
Diptera						
Tipulidae	1	-	-	-	-	-
Simuliidae	-	1	-	-	-	-
Elephariceridae						
Bibiocephala sp.	-	-	-	-	1	-
Chironomidae						
Eukiefferiella sp.	1	7	1	1	-	1
Metriocnemus sp.	2	-	1	-	-	-
Unid. Diamesini	-	-	-	-	10	2
Orthocladius	-	-	-	-	58	6
Diptera pupae	-	1	-	-	-	-
Misc. Insecta	-	1	-	-	-	-
Total number of invertebrates	99	60	133	43	199	63

Locality YOHO RIVER

Site number 120
 Grid reference 11U/NH355060
 Elevation (metres/feet) 1520/5000
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	18/VI/73	9/VIII/73
Collection number (999-)	74	123
Time	1400	1600
Air temperature (°C)	-	-
Sky	cloudy	rain
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	0.30	-
pH	7.8	8.7
Conductivity (@25°C)	220	88
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	-	-
Primary production	-	-
Water chemistry	X	X
Stream flow	(24/VII and 20/VIII/73)	
Water temperature	-	-

Yoho River (Site 120)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	74	74	74	123	123	123
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.37	0.28	1.09	1.04	0.83	0.66
Tricladida						
Polycelis coronata	-	-	2	-	-	-
Ephemeroptera						
Baetis sp. A.	10	7	20	20	15	10
Rithrogena (robusta ?)	7	9	21	69	58	67
Cinygmula sp.	14	4	46	5	16	25
Epeorus (ironopsis)						
grandis	-	-	-	2	2	1
Epeorus (iron) sp.	-	-	-	5	3	2
Plecoptera						
Arcynopteryx aurea	-	-	1	4	6	1
Alloperla (fidelis ?)	2	-	1	3	1	2
Nemoura oregonensis	1	-	2	22	11	1
Nemoura columbiana	-	-	-	1	-	-
Trichoptera						
Parapsyche sp.	-	-	1	1	-	-
Rhyacophila sp.	1	-	1	-	4	2
Diptera						
Tipulidae	-	-	1	2	-	-
Simuliidae	3	-	-	-	-	-
Chironomidae						
Diamesa sp.	-	2	1	-	-	-
Brillia sp.	1	-	5	-	-	-
Eukiefferiella sp.	3	9	3	-	-	-
Tanytarsus sp.	-	-	2	-	-	-
Unid. Diamesini	-	-	-	4	1	-
Diptera pupae	1	-	-	1	1	-
Aerial diptera	-	-	-	-	1	-
Misc. Insecta	1	-	-	1	-	-
Total number of invertebrates	44	31	107	140	119	111

Locality	LITTLE YOHO RIVER
Site number	121
Grid reference	11U/NH343088
Elevation (metres/feet)	1608/5290
Altitudinal belt	subalpine
Maximum depth (m)	0.5
Surface area (hectares)	-

Sampling date	4/VII/73	10/IX/73
Collection number (999-)	82	142
Time	1000	1900
Air temperature (°C)	-	-
Sky	-	clear
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	0.5	-
pH	8.1	-
Conductivity (@25°C)	147	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-
Water temperature	5.0	7.5

Little Yoho River (Site 121)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	82	82	142	142	142
Sample type	K1	K2	K1	K2	K3
Total wet weight (g)	0.76	0.17	0.71	0.35	0.68
Tricladida					
Polycelis coronata	-	1	3	4	4
Ephemeroptera					
Baetis sp. A.	92	82	14	15	18
Rithrogena (robusta ?)	50	23	19	32	27
Cinygmula sp.	4	-	1	1	1
Epeorus (ironopsis)					
grandis	15	4	-	-	-
Epeorus (iron) sp.	-	2	-	-	-
Parametetus sp.	-	-	27	-	4
Plecoptera					
Nemoura oregonensis	2	-	4	8	10
Nemoura columbiana	-	-	6	14	7
Arcynopteryx aurea	-	-	1	1	2
Alloperla (fidelis ?)	-	-	1	2	12
Unidentified	1	-	-	-	-
Trichoptera					
Banksiola sp.	-	-	-	-	1
Rhyacophila sp.	-	2	2	-	1
Diptera					
Tipulidae	-	2	5	-	11
Chironomidae					
Diamesa sp.	1	-	-	-	12
Eukiefferiella sp.	1	5	-	2	-
Syndiamesa sp.	-	-	1	-	-
Diamesa sp.	-	-	3	1	3
Simuliidae	-	1	-	-	-
Aerial diptera	-	3	-	-	-
Misc. Insecta	3	-	-	-	-
Acarina					
Sperchon sp.	1	-	-	-	-
Araneae	-	-	1	-	-
Total number of invertebrates	170	125	88	80	113

Locality TWIN FALLS CREEK

Site number 122
 Grid reference 11U/NH343089
 Elevation (metres/feet) 1608/5290
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	4/VII/73	10/IX/73
Collection number (999-)	83	143
Time	1200	1930
Air temperature (°C)	-	-
Sky	-	clear
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	-	-
pH	8.2	-
Conductivity (@25°C)	121	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-
Water temperature	7.5	-

Twin Falls Creek (Site 122)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	83	83	83	143	143	143
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.64	0.08	0.10	0.70	0.12	0.04
Ephemeroptera						
Baetis sp. A.	17	9	4	-	-	-
Rithrogena (robusta ?)	44	1	2	-	2	3
Cinygmula sp.	15	1	10	1	1	1
Epeorus (ironopsis) grandis	3	-	-	-	-	-
Epeorus (iron) sp.	4	-	-	-	-	-
Parameletus sp.	-	-	-	-	4	-
Plecoptera						
Arcynopteryx aurea	1	-	-	-	2	-
Capnia sp.	2	-	-	-	-	-
Nemoura oregonensis	2	-	1	-	-	-
Nemoura columbiana	-	-	-	-	1	-
Alloperla (fidelis ?)	-	-	-	1	2	1
Trichoptera						
Rhyacophila sp.	1	-	-	-	-	-
Diptera						
Tipulidae	1	-	-	-	-	-
Simuliidae	1	-	-	-	-	-
Chironomidae	-	-	-	-	-	-
Diamesa sp.	-	1	1	-	-	-
Pseudodiamesa sp.	-	-	-	20	15	9
Eukiefferiella sp.	1	-	-	-	-	-
Unident.	-	-	-	1	-	-
Diptera pupae	1	-	-	-	1	1
Misc. Insecta						
	2	1	-	-	-	-
Total number of invertebrates						
	95	13	18	23	28	15

Locality SHERBROOKE CREEK

Site number 123
 Grid reference 11U/NG435985
 Elevation (metres/feet) 1582/5205
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	15/VII/71	19/VIII/71	4/VII/73	8/VIII/73
Collection number (999-)	12	20	85	111
Time	1515	1400	1400	1100
Air temperature (°C)	21.0	23.0	-	-
Sky	clear	clear	clear	clear
Snow cover (m)	-	-	-	-
Ice cover (m)	-	-	-	-
Secchi disk (m)	0.5+	0.5+	0.5+	0.5+
pH	8.2	8.2	8.2	-
Conductivity (@25°C)	181	176	172	-
Samples collected				
Kick	X	X	X	X
Dredge	-	-	-	-
Phytoplankton	-	-	-	-
Macrophytes	-	-	-	-
Zooplankton	-	-	-	-
Shoreline	-	-	-	-
Shore trawl	-	-	-	-
Fish	-	-	-	-
Primary production	-	-	-	-
Water chemistry	X	-	X	-
Stream flow	(25/VII and 20/VIII/73)			
Water temperature	9.5	15.0	-	-

Sherbrooke Creek (Site 123)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	12	20	85	85	85	111	111	111
Sample type	K1	K1	K1	K2	K3	K1	K2	K3
Total wet weight (g)	-	-	0.56	0.34	0.35	0.95	0.15	0.39
Tricladida								
Polycelis coronata	-	-	2	3	-	-	2	1
Ephemeroptera								
Baetis sp. A.	7	1	1	3	7	17	1	4
Rithrogena (robusta ?)	2	-	8	18	30	79	17	51
Cinygmula sp.	1	2	9	30	11	9	-	8
Parameletus sp.	-	-	1	-	1	-	2	2
Epeorus (ironopsis)								
grandis	-	-	2	2	1	20	3	-
Epeorus (iron) sp.	-	1	-	-	-	3	-	-
Centroptilum sp.	-	1	-	-	-	-	-	-
Plecoptera								
Arcynopteryx aurea	-	-	-	-	1	15	-	2
Alloperla (fidelis ?)	-	-	1	-	3	-	-	-
Acroneuria pacifica	-	-	-	-	1	1	2	3
Peltoperla mariana	-	-	-	-	1	-	-	-
Nemoura oregonensis	-	-	2	4	3	6	2	6
Nemoura cataractae	-	-	-	-	1	-	-	-
Nemoura cinctipes	-	-	-	-	-	-	-	1
Nemoura sp.	-	-	-	2	-	-	-	-
Unidentified	2	9	-	-	-	-	-	-
Trichoptera								
Parapsyche sp.	-	-	5	2	2	2	1	-
Rhyacophila sp.	-	-	1	-	-	-	-	1
Diptera								
Tipulidae	-	-	-	-	1	-	-	-
Simuliidae	-	-	1	2	1	4	-	-
Chironomidae								
Diamesa sp.	-	17	1	-	-	-	-	-
Eukiefferiella sp.	-	-	-	2	-	-	-	-
Tanytarsus sp.	-	-	1	-	-	1	-	-
Metriocnemus sp.	-	-	-	-	-	1	-	1
Unidentified	-	4	-	-	-	-	-	-
Diptera pupae	-	-	-	-	-	3	2	3
Misc. Insecta	-	-	3	2	1	-	-	-
Total number of invertebrates	12	35	38	70	65	151	32	83

Locality UPPER SHERBROOKE CREEK

Site number	124
Grid reference	11U/NH425013
Elevation (metres/feet)	1800/5923
Altitudinal belt	subalpine
Maximum depth (m)	0.5
Surface area (hectares)	-

Sampling date	13/VII/73
Collection number (999-)	106

Time	1100
Air temperature (°C)	-
Sky	clear
Snow cover (m)	-
Ice cover (m)	-
Secchi disk (m)	0.5
pH	-
Conductivity (@25°C)	-

Samples collected

Kick	X
Dredge	-
Phytoplankton	-
Macrophytes	-
Zooplankton	-
Shoreline	-
Shore trawl	-
Fish	-
Primary production	-
Water chemistry	-
Stream flow	-

Water temperature -

Upper Sherbrooke Creek (Site 124)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	106	106	106
Sample type	K1	K2	K3
Total wet weight (g)	0.23	0.26	0.74
Ephemeroptera			
Baetis sp. A.	8	11	18
Rithrogena (robusta ?)	7	6	5
Cinygmula sp.	10	18	39
Ephemerella doddsi	2	-	1
Epeorus (iron) sp.	-	1	1
Plecoptera			
Arcynopteryx aurea	-	-	1
Alloperla (fidelis ?)	1	5	9
Capnia sp.	-	-	4
Nemoura columbiana	-	-	1
Nemoura sp.	-	-	1
Trichoptera			
Rhyacophila sp. .	-	-	1
Diptera			
Tipulidae	-	-	1
Simuliidae	1	-	-
Chironomidae			
Eukiefferiella sp.	2	3	8
Tanytarsus sp.	-	-	1
Total number of invertebrates	31	44	91

Locality

KICKING HORSE RIVER

Site number 125
 Grid reference 11U/NG436984
 Elevation (metres/feet) 1580/5200
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	15/VII/71	19/VIII/71	12/VI/73	7/VIII/73
Collection number (999-)	13	19	66	108
Time	1600	1300	1200	1300
Air temperature (°C)	21	23	-	-
Sky	clear	clear	overcast	rain
Snow cover (m)	-	-	-	-
Ice cover (m)	-	-	-	-
Secchi disk (m)	0.5+	0.5+	0.5+	0.5+
pH	8.0	8.15	8.35	-
Conductivity (@25°C)	165	154	165	-
Samples collected				
Kick	X	X	X	X
Dredge	-	-	-	-
Phytoplankton	-	-	-	-
Macrophytes	-	-	-	-
Zooplankton	-	-	-	-
Shoreline	-	-	-	-
Shore trawl	-	-	-	-
Fish	-	-	-	-
Primary production	-	-	-	-
Water chemistry	X	-	X	-
Stream flow		(25/VII/73)		
Water temperature	9.3	15.0	6.2	-

Kicking Horse River (Site 125)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	13	19	56	66	66	108	108	108
Sample type	K1	K1	K1	K2	K3	K1	K2	K3
Total wet weight (g)	-	-	1.53	0.62	1.83	0.36	0.66	0.50
Oligochaeta								
Rhynchelmis sp.	-	-	-	-	-	-	-	1
Tricladida								
Polycelis coronata	-	-	2	5	2	-	2	-
Ephemeroptera								
Baetis sp.	1	2	21	8	10	-	-	1
Rithrogena (robusta ?)	-	13	-	2	29	-	-	-
Cinygmula sp.	-	10	52	31	76	11	20	16
Ameletus sp.	-	-	7	-	-	5	-	1
Parametetus sp.	-	-	-	-	-	3	-	6
Ephemerella doddsi	2	1	2	2	5	-	-	-
Ephemerella flavilinea	3	-	-	-	-	-	-	-
Ephemerella (invaria)								
(inermis ?)	-	-	14	1	4	-	4	-
Epeorus (iron)	3	-	-	-	-	-	1	-
Epeorus (ironopsis)								
grandis	4	-	42	6	23	-	-	-
Epeorus coloradensis	-	-	6	3	1	-	1	-
Epeorus (fuscata)								
proserpina	-	-	-	-	1	-	-	-
Plecoptera								
Alloperla (fidelis ?)	1	2	10	5	3	4	3	2
Arcynopteryx aurea	-	-	2	-	-	-	-	-
Acronuia pacifica	-	-	1	-	-	1	2	1
Isoperla sp.	-	-	1	-	-	-	-	-
Capnia sp.	-	-	-	2	1	-	-	1
Nemoura oregonensis	-	-	1	4	12	9	6	3
Nemoura columbiana	-	-	-	-	-	-	3	-
Nemoura cataractae	-	-	-	-	-	2	1	-
Nemoura sp.	1	-	-	-	-	-	-	-
Trichoptera								
Glossosoma sp.	-	8	2	-	1	9	13	-
Parapsyche sp.	-	1	-	3	8	-	1	1
Psychomyia sp.	-	-	-	-	1	-	-	-
Rhyacophila sp.	-	-	1	-	2	1	3	-
Neothremma sp.	-	-	-	-	-	-	1	-
Diptera								
Tipulidae	-	-	2	2	3	1	-	-
Tetanoceridae	-	-	-	-	-	-	-	1
Chironomidae								
Eukiefferiella sp.	-	-	-	-	2	26	16	8
Metriocnemus sp.	-	-	2	3	-	-	4	-
Corynoneura sp.	-	-	-	-	-	2	-	-
Pentaneura sp.	9	-	-	-	-	-	-	-
Unidentified	-	3	-	-	-	-	-	-
Diptera pupae	-	-	-	-	-	2	-	-
Aerial diptera	-	-	-	1	-	-	-	-
Misc. Insecta	2	-	-	-	-	-	-	-
Acarnia								
Lebertia sp.	-	-	-	-	-	1	-	-
Total number of invertebrates	26	40	168	78	184	77	81	42

Locality CATARACT BROOK

Site number 126
 Grid reference 11U/NG456975
 Elevation (metres/feet) 1702/5600
 Altitudinal belt subalpine
 Maximum depth (m) 1.0
 Surface area (hectares) -

Sampling date	6/VI/73	6/VIII/73
Collection number (999-)	55	115
Time	0800	1500
Air temperature (°C)	-	-
Sky	overcast	clear
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	1.0+	1.0+
pH	8.2	-
Conductivity (@25°C)	137	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	(Aug. 2, 1973)	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-
Water temperature	3.5	-

Cataract Brook (Site 126)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	55	55	55	115	115	115
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	-	1.10	0.98	0.83	0.42	1.34
Oligochaeta						
Limnodrilus sp.	-	1	-	-	-	-
Tricladida						
Polycelis coronata	-	-	-	-	-	1
Ephemeroptera						
Baetis sp.	33	-	15	2	4	6
Rithrogena (robusta ?)	10	11	6	4	6	4
Cinygmula sp.	42	45	39	18	7	32
Epeorus (ironopsis) grandis	-	-	-	8	8	2
Epeorus (iron) sp.	-	-	-	23	24	30
Ephemerella doddsi	-	-	-	1	1	-
Ephemerella coloradensis	-	-	-	1	4	1
Plecoptera						
Isogenus sp.	2	4	4	-	-	-
Arcynopteryx aurea	1	-	-	2	-	2
Alloperla (fidelis ?)	-	2	-	-	1	1
Nemoura oregonensis	1	1	2	4	1	7
Nemoura columbiana	-	-	-	1	-	5
Capnia sp.	-	-	-	-	1	-
Trichoptera						
Glossosoma sp.	1	2	2	-	-	4
Neothremma sp.	-	22	41	5	2	16
Parapsyche sp.	-	2	1	2	2	3
Rhyacophila sp. A.	1	2	2	1	2	2
Diptera						
Simuliidae	36	-	55	2	-	-
Empididae	-	2	2	-	1	1
Heleidae						
Alluaudomyia sp.	-	-	-	-	-	1
Chironomidae						
Eukiefferiella sp.	5	2	5	2	1	4
Metriocnemus sp.	1	1	-	-	-	-
Orthocladius sp.	-	-	-	-	-	3
Tanytarsus sp.	1	5	1	-	-	-
Unidentified	1	-	-	-	-	-
Diptera pupae	-	1	-	-	-	-
Aerial diptera	-	-	-	1	-	1
Misc. Insecta	-	-	-	2	-	-
Gastropoda						
Lymnaea arctica	-	1	-	-	-	-
Pelecypoda						
Pisidium lilljeborgi	-	-	-	-	1	-
Total number of invertebrates	135	104	175	79	66	126

Locality CATARACT BROOK

Site number 127
 Grid reference 11U/NG457942
 Elevation (metres/feet) 1732/5700
 Altitudinal belt subalpine
 Maximum depth (m) -
 Surface area (hectares) -

Sampling date	6/VI/73	8/VIII/73
Collection number (999-)	61	114

Time	1100	1415
Air temperature (°C)	-	-
Sky	cloudy	clear
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	0.5+	0.5+
pH	8.21	-
Conductivity (@25°C)	121	-

Samples collected

Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	(2/VIII/73)	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-

Water temperature 3.5

Cataract Brook (Site 127)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	61	61	61	114	114	114
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.61	-	0.65	0.76	0.80	0.55
Tricladida						
Polycelis coronata	-	1	2	1	-	3
Ephemeroptera						
Baetis sp.	15	2	4	16	18	4
Rithrogena (robusta ?)	28	5	45	34	29	39
Cinygmula sp.	11	62	10	4	-	6
Ameletus sp.	-	2	-	-	-	4
Centroptilum sp.	-	-	-	-	-	1
Epeorus (ironopsis) grandis	2	-	8	-	4	-
Epeorus (iron) sp.	-	-	-	20	19	13
Ephemerella doddsi	1	-	2	2	2	-
Ephemerella sp.	-	-	-	1	-	2
Plecoptera						
Arcynopteryx aurea	-	1	-	3	2	3
Alloperla (fidelis ?)	6	9	9	-	2	6
Isoperla fulva	2	-	-	-	-	-
Peltoperla mariana	4	-	-	2	-	-
Capnia sp.	-	7	17	-	-	10
Nemoura oregonensis	2	2	1	1	-	-
Nemoura cataractae	1	5	2	-	-	-
Nemoura columbiana	-	-	-	1	-	1
Trichoptera						
Limnephilidae	-	-	3	-	-	-
Neothremma sp.	53	-	30	2	-	3
Parapsyche sp.	3	2	-	1	2	-
Rhyacophila sp.	2	7	-	3	3	3
Diptera						
Tipulidae	1	3	4	-	-	-
Empididae	-	-	-	-	-	2
Simuliidae	-	-	-	-	2	-
Chironomidae						
Eukiefferiella sp.	8	-	-	-	1	1
Metriocnemus sp.	-	1	5	-	-	-
Tanytarsus sp.	1	12	6	-	-	-
Orthocladius sp.	-	-	-	1	-	2
Diptera pupae	-	-	1	-	-	-
Aerial diptera	-	1	-	-	-	-
Acarina						
Sperchon sp.	4	1	1	-	-	-
Total number of invertebrates						
	144	123	150	92	84	103

Locality CATARACT BROOK

Site number 128
 Grid reference 11U/NG454920
 Elevation (metres/feet) 1854/6100
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	8/VI/73	8/VIII/73
Collection number (999-)	63	113
Time	1030	1400
Air temperature (°C)	-	-
Sky	cloudy	clear
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	0.5+	0.5+
pH	8.08	-
Conductivity (@25°C)	107	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	(25/VII and 21/VIII/73)	
Water temperature	3.5	-

Cataract Brook (Site 128)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	63	63	63	113	113	113
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.97	0.18	0.72	1.10	0.57	2.65
Tricladida						
Polycelis coronata	2	-	1	-	-	-
Ephemeroptera						
Baetis	-	4	5	33	19	20
Rithrogena (robusta?)	22	17	14	71	21	57
Cinygmula sp.	-	-	8	7	1	3
Epeorus (ironopsis)	-	8	2	7	32	5
grandis	-	-	-	11	5	13
Epeorus (iron) sp.	6	-	1	5	5	11
Ephemerella doddsi	-	-	-	1	-	2
Ephemerella coloradensis	-	-	-	-	-	-
Flecoptera						
Arcynopteryx aurea	-	-	1	3	1	2
Alloperla (fidelis ?)	-	1	6	1	2	3
Acroneturia pacifica	-	1	-	1	1	3
Peltoperla mariana	11	1	1	2	1	3
Isoperla sp.	5	-	-	-	-	-
Capnia sp.	11	2	3	1	1	12
Nemoura oregonensis	2	-	-	1	-	2
Nemoura cataractae	1	-	2	-	-	-
Trichoptera						
Glossosoma sp.	1	-	-	-	-	-
Neothremma sp.	-	-	1	1	-	2
Parapsyche sp.	8	-	1	3	1	1
Rhyacophila sp.	3	2	2	4	4	11
Diptera						
Tipulidae	-	-	-	1	-	-
Simuliidae	-	-	-	-	1	-
Chironomidae	-	-	-	-	-	-
Eukiefferiella sp.	13	-	3	1	2	3
Psectrocladius sp.	3	-	1	-	-	-
Tanytarsus sp.	8	-	2	-	-	-
Metriocnemus sp.	-	-	-	1	-	1
Orthocladius sp.	-	-	-	-	1	-
Unidentified	-	-	-	-	-	2
Diptera pupae	-	-	-	-	-	-
Aerial diptera	-	-	-	1	-	2
Misc. Insecta	-	-	-	-	1	1
Acarina						
Sperchon sp.	2	-	2	-	-	-
Total number of invertebrates	98	36	56	156	100	159

Locality MORNING GLORY CREEK

Site number 129
 Grid reference 11U/NG453920
 Elevation (metres/feet) 1854/6100
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date 5/VII/73
 Collection number (999-) 87

Time 0900
 Air temperature (°C) -
 Sky rain
 Snow cover (m) -
 Ice cover (m) -
 Secchi disk (m) 0.5+
 pH -
 Conductivity (@25°C) -

Samples collected

Kick X
 Dredge -
 Phytoplankton -
 Macrophytes -
 Zooplankton -
 Shoreline -
 Shore trawl -
 Fish -
 Primary production -
 Water chemistry -
 Stream flow (25/VII/73)

Water temperature -

Morning Glory Creek (Site 129)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	87	87	87
Sample type	K1	K2	K3
Total wet weight (g)	0.32	0.41	0.70
Tricladida			
Polycelis coronata	-	-	1
Ephemeroptera			
Baetis sp. A.	4	1	-
Rithrogena (robusta ?)	-	3	7
Cinygmula sp.	21	2	28
Parameletus sp.	2	5	3
Ameletus sp.	5	-	4
Epeorus (ironopsis) grandis	-	-	1
Epeorus (iron) sp.	5	17	8
Ephemerella coloradensis	-	1	-
Plecoptera			
Arcynopteryx aurea	-	-	1
Alloperla (fidelis ?)	1	-	2
Acroneuria pacifica	1	-	-
Peltoperla mariana	1	1	1
Isoperla sp.	-	1	-
Capnia sp.	1	3	2
Nemoura oregonensis	10	7	-
Nemoura cataractae	1	4	2
Trichoptera			
Glossosoma sp.	1	-	-
Limnephilidae	1	1	-
Neothremma sp.	25	9	19
Parapsyche sp.	-	4	1
Rhyacophila sp.	-	2	1
Diptera			
Tipulidae	-	1	-
Chironomidae	-	-	-
Eukiefferiella sp.	1	-	-
Metriocnemus sp.	1	2	-
Tanytarsus sp.	-	11	3
Acarina			
Sperchon sp.	2	3	2
Total number of invertebrates	83	81	86

Locality CATARACT BROOK

Site number 130
 Grid reference 11U/NG462897
 Elevation (metres/feet) 2014/6620
 Altitudinal belt subalpine
 Maximum depth (m) 0.5
 Surface area (hectares) -

Sampling date	6/VI/73	8/VIII/73
Collection number (999-)	62	112
Time	1000	1230
Air temperature (°C)	-	-
Sky	overcast	cloudy
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	0.5+	0.5+
pH	8.15	-
Conductivity (@25°C)	87	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	-	-
Primary production	-	-
Water chemistry	X	-
Stream flow	-	-
Water temperature	3.0	-

Cataract Brook (Site 130)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	62	62	62	112	112	112
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.60	0.70	0.50	0.18	0.16	0.40
Oligochaeta						
Limnodrilus sp.	-	1	-	-	1	-
Tubifex sp.	-	-	2	-	-	2
Tricladida						
Polycelis coronata	76	54	9	-	-	-
Ephemeroptera						
Baetis sp.	9	19	41	1	-	-
Cinygmula sp.	3	3	-	-	3	-
Ameletus sp.	11	27	2	-	-	3
Habrophlebiodes sp.	2	1	-	-	-	-
Plecoptera						
Isoperla ebria	1	-	-	-	-	-
Acrocheura pacifica	6	8	-	1	-	-
Isoperla sp.	17	27	1	-	-	-
Nemoura cataractae	4	4	-	-	-	-
Nemoura cinctepes	3	6	1	2	18	-
Capnia sp.	-	-	-	-	-	1
Trichoptera						
Neothremma sp.	-	-	1	-	-	-
Rhyacophila sp. B.	1	1	-	-	-	-
Limnophilidae (Unid.)	-	-	-	-	-	1
Diptera						
Tipulidae	-	1	-	-	-	-
Simuliidae	-	-	-	3	-	-
Chironomidae						
Pentaneura sp.	5	12	11	-	3	1
Fukiefferiella sp.	4	5	17	-	-	-
Psectrocladius sp.	18	58	30	-	-	-
Tanytarsus sp.	4	7	45	-	-	4
Pseudodiamesa sp.	-	-	-	13	4	9
Cricotopus sp. C.	-	-	-	17	20	24
Orthocladius sp.	-	-	-	20	17	13
Diptera pupae	-	-	-	1	1	-
Misc. Insecta	-	-	-	-	2	-
Acarina						
Hydrodroma sp.	-	1	-	-	-	-
Hygrobatas sp.	2	1	-	-	-	-
Limnesia sp.	-	3	-	-	-	-
Orbatei sp.	-	1	-	-	-	-
Sperchon sp.	1	4	-	-	-	-
Total number of invertebrates	167	244	160	58	69	58

Locality OPABIN CREEK

Site number 132
 Grid reference 11U/NG468892
 Elevation (metres/feet) 2014/6625
 Altitudinal belt subalpine
 Maximum depth (m) 0.3
 Surface area (hectares) -

Sampling date 5/VII/73
 Collection number (999-) 88

Time 1200
 Air temperature (°C) -
 Sky snow
 Snow cover (m) -
 Ice cover (m) -
 Secchi disk (m) 0.3+
 pH 7.8
 Conductivity (@25°C) 70

Samples collected

Kick	X
Dredge	-
Phytoplankton	-
Macrophytes	-
Zooplankton	-
Shoreline	-
Shore trawl	-
Fish	-
Primary production	-
Water chemistry	X
Stream flow	(25/VII and 22/VIII/73)

Water temperature 3.0

Opabin Creek (Site 132)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	88	88	88
Sample type	K1	K2	K3
Total wet weight (g)	0.63	0.71	0.82
Ephemeroptera			
Baetis sp. A.	21	33	24
Rithrogena (robusta ?)	13	9	14
Cinygmula sp.	2	2	1
Epeorus (iron) sp.	28	88	50
Plecoptera			
Alloperla (fidelis ?)	2	2	1
Peltoperla mariana	-	-	1
Nemoura oregonensis	-	3	-
Nemoura sp.	-	3	-
Trichoptera			
Rhyacophila sp.	-	-	1
Diptera			
Simuliidae	1	-	-
Chironomidae			
Diamesa sp.	39	16	6
Eukiefferiella sp.	11	9	2
Metriocnemus sp.	-	4	4
Diptera pupae	3	-	-
Aerial diptera	1	-	-
Total number of invertebrates	121	158	104

Locality	OESA CREEK
Site number	133
Grid reference	11U/NG472895
Elevation (metres/feet)	2014/6625
Altitudinal belt	subalpine
Maximum depth (m)	0.5
Surface area (hectares)	-

Sampling date	5/VII/73
Collection number (999-)	89

Time	1200
Air temperature (°C)	-
Sky	rain
Snow cover (m)	-
Ice cover (m)	-
Secchi disk (m)	0.5+
pH	7.9
Conductivity (@25°C)	86

Samples collected

Kick	X
Dredge	-
Phytoplankton	-
Macrophytes	-
Zooplankton	-
Shoreline	-
Shore trawl	-
Fish	-
Primary production	-
Water chemistry	X
Stream flow	(25/VII and 22/VIII/73)

Water temperature	2.8
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Oesa Creek (Site 133)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	89	89	89
Sample type	K1	K2	K3
Total wet weight (g)	0.94	0.56	1.59
Ephemeroptera			
Baetis sp. A.	4	6	89
Rithrogena (robusta ?)	1	-	1
Cinygmula sp.	24	46	93
Parameletus sp.	-	1	-
Ameletus sp.	3	-	-
Epeorus (iron) sp.	-	1	-
Plecoptera			
Arcynopteryx aurea	1	-	2
Peltoperla mariana	-	-	1
Trichoptera			
Rhyacophila sp.	-	-	1
Diptera			
Tipulidae	-	-	1
Simuliidae	2	1	-
Chironomidae			
Diamesa sp.	19	5	2
Eukiefferiella sp.	264	153	150
Metriocnemus sp.	6	11	27
Orthocladius sp.	47	31	30
Total number of invertebrates	371	255	397

Locality	ROSS CREEK
Site number	134
Grid reference	11U/NG486997
Elevation (metres/feet)	1632/5370
Altitudinal belt	subalpine
Maximum depth (m)	0.5
Surface area (hectares)	-

Sampling date	8/VI/73	9/VIII/73
Collection number (999-)	65	116
Time	1040	0745
Air temperature (°C)	-	-
Sky	cloudy	clear
Snow cover (m)	-	-
Ice cover (m)	-	-
Secchi disk (m)	0.5+	0.5+
pH	8.36	-
Conductivity (@25°C)	220	-
Samples collected		
Kick	X	X
Dredge	-	-
Phytoplankton	-	-
Macrophytes	-	-
Zooplankton	-	-
Shoreline	-	-
Shore trawl	-	-
Fish	(2/VIII/73)	-
Primary production	-	-
Water chemistry	X	-
Stream flow	(25/VII and 20/VIII/73)	-
Water temperature	5.0	-

Ross Creek (Site 134)

Summary of benthic invertebrate samples (numbers collected)

Coll. number	65	65	65	116	116	116
Sample type	K1	K2	K3	K1	K2	K3
Total wet weight (g)	0.52	0.30	0.23	0.51	0.19	0.40
Oligochaeta						
Limnodrilus sp.	-	1	-	-	-	-
Rhynchelmis sp.	1	-	-	-	-	-
Ephemeroptera						
Baetis sp.	-	-	1	6	11	4
Rithrogena (robusta?)	3	-	-	-	-	-
Cinygmula sp.	4	6	1	-	5	3
Ameletus sp.	1	11	-	-	-	-
Plecoptera						
Alloperla (fidelis?)	-	1	-	-	-	-
Acronuria pacifica	1	-	3	7	5	5
Isoperla fulva	-	1	-	-	-	-
Isoperla sp.	3	-	-	-	-	-
Nemoura oregonensis	1	-	-	-	-	1
Nemoura cataractae	1	15	1	-	-	-
Unidentified	1	-	-	-	-	-
Trichoptera						
Neothremma sp.	10	4	3	6	1	3
Parapsyche sp.	-	1	1	-	1	-
Rhyacophila sp.	10	10	8	-	1	-
Diptera						
Empididae	4	5	1	-	-	-
Simuliidae	-	-	-	-	2	-
Chironomidae						
Procladius sp.	-	1	-	-	-	-
Eukiefferiella sp.	2	-	-	2	2	-
Tanytarsus sp.	1	2	-	-	-	-
Orthocladius sp.	-	-	-	-	1	-
Collembola						
Podura aquatica	-	-	-	1	-	-
Coleoptera	-	1	-	-	-	-
Misc. Insecta	-	-	1	-	-	1
Gastropoda						
Valvata sp.	-	1	-	-	-	-
Total number of invertebrates	43	60	20	22	29	17

Summary of Fish Collection Data

Fish species	Age	Length (mm)	Weight (g)	Sex
<u>Lake O'Hara (Site 9)</u>				
Salmo clarki	3	171	42.2	F
	3	173	52.0	M
	4	258	182.5	F
	4	288	290.0	F
	5	272	229.5	F
	5	272	229.5	F
	5	255	211.5	F
	6	290	249.0	F
	6	295	319.0	F
	6	295	310.5	F
	7	317	391.0	F
<u>Ross Lake (Site 17)</u>				
Salvelinus fontinalis	3	188	74.5	F
	3	170	58.0	M
	4	252	193.0	F
	6	292	293.0	F
	6	248	202.0	F
	6	260	211.0	F
	7	300	307.0	M
	10	268	218.0	F
	11	300	307.0	F
<u>Wapta Lake (Site 20)</u>				
Salvelinus namaycush	5	217	118.0	-
	7	238	146.5	-
	7	256	179.0	-
	8	278	226.5	-
	9	300	302.3	F
	10	354	454.2	F
	10	360	430.5	-
	10	336	410.0	F
	10	363	480.5	-
	11	396	748.5	F
	11	458	1070.0	F
	11	450	1087.0	M
	12	450	1153.1	M

Summary of Fish Collection Data- Cont'd

Fish species	Age	Length (mm)	Weight (g)	Sex
<u>Emerald Lake (Site 26)</u>				
Salvelinus fontinalis	3	193	101.5	-
	4	320	424.0	F
	6	330	478.0	F
	6	338	647.0	-
	6	362	709.0	F
	6	380	639.0	F
	6	425	1049.0	F
	6	374	656.0	F
	7	449	1310.0	F
Salmo gairdneri	3	159	52.5	-
	3	168	53	M
<u>Sink Lake (Site 48)</u>				
Salmo gairdneri	-	140	40.0	-
	-	148	43.5	-
	-	157	51.0	-
	-	160	56.5	F
	-	170	63.0	-
	-	180	63.0	-
	-	180	75.5	F
<u>Summit Lake (Site 49)</u>				
Salvelinus fontinalis	2	106	16.9	F
Salmo gairdneri	2	86	8.2	-
	-	166	63.5	-
	2	170	71.5	-
	-	179	77.0	-
	2	183	83.2	-
	-	196	95.5	-
	3	199	105.5	-
	3	160	60.0	-
	-	190	100.0	-
	-	238	196.8	-

Summary of Fish Collection Data- Cont'd

Fish species	Age	Length (mm)	Weight (g)	Sex
<u>Hoodoo Creek (Site 106A)</u>				
Cottus cognatus	6	82	6.3	-
	6	81	6.3	-
	7	81	7.5	M
Prosopium coulteri	1	74	4.1	-
	1	75	4.4	-
	1	78	5.2	-
	1	79	5.1	-
Salvelinus fontinalis	1	55	1.9	-
	2	63	3.3	-
	2	109	16.5	-
	2	113	21.2	-
	2	116	23.4	-
	3	145	45.6	M
	3	181	67.7	-
	3	180	74.0	M
<u>Porcupine Creek (Site 107)</u>				
Salvelinus fontinalis	3	142	37.5	M
<u>Ottertail River (Site 108)</u>				
Cottus cognatus	3	62	2.5	F
	3	72	3.7	F
	3	63	3.9	F
	3	67	3.2	M
	3	60	3.0	F
	3	60	2.5	-
	4	75	5.0	F
	7	84	7.0	M
	7	89	7.0	M
Salvelinus malma	2	89	6.9	-
Prosopium coulteri	2	90	8.7	-
<u>Otterhead River (Site 111)</u>				
Salvelinus fontinalis	1	93	10.4	-
	2	99	12.2	-
	2	110	17.0	-
	2	112	16.7	-
	2	118	18.3	F
	2	121	20.5	F
	3	134	32.0	F
	4	168	71.5	F
	4	184	81.7	M
	6	245	209.0	M
	4	118	19.0	-
	5	153	37.5	F
	7	295	297.0	M
Salvelinus malma				

Summary of Fish Collection Data- Cont'd

Fish species	Age	Length (mm)	Weight (g)	Sex
<u>Lower Amiskwi River (Site 114)</u>				
Cottus cognatus	3	64	3.0	M
	4	75	4.5	M
	4	76	5.3	M
Salvelinus fontinalis	2	118	18.0	-
	5	219	113.0	F
Salvelinus malma	1	63	2.8	-
<u>Emerald Creek (Site 114B)</u>				
Salvelinus fontinalis	1	56	2.0	-
	2	70	4.5	-
	2	77	5.5	-
	2	84	7.2	M
	2	95	10.0	M
	2	98	12.2	-
	2	94	11.0	M
	2	110	14.0	M
	2	113	18.0	M
	3	142	43.5	F
	3	122	23.5	M
	3	139	30.0	M
	3	150	43.0	-
	3	181	74.5	M
<u>Otto Creek (Site 116)</u>				
Salvelinus malma	-	88	10.4	-
	1	80	5.9	-
	2	85	7.3	-
	2	83	6.4	-
	4	113	14.6	-
	4	115	21.4	-
	4	116	20.0	F
	5	116	17.5	F
	5	121	21.9	F
	5	141	33.0	F
	6	137	32.0	F
	6	140	38.1	-
	6	157	48.5	M
	6	162	55.4	M
	7	157	49.6	-
	7	169	57.6	M
	9	177	77.5	M
<u>Upper Amiskwi River (Site 117)</u>				
Salvelinus malma	2	71	4.1	-
	2	79	5.8	F
	2	87	7.7	M
	3	98	11.7	-
	5	175	75.0	M
	9	233	150.5	M

Summary of Fish Collection Data- Cont'd

Fish species	Age	Length (mm)	Weight (g)	Sex
<u>Kicking Horse River (Site 118)</u>				
Cottus cognatus	3	63	3.0	-
	3	61	2.0	-
Prosopium coulteri	3	104	12.8	-
Salvelinus fontinalis	2	81	7.1	-
	2	89	7.0	-
<u>Cataract Brook (Site 126-127)</u>				
Salvelinus fontinalis	1	59	2.9	-
	1	59	3.1	-
	1	60	3.6	-
	1	61	2.8	-
	1	63	3.9	-
	1	65	4.2	-
	1	66	4.0	-
	1	67	4.1	-
	1	70	4.5	-
	2	73	5.8	-
	2	80	6.9	-
	2	89	10.0	-
	2	96	11.6	M
	2	106	14.0	-
	2	117	19.5	-
	3	97	12.0	-
	3	103	15.5	M
	3	115	20.5	M
	3	116	19.6	M
	3	136	29.8	-
	3	147	37.0	F
	4	143	41.8	F
	-	168	58.0	M
<u>Ross Creek (Site 134)</u>				
Salvelinus fontinalis	2	108	20.5	M
	4	200	141.0	F
	4	189	104.8	M

SPECIES LIST

- Chlorophyta
 Volvocales
 Chlamydomonaceae
 Carteria sp.
 Chlamydomonas spp.
 Tetrasporales
 Palmellaceae
 Sphaerocystis schroeteri Chodat
 Chlorococcales
 Oocystaceae
 Ankistrodesmus falcatus (Corda) Ralfs
 Ankistrodesmus spiralis (Turner) Lemmerman
 Ankistrodesmus spp.
 Dictyosphaerium pulchellum Wood
 Lagerheimia ciliata (Lagerheim) Chodat.
 Lagerheimia longiseta (Lemm.) Printz
 Lagerheimia quadriseta (Lemm.) Smith
 Nephrocystium agardhianum Naegeli
 Oocystis spp.
 Oocystis borgei Snow
 Oocystis crassa Wittrock
 Oocystis elliptica West and West
 Oocystis eremosphaeria Smith
 Oocystis gigas Archer
 Oocystis parva West and West
 Oocystis (near arcticus)
 Quadrigula lacustris (Chod.) G. M. Smith
 Schroederia setigera (Schroed.) Lemmerman
 Tetraedon minimum (Braun.) Hansgirg
 Coelastraceae
 Coelastrum microporum Naegeli
 Scenedesmaceae
 Crucigenia irregularis Wille
 Crucigenia quadrata Morren
 Crucigenia rectangularis (Braun) Gay
 Scenedesmus bijuga (Turp.) Lagerheim
 Scenedesmus brasiliensis Bohlin
 Scenedesmus denticulatus Lagerheim
 Scenedesmus obliquus (Turp.) Kretzing
 Scenedesmus quadricauda (Turp.) de Brebisson
 Zygnematales
 Zygnemataceae
 Mougeotia sp.
 Hydrodictyaceae
 Pediastrum tetras (Ehrenberg) Ralfs
 Ulotricales
 Ulotrichaceae
 Ulothrix subconstricta West
 Ulothrix sp.
 Conjugales
 Desmidiaceae
 Cosmarium spp.
 Cosmarium sp. (near bioculatum)
 Cosmarium sp. (near sexnotatum)
 Cosmarium tetragonum var. Lundelli Cooke
 Staurostrum bieneanum Rabenhorst
 Cyanophyta
 Chroococcales
 Chroococcaceae
 Chroococcus frescottii Drouet and Daily
 Chroococcus minor (Kuetz.) Naegeli
 Gomphosphaeria lacustris Chodat
 Merismopedia elegans Braun
 Merismopedia glauca (Ehrenberg) Naegeli
 Merismopedia punctata Meyen
 Microcystis incerta Lemmerman
 Hormogonales
 Oscillatoriaceae
 Arthrospira jenneri (Kuetz.) Stizenbergi
 Lyngbya sp.
 Oscillatoria sp.
 Oscillatoria geminata Meneghini
 Oscillatoria limnetica Lemmerman
 Oscillatoria rubescens de Condolle
 Oscillatoria sp. (near major)
 Nostocaceae
 Anabaena sp.
 Nostoc paludosum Kuetzing
 Chrysophyta
 Rhizochrysidales
 Stylocaceae
 Bitrichia chodatii (Reverdin) Chodat.
 Lagynion sp. (?)
 Chromulinales
 Chromulinaceae
 Chromulina sp.
 Kephyrion spp.
 Kephyrion littorale Lund
 Kephyrion obliquum Hilliard
 Kephyriopsis spp.
 Stenocalyx sp.
 Chrysococcus sp.
 Ochromonadales
 Ochromonadaceae
 Ochromonas sp.
 Dinobryaceae
 Chrysolykos planktonicus
 Chrysolykos skujae (Nauwerck) Willen
 Dinobryon sp.
 Dinobryon asymmetricum Hilliard
 Dinobryon attenuatum Hilliard
 Dinobryon cylindricum Imhof
 Dinobryon sertularia Ehrenberg
 Dinobryon sociale Ehrenberg
 Dinobryon sociale var. americanum (Brunn) Bachman
 Pseudokephyrion sp.
 Pseudokephyrion hiemale Hilliard
 Pseudokephyrion hyalinum Hilliard
 Pseudokephyrion parvum Hilliard
 Pseudokephyrion undulatum Scherffel
 Monosigales
 Monosigaceae
 Monosiga sp. (near varians)
 Salpingoeca sp.
 Centrales
 Cocconeidaceae
 Cyclotella spp.
 Cyclotella minuta (?)
 Cyclotella ocellata Pantocsek
 Melosira italica var. subarctica Mull.
 Pennales
 Fragilariaceae
 Diatoma sp.
 Diatoma hiemale var. mesodon (Ehrenberg) Grun.
 Diatoma vulgare Bory.
 Fragilaria sp.
 Fragilaria brevistriata Grun.
 Fragilaria brevistriata var. capitata Herib.
 Fragilaria construens (Ehrenberg) Grun.
 Fragilaria crotonensis Kitton
 Fragilaria pinnata Ehrenberg
 Hannea arcus Patrick
 Opephora sp.
 Synedra spp.
 Synedra acus Kutz.
 Synedra radians Kutz.
 Synedra ulna (Nitzsch.) Ehrenberg
 Tabellaria fenestrata (Lyngb.) Kuetzing

- Achnanthaceae
 Achnanthes spp.
 Achnanthes exigua Grun.
 Achnanthes exigua var. heterovalvata Krasske
 Achnanthes flexella (Kutz.) Brun.
 Achnanthes lanceolata var. dubia Grun.
 Achnanthes linearis (near var. curta)
 Achnanthes microcephala (Kutz.) Grun.
 Achnanthes minutissima (Kutz.) Grun.
 Cocconeis sp.
 Cocconeis placentula Ehrenberg
 Naviculaceae
 Amphipleura pellucida (Ehrenberg) Kutz.
 Diploneis elliptica (Kutz.) Cl.
 Diploneis puella (Schum.) Cl.
 Navicula spp.
 Navicula elsinensis (Greg.) Ralfs
 Navicula menisculus var. upsaliensis (Gren) Grun.
 Navicula radiosa Kutz.
 Navicula tripunctata (Mull.) Bory
 Neidium blonde (Ehrenberg) Hust.
 Neidium globiceps Cleve
 Pinnularia spp.
 Stauroneis spp.
 Gomphonemaceae
 Gomphonema spp.
 Gomphonema acuminatum Ehrenberg
 Gomphonema acuminatum var. coronatum Ehrenberg
 Gomphonema intricatum Kutz.
 Gomphonema olivaceum (Lyng.) Kutz.
 Cymbellaceae
 Cymbella spp.
 Cymbella affinis Kutz.
 Cymbella amphicephala Naegeli
 Cymbella ventricosa Agardh.
 Epithemiaceae
 Denticula sp.
 Epithemia sp.
 Rhopalodia gibba Muller
 Nitzschaceae
 Nitzschia spp.
 Nitzschia palea (Kutz.) W.Sm.
 Nitzschia sigma W.Sm.
 Nitzschia suecica (Grun.) Cleve
 Nitzschia thermalis Kutz.
- Pyrrophyta
 Gymnodiniales
 Gymnodiniaceae
 Gymnodinium sp.
 Gymnodinium helveticum Penard.
 Peridinales
 Glenodiniaceae
 Glenodinium sp.
 Woloszynskia sp. (?)
 Peridiniaceae
 Peridinium sp.
 Peridinium inconspicuum
 Ceratiales
 Ceratium hirundinella (Muller) Schrank
- Cryptophyta
 Cryptomonadales
 Cryptomonadaceae
 Cryptomonas spp.
 Cryptomonas erosa Ehrenberg
 Cryptomonas ovata Ehrenberg
 Rhodomonas minuta Skuja
- Euglenophyta
 Euglenales
 Euglenaceae
 Trachelomonas sp. (near pulchella)
- Chlorophyta
 Characeae
 Chara sp.
 Bryophyta
 Hypnaceae
 Drepanocladus aduncus
 Pteridophyta
 Equisetaceae
 Equisetum arvense L.
 Equisetum fluviatile var. linnæanum L.
 Spermatophyta
 Najadaceae
 Potamogeton gramineus L.
 Potamogeton pectinatus L.
 Potamogeton praelongus Wulf.
 Cyperaceae
 Carex rostrata Stokes
 Ranunculaceae
 Ranunculus aquatilis L.
 Haloragidaceae
 Hippuris vulgaris L.
 Myriophyllum exalbescens Fern.

- Turbellaria
 Tricladida
 Planariidae
 Polycelis coronata (Girard)
 Neorhabdocoela
 Mesostoma arcticum (?)
 Rotifera (see section F)
 Hirudinea
 Rhynchobdellae
 Glossiphoniidae
 Glossiphonia complanata (L.)
 Helobdella stagnalis (L.)
 Arhynchobdellae
 Erpobdellidae
 Dina anoculata (?) Moore
 Dina dubia Moore and Meyer
 Dina parva Moore
 Erpobdella punctata (Leidy)
 Mooreobdella fervida (Verrill)
 Nephelopsis obscura (?) Verrill
 Trematoda
 Digenia
 Allocreadidae
 Crepidostomum farionis (Muller)
 Bunodera luciopercae (Muller)
 Cestoda
 Pseudophyllidae
 Amphicotyliidae
 Eubothrium salvelini Schrank
 Diphyllbothridae
 Diphyllbothrium sp.
 Nematoda
 Spiruroidea
 Thelaziidae
 Rhabdochona milleri Choquette
 Rhabdochona cotti Gustafson
 Oligochaeta
 Lumbricidae
 Rhynchelmis sp.
 Tubificidae
 Tubifex sp.
 Limnodrilus sp.
 Crustacea (see section F)
 Insecta
 Odonata
 Aeschnidae
 Aeschna interrupta Walker
 Aeschna palmata Hagen
 Libellulidae
 Sympetrum sp.
 Coenagrionidae
 Ischnura perparva Selys
 Enallagma boreale Selys
 Ephemeroptera
 Heptageniidae
 Cingula sp.
 Epeorus (Iron) sp.
 Epeorus (Iron) deceptivus (?) McDunnough
 Epeorus (Ironopsis) grandis McDunnough
 Rithrogena robusta (?) Dodds
 Baetidae
 Ameletus sp.
 Baetis spp.
 Centroptilum sp.
 Ephemerella doddsi Needham
 Ephemerella (Fuscata) proserpina Traver
 Ephemerella (Invaria) inermis (?) Eaton
 Ephemerella coloradensis Dodds
 Ephemerella (Simplex) margarita (?) Needham
 Habrophelbiodes sp.
 Paraleptophelbia bicornuta McDunnough
 Parameletus sp.
 Siphonurus occidentalis (?) Eaton
 Plecoptera
 Peltoperlidae
 Peltoperla mariana Ricker
 Nemouridae
 Capnia sp.
 Nemoura cataractae Naevé
 Nemoura cinctipes Banks
 Nemoura columbiana Claassen
 Nemoura oregonensis Claassen
 Nemoura sp.
 Perlodidae
 Arcynopteryx aurea
 Isogenus sp.
 Isoperla (sp. "C" sensu Ricker 1943)
 Isoperla ebria (Hagen)
 Isoperla fulva Claassen
 Chloroperlidae
 Alloperla fidelis (?) Banks
 Perlidae
 Acroneuria pacifica Banks
 Trichoptera
 Rhyacophilidae
 Rhyacophila spp.
 Glossosomatidae
 Glossosoma sp.
 Psychomyiidae
 Psychomyia sp.
 Hydropsychidae
 Parasyche sp.
 Phryganeidae
 Banksiola sp.
 Phryngana sp.
 Limnephilidae
 Glyptotaelius sp.
 Hesperophylax sp.
 Limnephilus sp.
 Neothremma sp.
 Leptoceridae
 Mystacodes sp.
 Brachycentridae
 Brachycentrus sp.
 Diptera
 Tipulidae
 Unident. sp.
 Blepharoceridae
 Bibiocephala sp.
 Culicidae
 Aedes spp.
 Chaoborus brunskilli (Saether)
 Tabanidae
 Unident. sp.
 Simuliidae
 Unident. sp.
 Tetanoceridae
 Unident. sp.
 Empididae
 Unident. sp.
 Ephydriidae
 Unident. sp.
 Heleidae
 Alluaudomyia sp.

Chironomidae

Procladius sp.
 Pentaneura sp.
 Diamesa sp.
 Prodiamesa sp.
 Brillia sp.
 Corynoneura sp.
 Cricotopus sp.
 Eukiefferiella sp.
 Metrocnemus sp.
 Orthocladius sp.
 Psectrocladius sp.
 Chironomus sp.
 Chironomus (Limnochironomus) sp.
 Dicrotendipes sp.
 Cryptochironomus sp.
 Pseudochironomus sp.
 Phaenopsectra sp.
 Tanytarsus sp.

Heteroptera

Corixidae

Arctocorisa sutilis (Uhler)
 Sigara (Vermicorixa) alternata (Say)

Gerridae

Gerris comatus Drake and Hottes
 Gerris dissortis

Mesovelidae

Mesovela sp.

Coleoptera

Dytiscidae

Agabus tristis Aube
 Hydroporus compertus Brown
 Hydroporus griseostriatus (DeGeer)
 Hydroporus occidentalis Sharp

Halplidae

Halplus sp.

Acari

Sperchonidae

Sperchon sp.

Lebertiidae

Lebertia sp.

Limnesiidae

Limnesia sp.

Hygrobatidae

Hygrobates sp.

Unionicolidae

Unionicola sp.

Pionidae

Piona sp.

Hydrodromidae

Hydrodroma sp.

Arrenuridae

Arrenuris sp.

Mollusca

Pelecypoda

Pisidium casternatum (Poli)
 Pisidium conventus Clessin
 Pisidium lilljeborgi Clessin
 Pisidium nitidum Jenyns
 Pisidium subtruncatum Malam
 Pisidium ventricosum Prime

Gastropoda

Lymnaea arctica Lea
 Gyralus parvus (Say)
 Physa gyrina Say

Chordata

Osteichthyes

Salmonidae

Salvelinus fontinalis (Mitchill)
 Salvelinus malma (Walbaum)
 Salvelinus namaycush (Walbaum)
 Salmo clarki Richardson
 Salmo gairdneri Richardson

Coregonidae

Prosopium coulteri Eigenman

Cottidae

Cottus cognatus Richardson