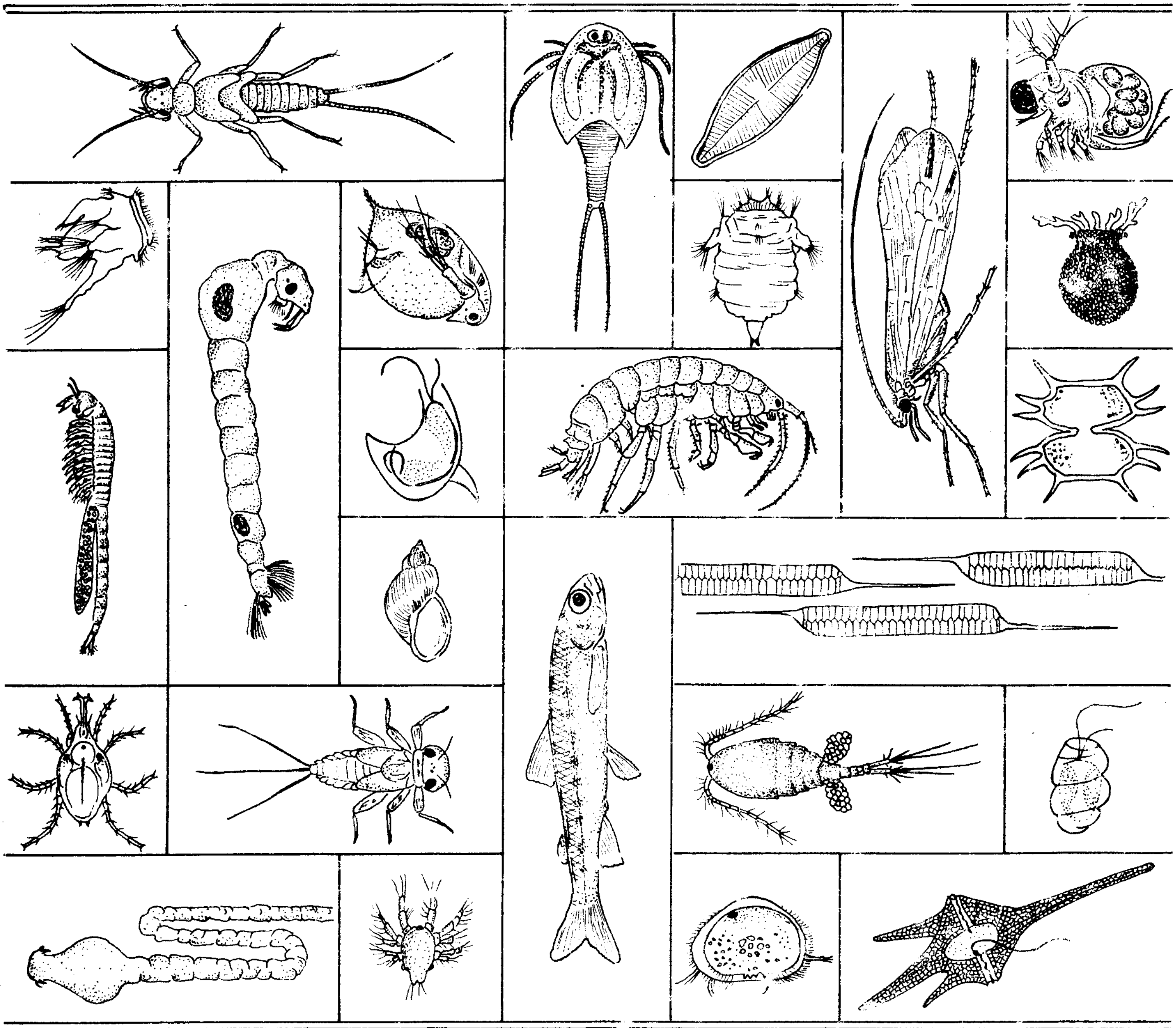
BANFF NATIONAL PARK



Prepared for
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by

CANADIAN WILDLIFE SERVICE
Calgary, Alberta

1976

Limnological Survey of the Lake Louise Area, Banff National Park

Part 2 - The Lakes

D.W. MAYHOOD and R.S. ANDERSON

Lake	Number*	Grid Reference	Area (ha)	Maximum Depth (m)
Agnes	174	11U/NG 525960	6.0	20.5
Annette	171	11U/NG 552907	5.3	13.7
Baker	198	11U/NH 667047	36.4	11.6
Baker, Little	199	11U/NH 675039	2.9	5.0
Boom	86	11U/NG 630793	99.6	32.0
Brachiopod	200	11U/NH 677034	2.1	3.0
Consolation, Lower	91	11U/NG 592850	14.5	11.3
Consolation, Upper	92	11U/NG 594843	10.7	16.2
Eiffel	87	11U/NG 528856	13.5	13.5
Herbert	182	11U/NH 542010	5.7	13.3
Herbert, Little	184	11U/NH 546001	0.6	8.2
Herbert Pond	183	11U/NH 541007	0.4	5.0
Hidden	192	11U/NH 620039	13.3	32.3
Island	165	11U/NG 618935	14.9	6.4
Kingfisher	167	11U/NG 583956	2.0	7.2
Kingfisher Pond	168	11U/NG 581961	0.5	6.1
Larch Valley East	-	11U/NG 548867	0.4	1.5
Larch Valley West	-	11U/NG 540866	0.2	3.3
Lost	179	11U/NH 505026	0.4	5.5
Louise	172	11U/NG 540958	84.5	70.1
McNair	166	11U/NG 587952	1.7	3.5
Mirror	173	11U/NG 529961	0.5	4.5
Moraine	89	11U/NG 570858	41.3	22.9
Mud	169	11U/NG 573989	7.3	7.2
O'Brien	96	11U/NG 640819	4.6	20.7
Ptarmigan	195	11U/NH 643039	27.9	21.3
Redoubt	197	11U/NH 645025	19.1	11.0
Sentinel	88	11U/NG 543871	2.8	6.7
Taylor	94	11U/NG 630828	27.0	43.9
Temple	170	11U/NG 571905	3.1	14.0
Tilted	201	11U/NH 679038	3.6	12.2

* Ward (1974)

LIMNOLOGICAL SURVEY OF THE LAKE LOUISE AREA,

BANFF NATIONAL PARK

Part 2: The Lakes

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Calgary, Alberta

ABSTRACT

A limnological survey of 31 lakes and ponds in the vicinity of Lake Louise, Banff National Park, was made. Data were gathered on the drainage basin features, morphometry, general attributes, water chemistry, phytoplankton, plankton primary productivity, zooplankton, macrophytes, shoreline fauna, benthic fauna and fish populations of the lakes. The data were presented in a "lake-by-lake"format for management reference purposes, and were used in a summary section to characterize the limnology of the study area.

Two distinct groups of lakes were discerned in the Lake Louise area: those on the floor of the Bow Valley (the "low lakes"), and those in the cirques and hanging valleys tributary to the Bow Valley (the "high lakes"). There were marked differences noted between the high and the low lakes with respect to their physical attributes, water chemistry and biological communities. The lakes within each group were similar physically, chemically and biologically, with few exceptions.

Nearly all of the fish populations of lakes in the study area were introduced. Probably fewer than half of them are capable of maintaining themselves without supplementary stocking, because natural recruitment is low or absent. Scarcity of suitable spawning habitat is believed to be the most important cause of poor natural recruitment in many of the lakes.

Growth of brook and cutthroat trout, the two most important sport fishery species in lakes of the study area, is slow. In the case of many of the brook trout and all of the cutthroat trout populations, fish growth is as slow as, or slower than, the slowest growth rates recorded in the literature. Nevertheless, such low growth rates are probably typical of those of brook and cutthroat trout in lakes in the southern Canadian Rocky Mountains. Similarly, individuals of these two species in the study area reached ages rarely recorded in the literature, but these ages are probably not particularly unusual for the two species in lakes of the southern Canadian Rocky Mountains.

Trout in lakes of the study area ate mainly Chironomidae, Trichoptera and Amphipoda. Use of the amphipod *Gammarus lacustris* as food in some trout populations was suggested as part of the reason for the

relatively higher growth rates of fish in those populations.

In most respects, the lakes of the study area do not differ greatly from those in the southern Canadian Rocky Mountain region in general. The low lakes, however, had some noteworthy inhabitants. A rare species of ostracode, *Notodromas monacha*, was found along the shoreline of Kingfisher Pond. The water strider *Gerris incognitus*, found in Little Herbert Lake and McNair Pond, may be a new but not unexpected record for Alberta. The planktonic copepod *Acanthodiaptomus denticornis*, found in most of the low lakes, appears in the Rocky Mountain Parks to be restricted to small lakes in the Bow Valley in Banff Park. However, it is known elsewhere in western Canada from several waters in central British Columbia, central Saskatchewan, and from a few other small lakes in the Bow Valley outside of Banff Park.

ACKNOWLEDGEMENTS

We are particularly grateful to our field assistants for their conscientious work. Rod Green collected many of the field data and samples in 1974, and ran many of the primary productivity incubations. Randall Pow assisted in all aspects of the field work in 1975, and did much of the preliminary sample sorting. Ralph Smith, David Donald, Dwight Mudry, Dennis Krochak and Greg Scott all assisted in the field at various times. Brian Smiley provided us with his original data on the fish populations of 8 lakes in the study area. Lois Green typed the two final sections of the report, and Catherine Mayhood provided drafting, typing, field and library research assistance on several occasions.

We were assisted on technical aspects of the work by several individuals and agencies. Rod Green identified and counted the phytoplankton, David Donald identified some of the Plecoptera and did most of the 1974-75 fish age determinations, Greg Scott identified the organisms in shoreline and bottom samples from Herbert and Little Herbert Lakes, and Dwight Mudry identified the fish parasites. Landis Hare identified several of the Orthocladiinae, confirmed our identifications of representative specimens of the remaining Chironomidae, and commented at length on some of the more puzzling aspects of chironomid taxonomy. The International Agency for ^{14}C Determination in Denmark did the radioactive counts on the filtered primary productivity samples, and the federal Water Quality Branch in Calgary did the laboratory chemical analyses of the water samples.

Many aspects of this report were discussed with our co-workers David Donald, Dwight Mudry and Rod Green. While we did not always follow their advice nor agree with their criticisms, they contributed to the content of this report in significant but intangible ways in addition to their other contributions acknowledged above.

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INTRODUCTION

We provided a detailed introduction to the present study with regard to previous limnological research in the study area and the goals of this survey in Part 1. A descriptive outline of the study area, glossary of technical terms, annotated and other bibliographies, and an overall list of the literature cited in the entire report were also presented.

In this short section we outline the format of Part 2. The lakes are arranged in alphabetical order in the main body of the report, each section containing all the survey data pertaining to that lake. Morphometry, drainage basin features and general attributes are listed first, followed by representative field and laboratory analyses of water chemistry. These are followed by quantitative lists of phytoplankton, zooplankton, macrophytes, shoreline fauna and bottom fauna; and by a description of the fish populations in the lake, if any. In most cases a bathymetric map, hypsographic curve, ionic diagram, representative thermal profiles, a primary productivity curve, fish growth diagram and length-weight curve are also provided. The significance of the data with respect to unique features or differences from earlier studies are noted in a brief discussion at the end of each section. Production estimates and management recommendations for each lake are deferred to Part 4.

The 31 survey lakes and their geographic coordinates, areas and maximum depths are listed on the inside front cover. A map of the study area illustrating the locations of the lakes is provided on the inside back cover of this volume.

A more detailed study of productivity in six of the lakes -- Mud, Kingfisher, Lower Consolation, Moraine, Baker and Ptarmigan -- is in progress (Mayhood, in preparation). It should be consulted for additional information on those lakes.

METHODS

General Attributes

The "Planning zone" designation in the text refers to the classification of the area in which the lake lies according to the 1971 provisional plan for the Lake Louise area. Distances quoted under the "Access" headings were obtained from Patton and Robinson (1971), or from topographic maps and hiking times noted in the field. For most lakes we have suggested a possible origin under the heading "Basin type", based mainly on incidental field observations. The duration of the open water period for each lake was estimated from direct observations of ice conditions, either by us or by other reliable observers (Park Wardens and scientists working in the area).

Morphometry and Drainage

Lakes were sounded with a portable echo sounder (Fish Lo-K-Tor, Lowrance Electronics). While an assistant rowed or paddled at a constant speed, soundings were taken at regular, timed intervals along several transects across each lake. Soundings were plotted on base maps drawn from enlarged aerial photographs, and were used to set the locations of contour lines. Air photos revealed considerable bottom detail, and were helpful in setting contours in many lakes. Scales of the air photos were determined from the formula

$$\frac{\text{elevation of aircraft} - \text{lake elevation}}{\text{lens diameter}} .$$

Lake elevations were obtained from 1:50,000 scale topographic maps (contour interval 30.5 m). Adequate photographs of Island, Temple, Taylor and O'Brien Lakes were unavailable, so outline maps for these lakes were enlarged from 1:50,000 scale topographic maps. Morphometric measurements were made from the lake maps using the methods described by Hutchinson (1957).

Rates of flow in outlet and major inlet streams were measured with a propellor-type flow meter (GM Mfg.) calibrated by the Hydraulics Division, Canada Centre for Inland Waters, Burlington. Thirty - second readings were taken at 60% of the site depth at several intervals across each stream. Width and mean depth were also measured to calculate stream discharge. In a few cases, floating wood chips were timed repeatedly over a stretch of stream of measured length, width and mean depth to estimate flow.

Water renewal times were calculated as the total lake volume at high water divided by the daily outflow or inflow. The estimated annual water renewal rate was calculated by dividing the estimated number of open water days by the water renewal time.

Drainage Basin Features

Drainage basin area and coverage were determined from topographic maps, supplemented by field observations and examination of air photos. Bedrock composition was estimated from 1:50,000 scale topographic maps on which the maps of Price and Mountjoy (1970) and Aitken (1967) were replotted. The Gog Group was assumed to be 100% quartzite; the Mt. Whyte, Cathedral, Stephen and Eldon Formations were combined and referred to as Cambrian carbonates, and the Devonian rocks in the Baker Lake area were referred to as Devonian carbonates (Belyea 1964, Aitken 1967, Baird 1967, Kucera 1974).

Light, Temperature, Sediments and Water Chemistry

Water transparency was measured with a 20 cm black and white Secchi disc following procedures recommended by Welch (1948). Water colour was noted against the white part of the disc at half the Secchi depth.

Water temperatures were measured with a mercury thermometer accurate to 0.1 °C, and by a thermistor thermometer (Yellow Springs Instruments Model 425C) calibrated at the beginning of each depth series against the mercury thermometer.

A mud sample was collected from near the deepest part of each lake with an Ekman grab, homogenized, dried at 100°C for 24 h, weighed, ashed at 650°C for 2 h and reweighed. The weight loss on ignition was assumed to represent the organic content of the sediments. No correction was made for carbonate or bicarbonate transformation.

Water samples for laboratory analysis were collected from a few centimetres below the surface in 2-litre double - rinsed plastic bottles. The bottles were shipped refrigerated in the dark to the Water Quality Laboratory, Inland Waters Directorate, Calgary, for analysis.

Samples for analysis in the field were collected in double - rinsed 1-litre plastic bottles. Conductivity was measured with a Dionic Series 3 portable meter, and pH with a Hellige comparator or an E.I.L. Model 308 electronic meter. Hach methods were used for other field determinations (Hach Chemical Company, Ames, Iowa).

<u>Phytoplankton and Primary Productivity</u>

Water samples for phytoplankton collections and primary productivity experiments were collected with a Van Dorn sampler or a student sampler (Research Instrument Company) from selected depths. Alternatively, samples were taken with a weighted and calibrated rubber - lined hose to obtain an integrated sample from a column of water (Tonolli 1971).

Phytoplankton samples were preserved with a few drops of Lugol's solution in the field, and were counted and identified on an inverted microscope (Utermöhl 1958). The taxonomic literature used in identification of the phytoplankton is listed in Appendix C in Part 1.

Primary productivity was measured by the ^{14}C method (Steemann - Nielsen 1951, 1952). Details of the incubation, filtration and counting procedures, and of the ancillary chemical analyses have been summarized elsewhere (Anderson 1968a, 1974a). Most incubations were run for 3 to 4 h in the interval 0800 - 1200 h Mountain Standard Time, but occasionally 3 to 4 h incubations at other times were used.

Zooplankton

Zooplankton collections were made with a #20 Wisconsin - style plankton net (mouth diameter 25 cm), usually by making vertical hauls near the deepest part of the lake, or occasionally in small ponds by tossing the net from shore. Details of the use of the net have been described previously (Anderson 1974b). Samples were taken in duplicate, usually on several dates and often in more than one year. The samples were preserved at the time of collection with a few drops of 37% formaldehyde solution. Taxonomic literature consulted in identifying the specimens is listed in Appendix C of Part 1. Counts were corrected for net inefficiency in the manner of Anderson (1970a).

Bottom and Shoreline Organisms

Macrophytes were identified to genus in the field, and their locations and abundances were noted on sketch maps. Some specimens were pressed and dried for identification in the laboratory.

Qualitative shoreline collections were made by searching under rocks, sticks and debris along the shore, and sweeping the dislodged animals from the water with a small aquarium net or a kitchen strainer. Collections were typically made for 15 to 30 minutes, often on two or three dates. The specimens were stored in 10% formalin (3.7% formaldehyde solution).

Bottom samples were collected with a 15.24 cm (6 inch) square Ekman grab, usually from 2 to 4 locations chosen to represent different parts of the lake bottom. More samples, up to 11, were taken from the larger lakes. Samples were seived through a screened bucket (mesh aperture 0.36 mm X 0.52 mm), and the residue was stored in formalin. In the laboratory, grab samples were sorted under 6X magnification and the animals were stored in 10% formalin.

Chironomidae larvae in the bottom and shoreline samples from each lake were sorted into recognizable groups, and two or more specimens from each group were mounted and cleared in Turtox CMC - 9 mounting medium on glass slides. Other taxa were given no special treatment before being identified and counted. Animals were identified with the aid of the following keys and descriptions.

General references: Pennak (1953), Edmondson (1959), Usinger (1956)
Ephemeroptera: Needham, Traver and Hsu (1935)
Odonata: Needham and Westfall (1955), Walker (1912, 1925, 1953)
Hemiptera: Brooks and Kelton (1967)
Trichoptera: Ross (1944)
Coleoptera: Larson (1975)
Diptera:
  Chaoboridae - Cook (1956), Saether (1970)
  Chironomidae - Hamilton and Saether (pers. comm.), Saether (1969, 1971), Hamilton, Saether and Oliver (1969) Stewart and Loch (1973), Mason (1973), Hilsenhoff (1975)
Mollusca: Burch (1972), Clarke (1973)

In addition, representative specimens of aquatic beetles identified by Dr. D. Larson and chironomid specimens identified by Drs. A. Hamilton and O. Saether were used to verify some specimens in those groups.

Bottom samples were weighed by groups of easily separated taxa. Specimens were sorted, blotted on tissue to remove adhering preservative, and weighed to the nearest 0.0001 gram on an electronic balance.

Fish

Fish were collected with gill nets. Specifications of the gear used are given in the text for each lake.

Specimens were weighed to the nearest gram and their fork lengths were measured to the nearest millimetre. Gonads, stomachs, otoliths and sometimes scales were retained for laboratory examination. The gonads and stomachs were stored in 10% (1973) or 15% (1974-1975) formalin. In a few cases, fish were frozen whole and stored for later laboratory analysis.

In the laboratory, specimens were aged using the otolith method (Tesch 1971), and sexual maturity was judged from the appearance of the gonads on Kesteven's modified scale (Bagenal 1971). Gonads of many immature specimens were examined under 6X to 50X magnification to determine sex. Stomach contents were examined and identified under a dissecting microscope. The abundance of each taxon was judged arbitrarily as rare, common or abundant (1973 samples), or else the percentage of the total volume of stomach contents which each taxon comprised was estimated by eye (1974-1975 collections). Small numbers of fish from selected lakes were examined for parasites. Details of the parasite analysis are described by Mudry and Anderson (1976, in press). Only frozen specimens were used for parasite examination.

The fish data for 1973 were provided by Mr. B. D. Smiley, whose report (Smiley 1976) deals in detail with the fish populations in six of the survey lakes. His report should be consulted for additional information concerning methods and other details of his work.

The following points of possible confusion in the text should be noted.

1. Water renewal times vary seasonally and yearly, but our estimates were often made only once during the summer in only one year. Our estimates were based on the assumptions, usually not strictly true, that there is no outflow during the period of ice cover, and that the lakes mix completely throughout the open-water season. Our figures nevertheless provide rough indices of retention time for the lakes.

2. The field water chemistry data refer to surface samples taken during the open-water period, and are frequently means of several analyses, the numbers of which are given in parentheses in each case.

3. Maximum crustacean zooplankton standing crop figures refer to the maximum observed on any one date. Since the maximum number of each species did not usually occur on the same dates, the maximum standing crop and the sum of the maximum individual numbers do not usually agree. Also, neonates and nauplii were excluded from the individual species figures, but were included in the maximum standing crop figures.

4. Shoreline fauna collections are not quantitatively comparable except on a "rare - occasional - common - abundant" scale, because the method could not be standardized for use on all types of shoreline.

5. The ages given for the fish are the numbers of summers growth visible on the otoliths. The fish caught either early or late in the season were arbitrarily assigned an annulus on the edge of their otoliths on the assumptions that growth had not yet commenced (early season) or had been completed (late season).

LAKE AGNES

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 525960, NTS map sheet No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Chateau Lake Louise 3.4 km (2.1 mi)

Elevation: 2118 m

Altitudinal zone: upper subalpine

Basin type: cirque

Length: 542 m

Mean width: 111 m

Area: 6.0 ha

Maximum depth: 20.5 m

Mean depth: 7.1 m

Volume: $42.6 \times 10^4 m^3$

Shoreline length: 1267 m

Shoreline development: 1.46

Volume development: 1.04

Mean depth/max. depth: 0.34

Area/mean depth: 0.84

Water level fluctuation: minimal - less than 30 cm drop through the summer (1975)

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 3	16.08	37.7
3 - 6	11.94	28.0
6 - 9	7.73	18.1
9 - 12	4.34	10.2
12 - 15	2.04	4.8
15 - 20.5	0.52	1.2

Water renewal time: 32 days (22 vii 75), or approximately 4 times per year

Open-water period: late June to late October (approximately 120 ice-free days)

Catchment area: 178 ha

Bedrock composition of catchment area: 60% quartzite, 40% Cambrian carbonates

Catchment area coverage: 5% forest, 95% exposed rock and low vegetation

(Catchment area - lake area)/lake area: 29

Human activities in catchment area: unauthorized camping, hiking trail to lookout on Big Beehive, teahouse at lake outlet (waste from toilets stored and removed from catchment area). Fishing forbidden.

Bottom composition: 80 to 90% of the lake bottom is covered with rock fragments of various sizes. The deepest portion of the lake bottom is covered by sandy black sediments having an organic content of 6.2%.

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

Conductivity: 132 µmho/cm @ 25C pH: 8.3 units (n = 2)

Total alkalinity as $CaCO_3$: 65.0 (n = 2) Total acidity: 9.1

Total hardness as $CaCO_3$: 68.4

Variation with depth (22 vii 75):

	composite surface to 10 m	14 m
conductivity	132 µmho/cm @ 25C	154 µmho/cm @ 25C
pH	8.1 units	7.6 units
total alkalinity	61.5	75.1

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 3 viii 66 Depth: 0.5 m

Turbidity: 0.2 JTU Colour: 0 HU

pH: 7.9 units Sum of constituents: 60.2

Conductivity: 115 µmho/cm @ 25C Sum const./cond: 0.52

Total alkalinity as $CaCO_3$: 53.6

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 58.3

Major constituents

Calcium: 14.3 Magnesium: 5.5 Sodium: 0.2 Potassium: 0.1
Bicarbonate: 65.3 Carbonate: 0 Sulphate: 5.5 Chloride: 0.2

Minor constituents

Aluminum: 0.04 Iron: 0.00 (both total and dissolved)
Manganese: 0.000 (both total and dissolved) Copper: 0.000
Zinc: 0.000
Fluoride: 0.01 Phosphate: $<$0.05 (total) Nitrate: 0.2

Silica: 2.0

Ammonia: 0.0

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 22 vii 75
Depth: 0 - 10 m composite sample

Chlorophyta	
Ankistrodesmus falcatus var. acicularis	8
Dictyosphaerium elegans	36
Scenedesmus sp.	11
Chrysophyta	
Chrysophyceae	
Bitrichia chodatii	31
Dinobryon cylindricum	17
D. sociale	14
Mallomonas nr. acaroides	36
Spiniferomonas bourrellii	14
Chrysophyta (continued)	
Diatomaceae	
Cyclotella sp.	372
Cymbella sp.	3
Pinnularia borealis	3
Synedra sp.	355
Cryptophyta	
Rhodomonas minuta	28
Total	928

b. Zooplankton (collections: 3 viii 66, 18 vii 73, 27 x 74, 22 vii 75)

Units are maximum numbers per litre.

Rotifera	
Kellicottia longispina	0.1 - 1
Polyarthra vulgaris	1000 - 10,000
Synchaeta	10 - 100
Cladocera	
Daphnia (pulex?)	<0.1
Copepoda	
Eucyclops nr. speratus	0.01
Orthocyclops modestus	5.77
Amphipoda	
Gammarus lacustris	0.021
Insecta	
Chironomidae larvae	0.021

maximum crustacean standing crop:
6.1 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

no macrophytes found

b. Shoreline fauna (units are numbers collected)

collections:	18 vii 73	22 viii 75 (15 min.)
Crustacea		
Amphipoda		
Gammarus lacustris		31
Insecta		
Trichoptera		
unidentified pupae	39	
Limnephilidae larvae		19
Coleoptera		
Hydroporus compertus adults		2
Diptera		
Chironomidae		
Orthocladiinae larvae	2	

c. Bottom fauna (collection: 22 vii 75, n = 2)
Units are mean number per square metre.

Annelida	
Oligochaeta	43
Insecta	
Chironomidae	
<u>Chironomus</u> larvae	2863
<u>Tanytarsus</u> larvae	86
Chironomini pupae	43

Standing crop as mean gm preserved wet weight/m^2:

Chironomidae (mainly) 6.979

3. Fish

Collection date: 6 - 7 x 75 Set duration: 14 h

Gear: 9 m each of 1, 1½, 2, 3, 4- inch mesh green nylon monofilament gillnet set on float

Catch: 1 splake (<u>Salvelinus namaycush</u> X <u>S. fontinalis</u>) mature male, near spawning condition, age 7?, fork length 355 mm, weight 602 gm, mutilated lower jaw, empty stomach

D. <u>Discussion</u>

Kucera (1974) briefly described the probable origin of the lake basin, and illustrated the setting with two excellent photographs. According to his interpretation, Lake Agnes lies in a small hanging valley, in "a rock basin ... formed by the plucking action of the glacier on shattered or heavily jointed bedrock."

Kucera (1974) gave the lake elevation as 6685 feet (2037 m), and Rawson (1939) used the figure 6885 feet (2098 m). Our choice, 2118 m, was taken from a National Topographic Series map which placed the lake between the 6900- and 7000-foot contours. Rawson's (1939) estimate of the lake area of 35 acres (14.2 ha) is definitely too large by a factor of at least 2.

We made no soundings east of the eastern tip of the 12 m contour (Fig. 2.1), because we were forced off the lake by a sudden blizzard. Positions of the 3, 6, and 9 m contours east of that point are therefore conjectural.

The extrapolation of the primary productivity curve to the maximum depth (Fig. 2.3) was arbitrary. We assumed that light and therefore photosynthesis must have been very low at 20.5 m, because that was 3.9 times greater than the Secchi depth. Light intensity is typically about

1% of the surface intensity at 2.5 times the Secchi depth, although factors of 4 or 5 times have occasionally been reported (Strickland (1958). In any case, any error introduced by extrapolation of the curve is unlikely to have an important effect on total phytoplankton productivity in the entire lake, since the volume of water below 14 m is only about 6 or 7% of the total lake volume (p. 9).

Rawson (1939) found that suspended silt restricted the Secchi depth to only 2.5 m in late August, 1938, or less than half of the lowest reading recorded in recent years (Fig. 2.2). He noted, however, that the lake was much clearer in July, 1938. The lowest Secchi depth recorded in the present survey (5.3 m on 22 vii 75) likewise was owing to suspended silt.

Rawson's temperature readings indicate thermal stratification in August, 1938 similar to that observed by us recently (Fig. 2.2), and his oxygen determinations show a slightly lower concentration at 17 m than at the surface. Slight chemical stratification comparable to the dissolved oxygen stratification found by Rawson was apparent on 22 vii 75 in the present study.

Rawson's shoreline collections, like ours, contained numbers of Gammarus, Trichoptera, and aquatic Coleoptera; however, he reported planktonic organisms to be abundant -- particularly Diaptomus sp. He also reported finding Daphnia pulex, but made no mention of finding any cyclopoids in his samples. In contrast, plankton collections made since 1966 have been sparse, Diaptomus has been absent, Daphnia pulex was found only once and then only in low numbers, and the cyclopoid Orthocyclops modestus has dominated the meagre crustacean plankton.

It is possible that these changes in plankton composition and abundance resulted from the introduction of fish, which were absent from the lake before 1951 (National Parks stocking records, Ward 1974). There is evidence that similar changes in zooplankton composition in other high lakes in Banff Park resulted from the introduction of trout into lakes that were previously free of fish (Anderson 1972).

Reed (1959) reported finding Diaptomus sicilis in Rawson's samples from Lake Agnes. We question this record. In a survey of hundreds of mountain lakes in southwestern Alberta and southeastern British Columbia, D. sicilis characteristically occurred only in low-elevation lakes at 1675 m or lower (usually much lower), and of a character considerably different from that of Lake Agnes (Anderson 1971, 1974b). Furthermore, D. sicilis is a small species, but Rawson specifically mentions that the Diaptomus in Agnes was large (Rawson 1939, p.35).

Splake (Salvelinus namaycush X S. fontinalis) were stocked in Lake Agnes in 1951, and the population has maintained itself by natural recruitment ever since (Goldberg et al. 1967, Ward 1974). The single specimen we collected must have resulted from natural reproduction in the lake. The low catch (1 fish in 14 h) might be owing to concentration of the population elsewhere in the lake, perhaps for spawning, or it may indicate a small population. Further investigation is needed to assess the present status of the Lake Agnes splake population.

No other fish species occur or have occurred in the lake. A recommendation by Rawson (1939) to stock Lake Agnes with golden trout (Salmo aguabonita) was evidently never acted upon (National Parks stocking records).

The large crustacean Mysis relicta was introduced into Lake Agnes a few years ago (J.C. Ward, personal communication), but recent attempts to collect it from the lake have not been successful (Anderson and Donald, unpublished data).

Addendum

We test-fished Lake Agnes on July 15, 1976 by angling with barbless hooks. We caught no fish, saw no fish and saw no rises in approximately 4 h of angling by two people. In past years, fish were readily caught by a variety of lures similar to those used by us (A.C. Colbeck, personal communication). The lady who runs the teahouse said she had seen only a few rises in 1975 and 1976, but that fish rises were much more frequent "a few years ago". Our field notes record that fish were frequently rising to the surface on July 18, 1973. These observations suggest that the splake population in Lake Agnes has declined appreciably over the past two or three years, and tend to confirm the suggestion made above, based on gillnet catches, that the present population is small.

Lake Agnes has been closed to angling for many years, but poaching is evidently not uncommon according to local people. Poaching might account for the decline in the splake population.

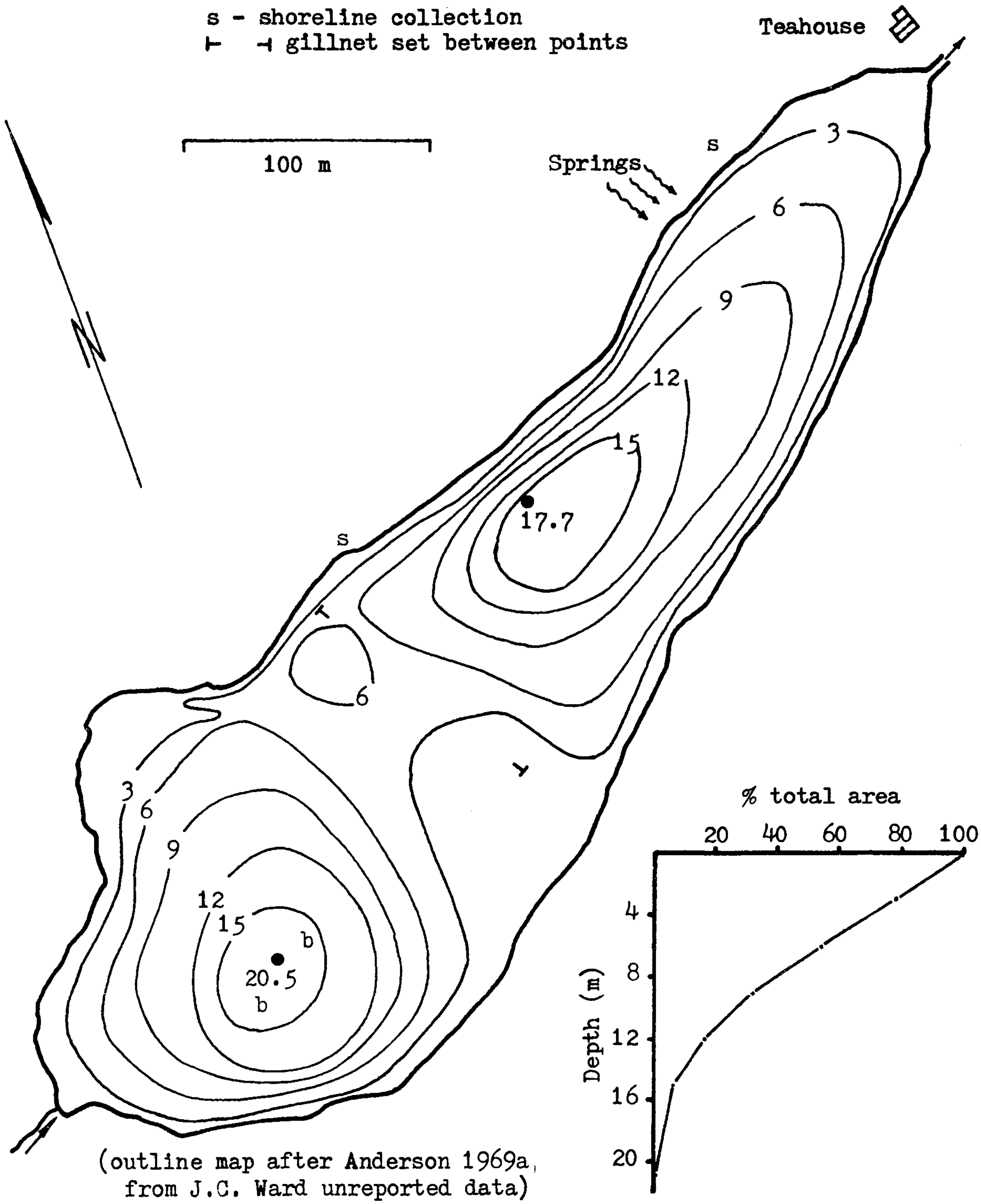
The Lake Agnes splake were of scientific interest to fish geneticists, since they formed an isolated, breeding population that provided an opportunity to study the impact of natural selection on the transmittance of certain genes (Goldberg et al. 1967).

The adult stoneflies Isocapnia (missourii?) and Capnia trava, and the adult caddisflies Apatania zonella and Hesperophylax incisus were collected at Lake Agnes on July 15, 1976[1]. I. missourii is described as very rare by Gaufin et al. (1966). A. zonella, also reported from this lake by Nimmo (1971), is apparently quite uncommon in southern Alberta and southeastern British Columbia according to that author.

1. Mr. R. Mutch identified the stoneflies and H. incisus, and agreed with our identification of A. zonella. The Trichoptera have been sent to Dr. Nimmo for verification.

Figure 2.1. Bathymetric map and hypsographic curve of Lake Agnes. Depths are in metres.

b - bottom fauna collection
s - shoreline collection
⊢ ⊣ gillnet set between points



(outline map after Anderson 1969a, from J.C. Ward unreported data)

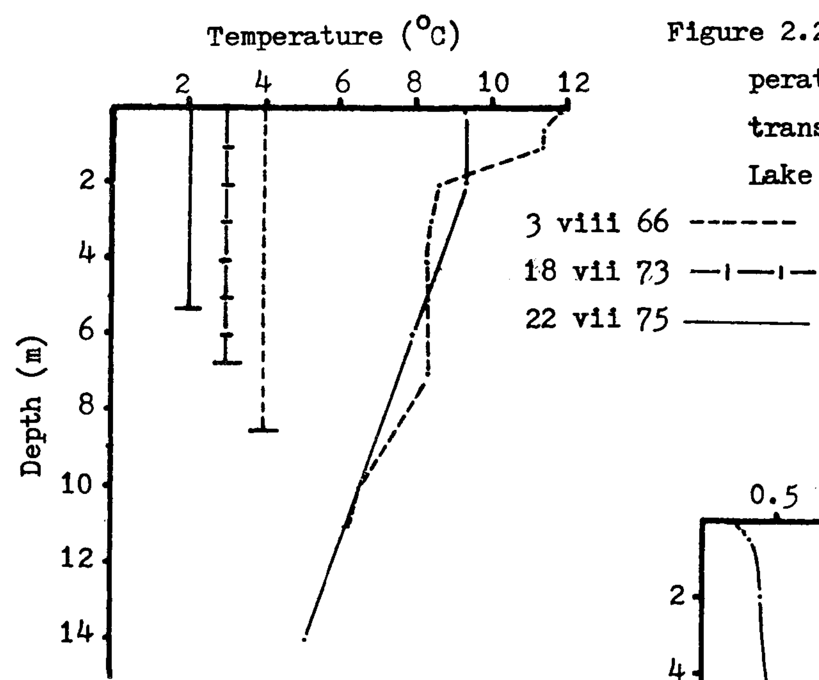


Figure 2.2. Representative temperature profiles and Secchi transparency readings (⊥), Lake Agnes.

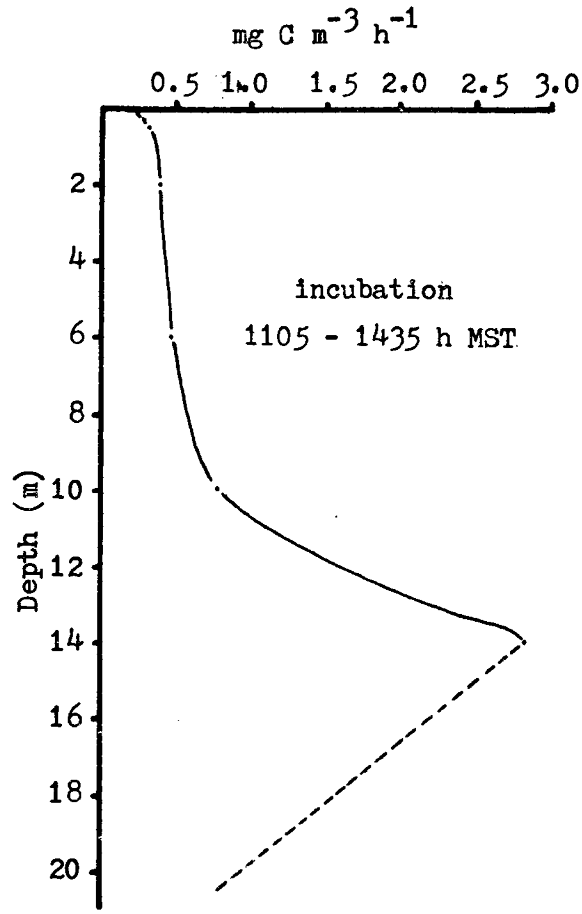


Figure 2.3. Profile of primary productivity, Lake Agnes 22 vii 75. Points are net figures (light minus dark). Samples from 0 to 10 m were taken with a hose, and the 14 m sample was taken with a student sampler.

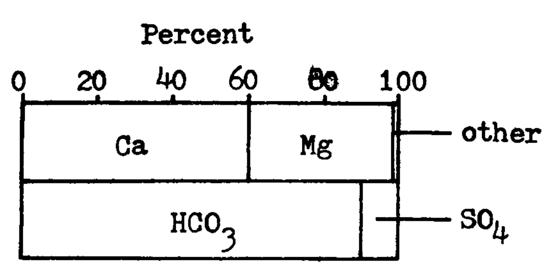


Figure 2.4. Percent ionic composition of surface water calculated on the basis of equivalent weights, Lake Agnes 3 viii 66.

ANNETTE LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 552907, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Moraine Lake Road 5.5 km (3.4 mi)

Elevation: 1966 m

Altitudinal zone: upper subalpine

Basin type: dammed behind lateral moraine (Kucera 1974)

Length: 306 m

Mean width: 173 m

Area: 5.3 ha

Maximum depth: 13.7 m

Mean depth: 6.3 m

Volume: $33.5 \times 10^4 m^3$

Shoreline length: 962 m

Shoreline development: 1.18

Volume development: 1.38

Mean depth/max. depth: 0.46

Area/mean depth: 0.84

Water level fluctuation: minimal - probably less than 30 cm drop through summer (1975)

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 2	9.57	28.6
2 - 4	7.48	22.3
4 - 6	5.83	17.4
6 - 8	4.67	13.9
8 - 10	3.39	10.1
10 - 12	2.13	6.4
12 - 13.7	0.45	1.3

Water renewal time: 16 days (1 viii 75)

Open-water period: no observations

Catchment area: 288 ha

Bedrock composition of catchment area: 74% quartzite, 26% Cambrian carbonate rocks

Catchment area coverage: 12% forest, 21% glacier, 67% exposed rock and low plants

(Catchment area - lake area)/lake area: 53

Human activities in catchment area: short section of Paradise Valley trail

Bottom composition: organic content of sediments 8.0%

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

Colour (½ Secchi): milky white; turbid, silty water

Conductivity: 151 µmhos/cm @ 25C (n = 2) pH: 8.05 units (n = 2)

Total alkalinity as $CaCO_3$: 71.7 (n = 2)

Variation with depth (1 viii 75):

	0.5 m	10 m
Conductivity:	143 µmho/cm @ 25C	143 µmho/cm @ 25C
pH:	8.3 units	8.2 units
Total alkalinity:	68.3	75.1

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 5 ix 75 Depth: surface

Turbidity: 0.9 JTU Colour: less than 0.5 HU

pH: 8.1 units Sum of constituents: 68.96

Conductivity: 129 µmho/cm @ 25C Sum const./cond: 0.53

Total alkalinity as $CaCO_3$: 60.4

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 68.1

Total inorganic carbon: 15 Total organic carbon: less than 1

Major constituents

Calcium: 17.7 Magnesium: 5.8 Sodium: 0.3 Potassium: 0.3
Bicarbonate: 73.6 Carbonate: 0 Sulphate: 4.5 Chloride: 0.3

Minor constituents
Total phosphorus: 0.003 Nitrogen (nitrate + nitrite): 0.11
Kjeldahl nitrogen: 0.1

Silica: 3.3

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 1 viii 75
Depth: 0 - 10 m composite sample

Chlorophyta	
Dictyosphaerium elegans	39
Chrysophyta	
Chrysophyceae	
Bitrichia chodatii	14
Chromulina sp.	3
Pseudokephyrion nr. *hyalinum*	42
Chrysophyta (continued)	
Diatomaceae	
Achnanthes sp.	6
Cyclotella sp.	126
Synedra sp.	22
Cryptophyta	
Rhodomonas minuta	1364
Total	1616

b. Zooplankton (collections: 29 viii 68, 1 viii 75)
Units are maximum numbers per litre.

maximum crustacean standing crop: 18.8 animals/l

Cladocera	
Daphnia middendorffiana	0.38
Copepoda	
Diaptomus arcticus	18.8

2. Bottom and Shoreline Organisms

a. Macrophytes
no macrophytes found

b. Shoreline fauna (collection: 5 ix 75, 20 minutes)
Units are numbers collected.

Crustacea	
Amphipoda	
Gammarus lacustris	2
Insecta	
Plecoptera	
Alloperla	8
Nemoura oregonensis or *haysi*	16
Trichoptera	
Limnephilidae	9
Insecta (continued)	
Diptera	
Chironomidae	
unidentified	1
Tanytarsini	1

c. Bottom fauna (collection: 1 viii 75, n = 2)
Units are mean no./m^2.

Crustacea	
Copepoda	
Diaptomus copepodids	22
Amphipoda	
Gammarus lacustris	108
Insecta	
Diptera	
Chironomidae	
Procladius s. str.	86
Parakiefferiella?	129
Limnophyes (*karelicus* type)	65
Protanypus	22
Chironomidae (continued)	
Chironomus	689
Stictochironomus?	151
Micropsectra	43
unidentified pupae	22
Mollusca	
Pelecypoda	
Pisidium	409

Standing crop (mean gm preserved wet weight/m^2):

Chironomidae	4.202	
Pisidium	0.482	(with shell)
Gammarus lacustris	5.212	

3. Fish

Collection date: 5 ix 75 Set duration: 3 h 10 min

Gear: 20 m each of 3/4, 1½, 2, 3, 4 - inch mesh green multifilament nylon gillnet set on bottom.

Catch: nil

D. Discussion

Kucera (1974) presented a photograph which well illustrates the setting of Annette Lake. It lies at the base of Mt. Temple, dammed behind a lateral moraine at the leading edge of a rock landslide.

Annette Lake provides a rather inhospitable habitat for its few inhabitants. It is cold, silty, well - shaded from the sun much of the day, and is subject to frequent high winds, judging from the wind - blasted trees on its north shore. The open water period is probably about 120 days or less.

Originally, Annette Lake was free of fish. Cutthroat trout (Salmo clarki) were stocked in 1959 and rainbow trout (S. gairdneri) were added in 1964. Some natural recruitment of both species is said to occur (Ward 1974).[1] If so, underground inflow along the rockslide on the west side might provide suitable spawning sites.[2] The lake was last stocked with rainbow in 1965 (1000 fingerlings) and with cutthroat in 1966 (2000 fingerlings). Present policy dictates no further stocking (National Parks stocking records).

More test netting would be required to assess the present status of the trout populations in Annette Lake. The 3 h set made in 1975 was too short to adequately demonstrate the presence or absence of fish. We saw no fish in two visits to the lake in 1975, but an angler we spoke to reported seeing some.

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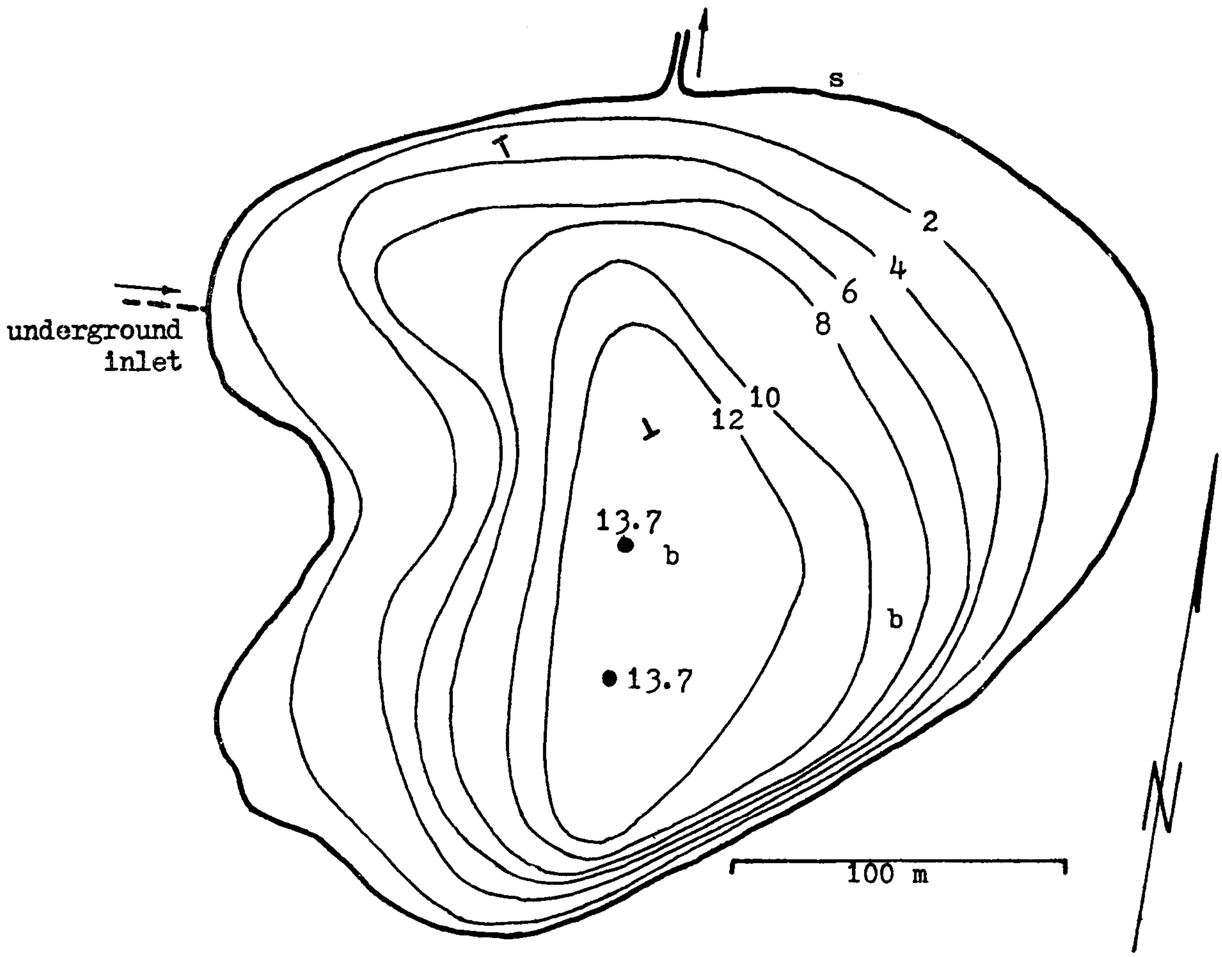
1. This information appears on Ward's p. C4. He indicates that both species occur in the lake on p. D60. Elsewhere, however, (p. 16) he states that only rainbows now occur.

2. Carlander (1969) pointed out after extensively reviewing the literature that rainbows and cutthroats appear to spawn successfully only in streams. The only stream available to Annette Lake fish is the outlet, which is torrential. We suspect that natural recruitment is limited, at best, in this lake.



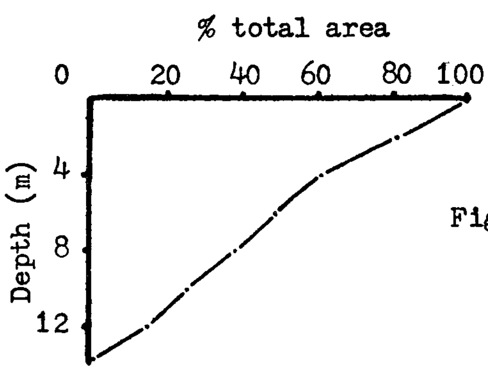


Figure 2.5. Bathymetric map and hypsographic curve of Annette Lake. Depths are in metres.

b - bottom fauna collection
s - shoreline collection
⊢ ⊣ gillnet set between points

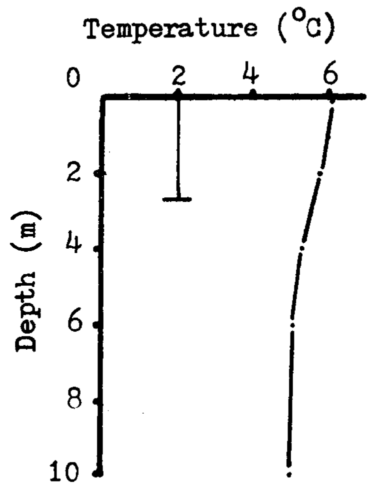


Figure 2.6. Temperature profile and Secchi transparency reading (⊥), Annette Lake, 1 viii 75.

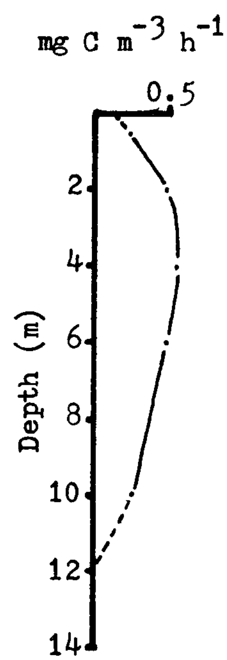


Figure 2.7. Profile of primary productivity, Annette Lake, 1 viii 75. Points are net figures (light minus dark). Samples were collected from discrete depths (student sampler). Incubation 0850 - 1215 h MST.

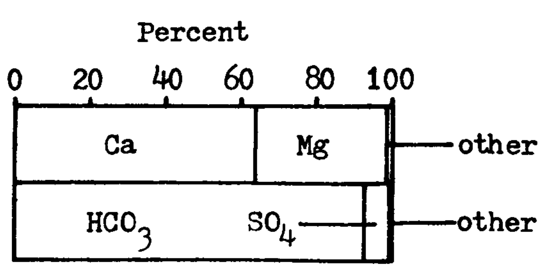


Figure 2.8. Percent ionic composition of surface water calculated on the basis of equivalent weights, Annette Lake, 5 ix 75.

BAKER LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NH 667047, NTS Map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: restricted road to Temple Lodge, then by trail approximately 8.1 km (5 mi)

Elevation: 2210 m

Altitudinal zone: treeline

Basin type: dammed behind tilted rock strata

Length: 1153 m

Mean width 316 m

Area: 36.4 ha

Maximum depth: 11.6 m

Mean depth: 5.4 m

Volume: 198.6 x $10^4 m^3$

Shoreline length: 3138 m

Shoreline development: 1.47

Volume development: 1.41

Mean depth/max. depth: 0.47

Area/mean depth: 6.74

Water level fluctuation: minimal - water level dropped 30 cm or less during the summers of 1974 and 1975.

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 2	64.83	32.6
2 - 4	52.58	26.5
4 - 6	40.88	20.6
6 - 8	26.36	13.3
8 - 10	12.27	6.2
10 - 11.6	1.69	0.8

Water renewal time: 42 - 115 days (30 vii 74, 28 viii 74) or approximately 1.5 times per year

Open-water period: early July to probably late October (100 - 120 ice-free days; no direct observation of freeze-up date).

Catchment area: 806 ha

Bedrock composition of catchment area: 42% Devonian carbonate, 41% quartzite, 13% Miette Group, 4% Cambrian carbonate rocks.

Catchment area coverage: 10% scattered clumps of trees, 90% exposed rocks and low plants

(Catchment area - lake area)/lake area: 21

Human activities in catchment area: primitive campsite near lake outlet; unauthorized campsites along south shore also frequently used. Trails, horseback riding, angling. Includes activities in Ptarmigan and Little Baker catchment areas.

Bottom composition: The central portion of the lake bottom is covered mainly by black silty sediments having an organic content of 12.8% by weight. Much of the peripheral area is sandy.

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

Conductivity: 143 µmho/cm @ 25C   pH: 7.7 units (n = 2)

Total alkalinity as $CaCO_3$: 54.6   Total acidity: 3.42

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 68.4

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 22 vii 66   Depth: 0.5 m

Turbidity: 0.3 JTU   Colour: 5 HU

pH: 8.1 units   Sum of constituents: 54.7

Conductivity: 104 µmho/cm @ 25C   Sum const./cond: 0.53

Total alkalinity as $CaCO_3$: 39.3

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 49.8

Major constituents

Calcium: 11.0 Magnesium: 5.4 Sodium: 0.6 Potassium: 0.3
Bicarbonate: 47.9 Carbonate: 0 Sulphate: 11.7 Chloride: 0.1

Minor constituents

Iron (total): 0.02 Iron (dissolved): < 0.01 Aluminum: 0.00
Manganese (total): 0.010 Manganese (dissolved): 0.005
Copper: 0.000 Zinc: 0.005

Flouride: 0.04 Phosphate (total): 0.10 Nitrate: < 0.05

Silica: 1.9

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 28 viii 74

Depth: 0 - 10 m composite sample

Chlorophyta	
Ankistrodesmus sp.	63
Chlamydomonas botrys	8
Chlamydomonas sp.	14
Dictyosphaerium ehrenbergianum	150
Oocystis borgei	21
O. lacustris	21
O. parva	378
Oocystis sp.	44
Quadrigula sp.	12
Schroederia setigera	28
Sphaerocystis schroeteri	21
Chrysophyta	
Chrysophyceae	
Bitrichia chodatii	6
Chrysosphaera sp. ?	192
Chromulina sp. A	3
" sp. B	15
Chrysophyceae (continued)	
Ochromonas nr. *sphaerica*	4
Diatomaceae	
Amphora ovalis	2
Cyclotella sp.	15
Cymbella ventricosa	2
Synedra radians	2
Cryptophyta	
Cryptomonas sp.	8
Rhodomonas minuta	39
Total	1048

b. Zooplankton (collections: 22 vii 66, 19 viii 66, 30 vii 74, 28 viii 74)

Units are maximum numbers per litre.

Rotifera	
Kellicottia longispina	< 0.1
Proalinopsis ?	0.1 - 1
Cladocera	
Chydorus sphaericus	0.41
Daphnia middendorffiana	0.79
Copepoda	
Diaptomus arcticus	0.974
D. tyrrelli	6.477
Acanthocyclops vernalis	0.24
Eucyclops speratus	0.006
?*Macrocyclops albidus*	0.006
Amphipoda	
Gammarus lacustris	0.015

maximum crustacean standing crop: 8.7 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

Potamogeton (*praelongus*?) appeared frequently in Ekman grab samples from the west end of the lake, and an unidentified Characeae species occurred frequently in such samples taken in the large bay along the south shore.

b. Shoreline fauna

Units are numbers collected.

collections:	30 vii 74 (30 min)	28 viii 74 (30 min)
Annelida		
Oligochaeta	2	6
Hirudinoidea		2
Crustacea		
Copepoda		
Diaptomus arcticus		15
Amphipoda		
Gammarus lacustris	59	

b. Shoreline fauna (continued)

	30 vii 74 (30 min)	28 viii 74 (30 min)
Insecta		
Ephemeroptera		
Parameletus	3	
Siphlonurus		42
Trichoptera		
unidentified pupae	11	
Coleoptera		
Rhantus or *Colymbetes* larvae		1
Diptera		
Tipulidae		
Dicranota	1	
Chironomidae		
Orthocladiinae	8	2
Cryptochironomus	1	1
unidentified larvae	1	1
Arachnida		
Hydracarina		
Lebertia	5	3
Mollusca		
Gastropoda		
Lymnaea		4
Pelecypoda		
Sphaeriidae	7	25

c. Bottom fauna (collection: 30 vii 74, n = 7)
Units are mean no./m^2.

Nematoda	6
Annelida	
Oligochaeta (2 spp.)	86
Hirudinoidea	6
Crustacea	
Copepoda	
Diaptomus copepodids	6
Amphipoda	
Gammarus lacustris	271
Insecta	
Diptera	
Chironomidae	
Procladius s. str.	277
Corynoneura	80
Cricotopus	308
Paracladius?	12
Psectrocladius?	12
Paratrichocladius?	18
Chironomidae (continued)	
Chironomus	62
Paracladopelma	37
Phaenopsectra s. str.	68
Stictochironomus	18
Chironomini pupae	6
Cladotanytarsus	221
Tanytarsus	584
" pupae	615
Arachnida	
Hydracarina	
Lebertia	6
Mollusca	
Pelecypoda	
Pisidium	1495

Standing crop (mean preserved wet weight/m^2):

Gammarus lacustris	7.285 gm
Chironomidae mainly	3.240 gm
Sphaeriidae mainly	5.178 gm (with shell)
Oligochaeta	1.911 gm
Hirudinoidea	0.666 gm

3. Fish (data courtesy Mr. B. D. Smiley)

Collection date: 14 and 16 vii 73   Set duration: about 20 h overnight each date

Gear: 7.6 m each of 3/4, 1, 1½, 2, 3, 4-inch mesh green monofilament nylon gillnet. Four gangs were set on each date.

Catch: 65 brook trout (*Salvelinus fontinalis*): 28 males, 29 females, 8 unsexed
12 cutthroat trout (*Salmo clarki*): 4 males, 6 females, 2 unsexed

a. Brook trout

Age:	0	1	2	3	4	5	6	8
Number:	2	1	24	11	10	6	1	1
Mean fork l. (mm):	81.5	98	200.6	261.1	327.1	385.7	461	500
Mean wt. (gm):	5.8	10	102.3	253.4	559.4	959.7	1508	1660

Maturity: no observations

Food: 25 stomachs examined, 6 (24%) empty

Food item	% of fish with item	no. fish in which item rated rare	common	abundant
Cladocera	32	2	4	2
Gammarus lacustris	44	1	6	4
Diptera pupae	16	3	1	
Limnephilidae larvae	4	1		
Hirudinoidea	12		2	1

b. Cutthroat trout

Age:	2	3	4	5	7
Number:	2	5	3	1	1
Mean fork l. (mm):	202.0	173.8	207.0	312	385
Mean wt. (gm):	100.5	58.6	104.0	981	1047

Maturity: no observations

Food: 7 stomachs examined, 1 (14%) empty

Food item	% of fish with item	no. fish in which item rated rare	common	abundant
Cladocera	29		1	1
Gammarus lacustris	29		2	
Limnephilidae larvae	14	1		
Hirudinoidea	29	1	1	

D. <u>Discussion</u>

A photograph illustrating the setting of Baker Lake is presented by Baird (1967, p. 231). The caption mistakenly identifies the scene as a view of the "interior country about 10 miles east of Bow Pass."

Cutthroat trout were first stocked in Baker Lake in 1931, and were added in quantity in several subsequent years (National Parks stocking records). Natural recruitment occurs, the lower reaches of Ptarmigan Creek being used as a spawning ground (Rawson 1939, Ward 1974, Smiley 1976). Spawning takes place in late June (Smiley 1976), and may persist into late July (Rawson 1939).

Brook trout were stocked once, in 1965, and have maintained a population by natural recruitment ever since (National Parks stocking records, Ward 1974, Smiley 1976).

Rawson (1939) noted that the largest Baker Lake cutthroats that he caught in 1937 - 1938 were 18 to 20 inches (457 - 508 mm) long, weighed about 4 pounds (1818 gm) and appeared to be 4 or 5 years old judging from scale readings. These fish were therefore considerably larger than the largest cutthroat, an age 7 fish, collected in 1973 (p. 27). However, it would be unwarranted to assume that there has been a decline in the growth rate of Baker Lake cutthroats since 1938, considering the typically wide spread of sizes within age groups of trout (e.g; Fig. 2.13) and the fact that ages estimated from scales may be in error by a year or more (Smiley 1976).

In July, 1973, cutthroat trout were typically smaller than brook trout of the same age (Fig. 2.13) and were much less abundant in the catch than were brook trout. In September, 1973, cutthroat again made up only a small proportion of the catch (Smiley 1976), indicating that the low number caught in July was not simply because cutthroats were in Ptarmigan Creek spawning out of reach of the nets. The small number of cutthroats in the catch probably reflects a small cutthroat population relative to that of the brook trout.

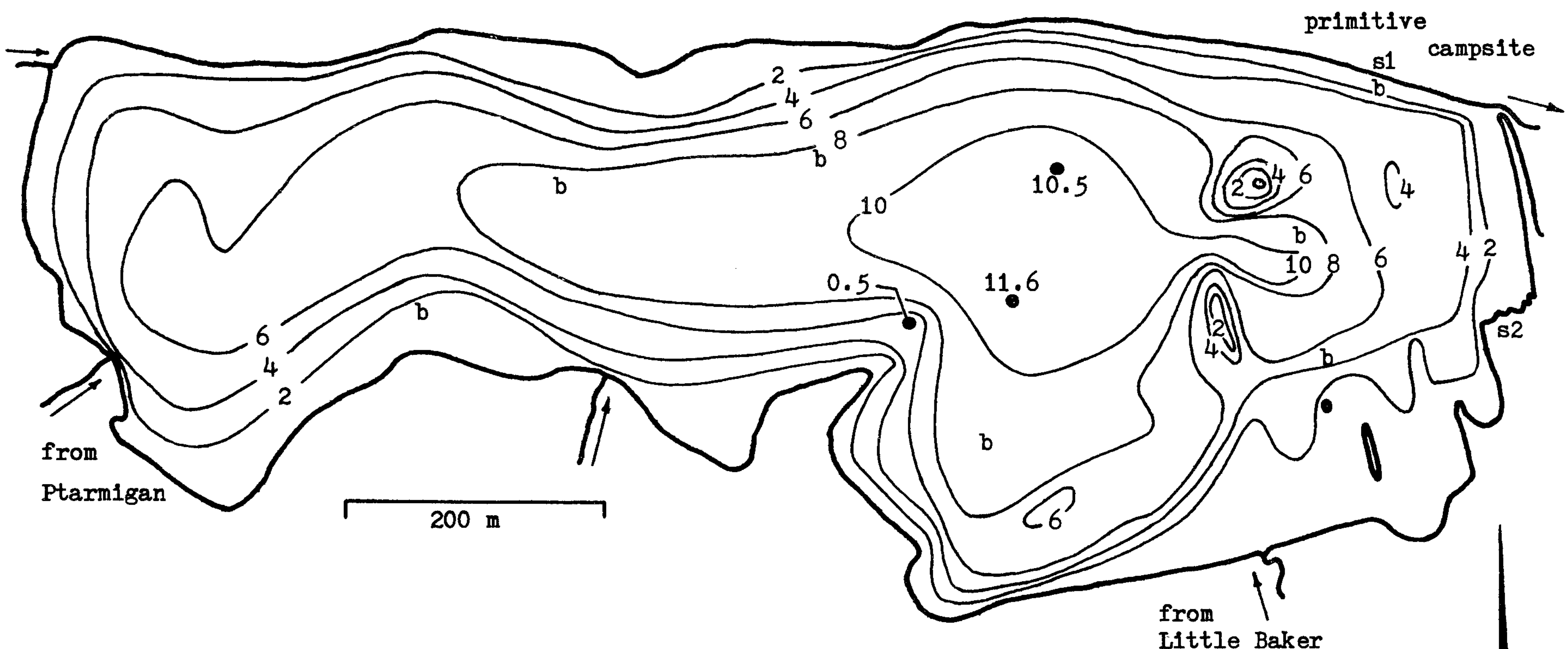
Rawson (1939) caught a total of 63 cutthroat trout from Baker Lake in gillnets set on August 30, 1937 and July 28, 1938. He did not specify the mesh size, set duration or (in one case) the length of the net used. It seems safe to assume that he used a range of mesh sizes from about $1\frac{1}{2}$ or 2 inches to perhaps 4 inches (fish size ranged from 7 to 18 inches), and set durations of about 24 hours (sets were made on one date only each year).

The July 1938 set was 50 yards (45.7 m) long and captured 23 cutthroat trout, or about 0.02 fish per metre of net per hour. In contrast, the July 1973 set captured only 12 cutthroat trout, in 182.4 m of net set for about 40 hours, or 0.002 fish per metre of net per hour.

Rawson caught cutthroat at a rate 10 times greater in 1938 in Baker Lake than we did in 1973, even though we might reasonably expect our nearly transparent nylon monofilament nets to be more efficient than the cotton or linen nets which Rawson must have used.

Though this evidence is far from conclusive, in view of the several assumptions that had to be made in the comparison, it tends to support the conviction expressed to us by some anglers and Park employees that the cutthroat trout population in Baker Lake has declined appreciably over the years.

Substitution into Smiley's (1976) length - weight equations for both brook and cutthroat trout shows that they are incorrect. His comments on the condition of fish in the two populations, which are based on the slope coefficients of these equations, are therefore invalid.



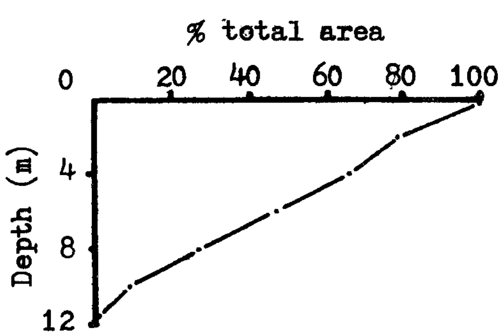


Figure 2.9. Bathymetric map and hypsographic curve of Baker Lake. Depths are in metres.

b - bottom fauna collection
s - shoreline collection

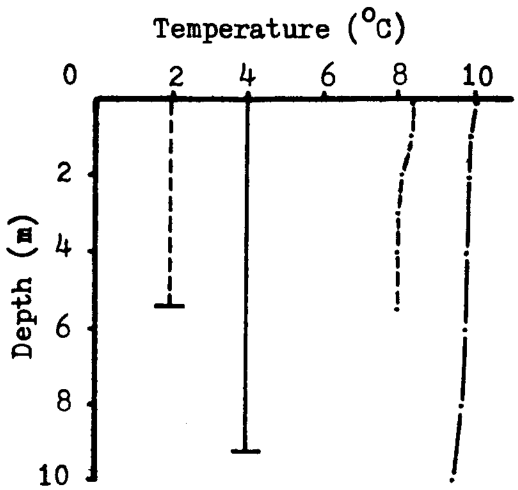


Figure 2.10. Selected temperature profiles and Secchi transparency readings (⊥), Baker Lake.
22 vii 66 ----
28 viii 74 ——

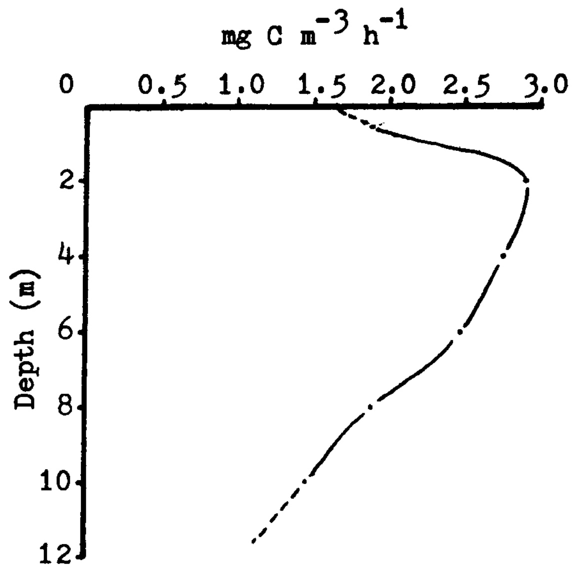


Figure 2.11. Profile of primary productivity, Baker Lake, 28 viii 74. Points are net figures (light minus dark). Samples were collected with a hose. Incubation 0845 - 1155 h MST.

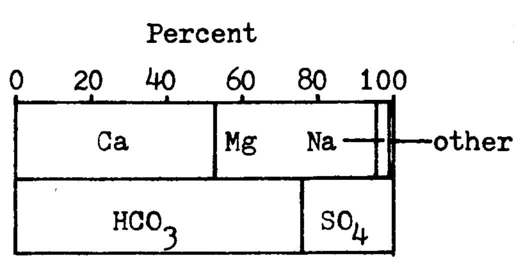


Figure 2.12. Percent ionic composition of surface water calculated on the basis of equivalent weights, Baker Lake, 22 vii 66.

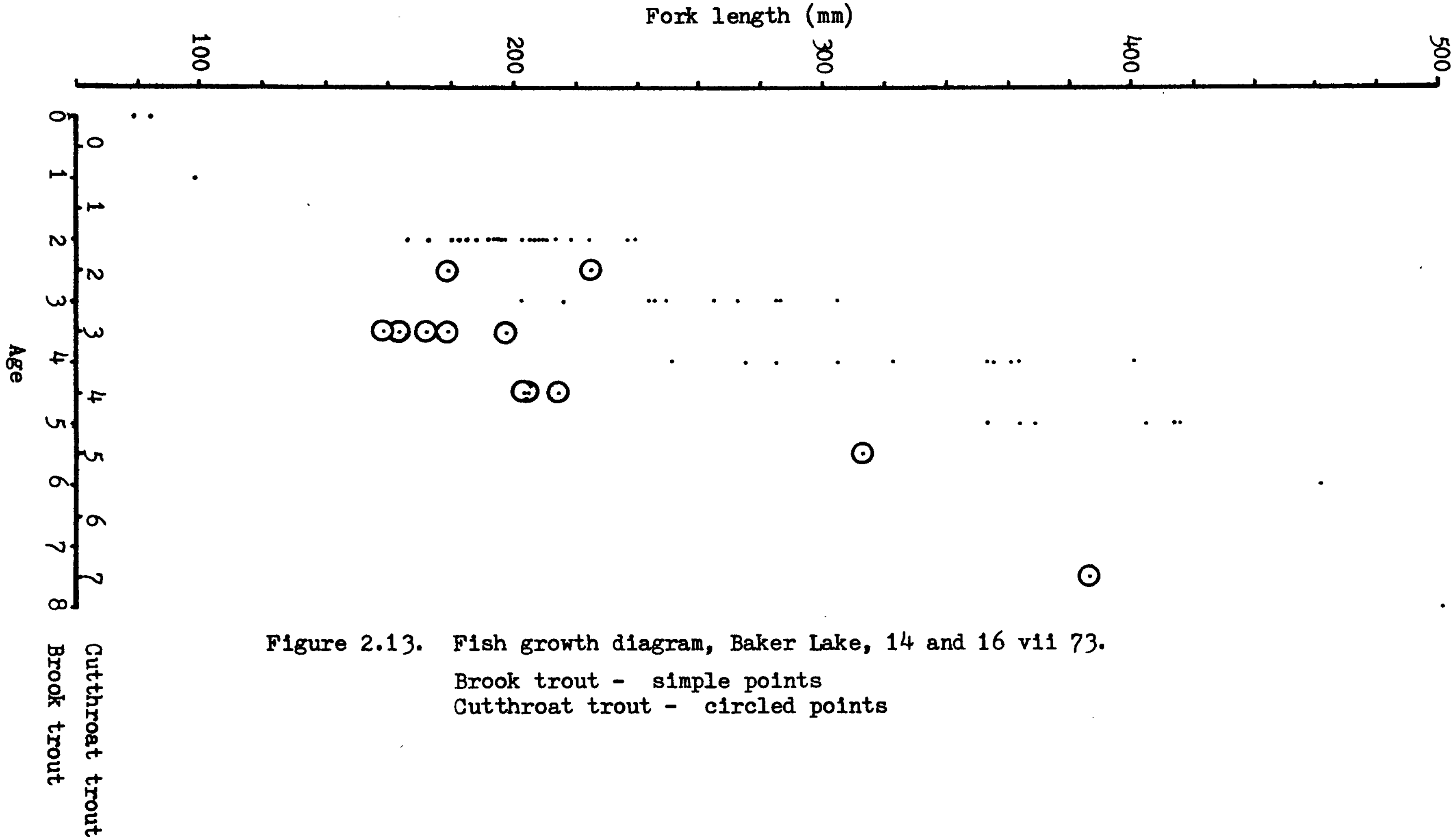


Figure 2.13. Fish growth diagram, Baker Lake, 14 and 16 vii 73.

Brook trout - simple points
Cutthroat trout - circled points

LITTLE BAKER LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NH 675039, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: restricted road to Temple Lodge, then by trail approximately 10.5 km (6.5 mi)

Elevation: 2240 m

Altitudinal zone: treeline

Basin type: depression in the upturned edges of rock strata

Length: 328 m

Mean width: 88 m

Area: 2.9 ha

Maximum depth: 5.0 m

Mean depth: 2.0 m

Volume: $5.7 \times 10^4 m^3$

Shoreline length: 1207 m

Shoreline development: 2.00

Volume development: 1.18

Mean depth/max. depth: 0.40

Area/mean depth: 1.45

Water level fluctuation: minimal - high water marks suggest a drop of less than 30 cm through the summer (1975)

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 1	2.39	41.8
1 - 2	1.65	28.8
2 - 3	1.06	18.4
3 - 4	0.53	9.2
4 - 5	0.10	1.8

Water renewal time: 47 days (21 viii 75), based on visual comparison of outflow to the inflow of Brachiopod (about the same)

Open-water period: no observations

Catchment area: 19 ha

Bedrock composition of catchment area: 100% Devonian carbonate rocks

Catchment area coverage: 20% scattered clumps of trees, 80% exposed rock and low plants

Catchment area - lake area)/lake area: 5.6

Human activities in catchment area: hiking, angling

Bottom composition: organic content of sediments 44.3%

Secchi depth: very clear to bottom (19 viii 66, 28 viii 75)

Colour (½ Secchi): light blue-green (28 viii 75)

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

pH: 8.4 units — Total acidity: 4.56

Total alkalinity as $CaCO_3$: 88.8

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 102.6

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 21 viii 75	Depth: surface
Turbidity: 0.8 JTU	Colour: less than 5 HU
pH: 8.5 units	Sum of constituents: 99.1
Conductivity: 172 µmho/cm @ 25C	Sum const./cond: 0.58
Total alkalinity as $CaCO_3$: 80.7	
Phenolphthalein alkalinity as $CaCO_3$: 0.2	
Total hardness as $CaCO_3$: 98.0	
Total inorganic carbon: 18	Total organic carbon: 3

Major constituents

Calcium: 24.2 Magnesium: 9.2 Sodium: 0.2 Potassium: 0.2
Bicarbonate: 97.9 Carbonate: 0.3 Sulphate: 11.6 Chloride: 0.2

Minor constituents

Phosphorus (total): 0.005 Nitrogen (nitrate + nitrite): 0.02
Kjeldahl nitrogen: 0.3

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 28 viii 75

Depth: surface

Chlorophyta	
Ankistrodesmus falcatus	11
Carteria sp.	6
Chlamydomonas sp.	36
Oocystis borgei	3
O. parva	90
Quadrigula lacustris	31
Sphaerocystis schroeteri	78
Tetraëdron minimum	3
Chrysophyta	
Chrysophyceae	
Chromulina sp.	45
Chrysochromulina parva	31
Chrysophyceae (continued)	
Dinobryon sociale	3
Ochromonas sp.	31
Pseudokephyrion hyalinum	11
Diatomaceae	
Achnanthes exigua var. *heterovalvata*	3
Achnanthes sp.	17
Cyclotella nr. *kuetzingianum*	42
Cyclotella sp.	8
Cymbella ventricosa	3
Fragilaria pinnata	3

Diatomaceae (continued)		Cryptophyta	
Fragilaria sp.	59	Cryptomonas obovata	6
Navicula sp.	6	Cryptomonas sp.	3
Nitzschia amphibia var. genuina	6	Rhodomonas minuta	50
Pinnularia sp.	3	Total	602
Synedra radians	11		
S. ulna	3		

b. Zooplankton (collections: 19 viii 66, 28 viii 75)
Units are maximum numbers per litre.

Cladocera		Copepoda	
Alona (rectangula?)	0.10	Diaptomus arcticus	0.52
Alonella nana	0.06	D. tyrrelli	34.28
Chydorus sphaericus	0.29	?Eucyclops agilis	trace
Daphnia middendorffiana	1.74		

maximum crustacean standing crop: 37.0 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes
no macrophytes found

b. Shoreline fauna
no collections

c. Bottom fauna (collection: 21 viii 75, n = 1)
Units are mean number/m^2.

Crustacea		Chironomidae (continued)	
Amphipoda		Tanytarsus	3315
Gammarus lacustris	603	" pupae	43
Insecta		Mollusca	
Diptera		Pelecypoda	
Chironomidae		Pisidium	258
Procladius s. str.	2281		

Standing crop (mean preserved wet weight/m^2):

Gammarus lacustris	18.596 gm
Pisidium	2.682 gm
Chironomidae	6.006 gm

3. Fish (B. D. Smiley data)

Collection date: 12 and 13 vii 73 Set duration: about 20 h overnight each date

Gear: 7.6 m each of 3/4, 1, 1½, 2, 3, 4-inch mesh green monofilament nylon gillnet. Two gangs were set on each date.

Catch: 6 brook trout (Salvelinus fontinalis): 2 males, 3 females, 1 unsexed
2 cutthroat trout (Salmo clarki): 2 unsexed

a. Cutthroat trout

specimen 1: age 4, fork length 194 mm, weight 88 gm, immature
specimen 2: age 3, fork length 150 mm, weight 35 gm, immature

a. Cutthroat trout (continued)

Food: The stomachs of both specimens contained only unidentified Diptera pupae, which were rated "abundant" in both.

b. Brook trout

Age:	2	3	4	6	(6 or 7?)
Number:	1	2	1	1	1
Mean fork l. (mm):	165	181.0	279	340	425
Mean wt. (gm):	52	85.2	348	604	1852

Maturity: The age 2 specimen and one of the age 3 specimens (fork l. 145 mm, wt. 42 gm) were judged to be immature. The remainder were mature.

Food: 4 stomachs examined, none were empty

Food item	% of fish with item	no. fish in which item rated rare	common	abundant
Gammarus lacustris	75		2	1
unidentified Diptera pupae	75		3	

D. Discussion

Rawson (1939) found "numerous large copepods, some leeches, caddis and chironomid larvae" in shoreline collections from Little Baker Lake (which he referred to as "unnamed A") made in late July, 1938. We also noticed large numbers of copepods, probably Diaptomus arcticus, near shore in August, 1975. Similarly, the clarity of the water noted by us in 1966 and 1975 was also noted by Rawson in 1938.

Ward (1974) reported that cutthroat trout were stocked in Little Baker Lake in 1935, but that they did not reproduce. Rawson (1939) made no mention of fish in the lake when he examined it in 1938, did not list any stocking of cutthroat in Little Baker in his record of cutthroat stocking in Banff waters from 1929 to 1938, but did suggest a small number of cutthroat be placed in the lake. National Park stocking records do not mention any cutthroat stocking in Little Baker.

The probability of a confusion in the naming of Brachiopod, Little Baker and Tilted Lakes (Anderson 1969a, p.7) leads us to question the accuracy of the stocking records for all of these three lakes. It is possible that cutthroats reportedly stocked in Tilted and Brachiopod Lakes in fact were placed in Little Baker.

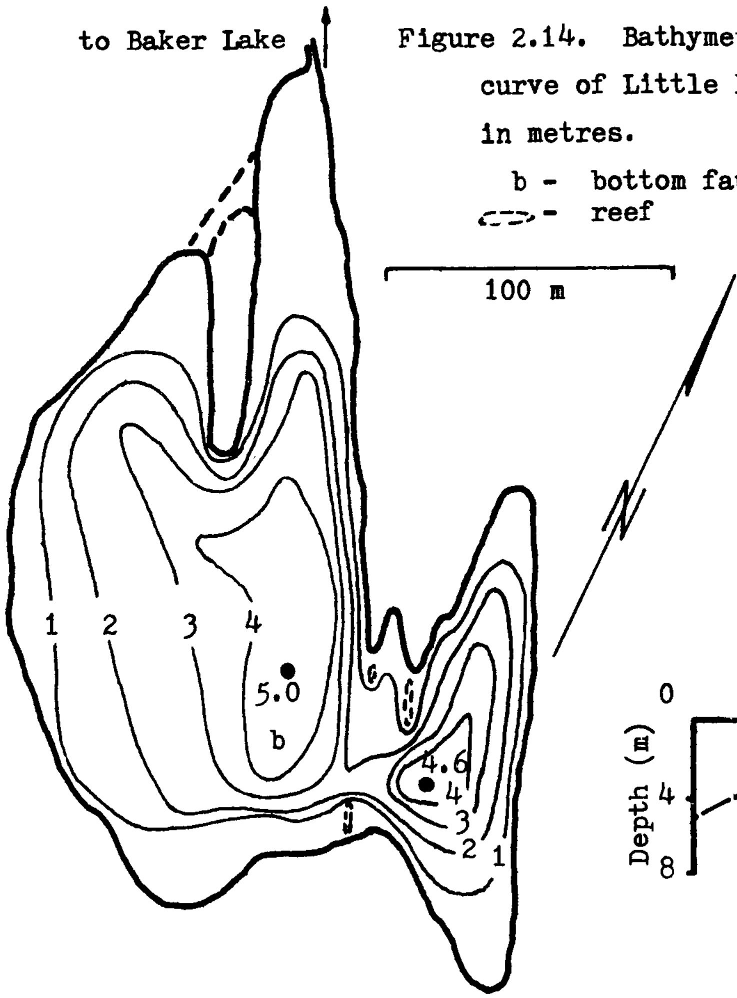
Brook trout were stocked in Little Baker first in 1962, and again in 1967 and 1971 (National Park stocking records, Ward 1974). Ward believed there was no natural recruitment of brook trout in the lake.

These records are suspect because of the confusion over the names of the lakes, as mentioned above.

The fact that the ages of several brook trout specimens collected in 1973 do not correspond to the recorded stocking dates may be owing to inaccurate age determinations, unrecorded stocking, natural recruitment or immigration of fish from Baker Lake via the Little Baker outlet. Similarly, the cutthroats found in Little Baker may have arrived there by unrecorded stocking, natural recruitment or immigration from Baker Lake. The very low catches suggest that both fish populations in the lake are small.

Addendum

Fish parasites: One of 2 brook trout examined for parasites was infected with the trematode *Crepidostomum farionis* (3 worms) (Mudry and Anderson 1976, in press).



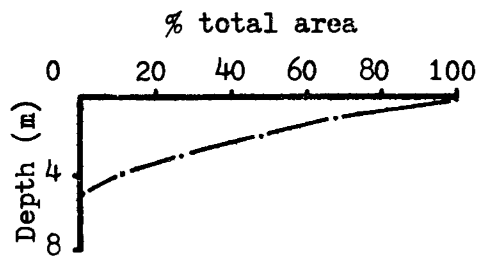


Figure 2.14. Bathymetric map and hypsographic curve of Little Baker Lake. Depths are in metres.

b - bottom fauna collection

- reef

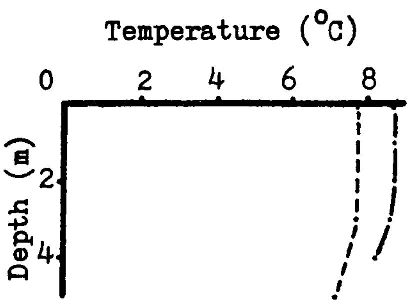


Figure 2.15. Representative temperature profiles, Little Baker Lake.

19 viii 66 -----

28 viii 75 ———

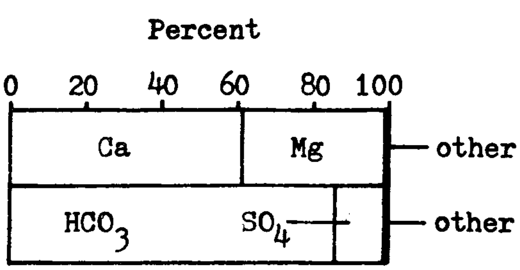


Figure 2.16. Percent ionic composition of surface water calculated on the basis of equivalent weights, Little Baker Lake, 21 viii 75.

BOOM LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 630793, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Banff-Radium Highway 5.2 km (3.2 mi)

Elevation: 1893 m

Altitudinal zone: lower subalpine

Basin type: deepest part of the basin excavated at the base of an ice-fall; a valley rock basin formed by glacial corrasion and dammed by drift

Length: 2723 m

Mean width: 366 m

Area: 99.6 ha

Maximum depth: 32.0 m

Mean depth: 13.2 m

Volume: 1316.8 x $10^4 m^3$

Shoreline length: 6480 m

Shoreline development: 1.83

Volume development: 1.24

Mean depth/max. depth: 0.41

Area/mean depth: 7.54

Water level fluctuation: minimal - water level drop less than 30 cm through the summer (1975)

Stratum (m)	Volume ($10^4 m^3$)	% Total Volume
0 - 5	420.34	31.9
5 - 10	308.36	23.4
10 - 15	243.15	18.5
15 - 20	170.37	12.9
20 - 25	109.56	8.3
25 - 30	60.50	4.6
30 - 32.0	4.50	0.4

Water renewal time: 314 days (23 vii 75), or approximately 0.5 times per year

Open-water period: early June to probably mid November (approximately 160 ice-free days, no direct observation of freeze-up date)

Catchment area: 1692 ha

Bedrock composition of catchment area: 49% quartzite 51% Cambrian carbonate rocks

Catchment area coverage: 24% forest, 14% glacier, 62% exposed rock and low plants

(Catchment area - lake area)/lake area: 16

Human activities in catchment area: hiking, angling. Unauthorized campsite at trail end on lakeshore frequently used.

Bottom composition: The deep sediments have an organic content of 5.2%. The bottom of the extreme east end of the lake between the log booms is covered with light-coloured flocculent sediments. The bottom in near-shore areas is dominated by avalanche debris (especially large rocks and tree trunks).

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

Conductivity: 176 µmho/cm @ 25C pH: 7.9 units

Variation with depth (23 vii 75):

	0 - 10 m composite	15 m
Conductivity:	192.5 µmho/cm @ 25C	198.0 µmho/cm @ 25C
pH:	8.2 units	8.1 units
Total alkalinity:	95.6	95.6

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 16 vii 73 Depth: surface

Turbidity: 0.1 JTU Colour: 0 HU

pH: 8.1 units Sum of constituents: 82.0

Conductivity: 145 µmho/cm @ 25C Sum const./cond: 0.57

Total alkalinity as $CaCO_3$: 78.0

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 81.0

Total inorganic carbon: 12 Total organic carbon: 1

Major constituents

Calcium: 18.0 Magnesium: 8.8 Sodium: 0.3 Potassium: 0.1
Bicarbonate: 95.1 Carbonate: 0 Sulphate: 4.2 Chloride: 0.3

Minor constituents

Copper: < 0.002 Iron: < 0.05 Lead: < 0.004 Manganese: < 0.008
Zinc: 0.002
Fluoride: < 0.05 Nitrogen (nitrate + nitrite): 0.01
Phosphate: < 0.003 (ortho), < 0.003 (total)

Silica: 3.3

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 23 vii 75

a. Phytoplankton (continued)

Depth (m):	composite 0 - 10 m	15 m
Chlorophyta		
Dictyosphaerium pulchellum		53
Oocystis parva		6
Chrysophyta		
Chrysophyceae		
Bitrichia chodatii		11
Chromulina sp.	3	14
Chrysochromulina parva	3	31
Conradocystis sp. ?	6	
Dinobryon sociale		8
Kephyrion sp.		48
Nephrodiella sp. ?		90
Ochromonas sp.		3
Pseudokephyrion hiemale	1	
Pseudokephyrion nr. *hyalinum*	3	
Spiniferomonas nr. *bourrellii*		14
Diatomaceae		
Achnanthes linearis var. *curta*	1	
Achnanthes sp.	1	
Cyclotella nr. *kuetzingianum*	3	56
Cyclotella sp.	8	577
Fragilaria construens		3
Navicula sp.	1	
Synedra delicatissima		11
Synedra sp.	27	8
Cryptophyta		
Rhodomonas minuta	1	28
Totals	58	961

b. Zooplankton (collections: 16 vii 73, 23 vii 75)
Units are maximum numbers per litre.

Rotifera	
Kellicottia longispina	10 - 100
Keratella quadrata	< 0.1
Polyarthra vulgaris	10 - 100
Synchaeta (*oblonga*?)	10 - 100
Cladocera	
Bosmina longirostris	2.81
Cladocera (continued)	
Daphnia (*pulex*?)	0.31
Scapholeberis kingi	0.04
Copepoda	
Diaptomus tyrrelli	17.04
Acanthocyclops vernalis	0.01

maximum crustacean standing crop: 23.9 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

no collection made; some fairly extensive beds of emergent sedges (*Carex*) near shore at the shallow east end (much less than 1% of the total lake area)

b. Shoreline fauna (collection: 16 vii 73; 30 min)
Units are numbers collected.

Crustacea	
Cladocera	
Scapholeberis kingi	2
Insecta	
Megaloptera	
Sialis adult	1
Trichoptera	
unidentified pupae	12
Limnephilidae (3 spp.)	26
Ephemeroptera	
Callibaetis hageni	65
Insecta (continued)	
Diptera	
Chironomidae	
Tanypodinae	1
Arachnida	
Hydracarina	
Arrenurus	1
Limnesia	1
Piona	1

c. Bottom fauna (collection: 9 vii 75, n = 11)
Units are mean numbers/m^2.

Nematoda	16
Annelida	
Oligochaeta	86
Hirudinoidea	
Helobdella stagnalis	4
Crustacea	
Cladocera	
Simocephalus vetulus	23
Copepoda	
Diaptomus	4
Amphipoda	
Hyalella azteca	55
Insecta	
Trichoptera	
Limnephilidae	4
Diptera	
Chironomidae	
Ablabesmyia	27
Procladius s. str.	2501
Thienemannimyia group	20
Orthocladiinae? pupae	90
Cricotopus	8
Heterotrissocladius	12
Chironomidae (continued)	
Paracladius	110
Psectrocladius	560
Chironomus	297
Cryptochironomus	4
Cryptocladopelma	55
Dicrotendipes ? pupae	90
Pagastiella	180
Paracladopelma	8
Phaenopsectra s. str.	145
Stictochironomus	180
Constempellina	4
Micropsectra / *Tanytarsus*	951
Micropsectra pupae	98
Tanytarsus pupae	364
Mollusca	
Gastropoda	4

Standing crop (mean preserved wet weight/m^2):

Chironomidae mainly	11.218 gm
Trichoptera	4.153 gm
Hyalella azteca	0.253 gm
Oligochaeta	0.072 gm
Helobdella stagnalis	0.018 gm

3. Fish

Collection date: 6-7 x 75   Set duration: 24 h

Gear: 20 m each of 3/4, 1½, 2, 3, 4-inch mesh green multifilament nylon gillnet set at the surface on float.

Catch: 21 cutthroat trout (Salmo clarki); 14 males, 7 females

Age:	3	4	5	6	7	9
Number:	3	5	4	2	1	1
Mean fork l. (mm):	164.3	171.8	191.5	198.0	255	325
Mean wt. (gm):	52.0	62.6	84.0	87.5	185	418

Maturity: The age 3 males were judged to be mature, but the youngest mature female was age 5. Only four of the seven females were aged.

Food: 21 stomachs examined, 1 (5%) empty

Food item	% of fish with item	mean % total stomach contents by volume
Trichoptera	70	33.2
unidentified insect parts	45	22.0
Ephemeroptera	57	20.8
Gastropoda	20	10.8
Hyalella azteca	30	4.8
flying insect parts	5	4.0
Dytiscidae	10	2.0
Hymenoptera	5	1.0
terrestrial Arachnida	5	1.0
Chironomidae	10	~0

Parasites: Five of the specimens were examined for parasites. All 5 were infected with Crepidostomum farionis (mean 9.12 per host, range 15-307), and 3 were also infected with Diphyllobothrium sp. larvae (mean 2.3 per host, range 1-4) (Mudry and Anderson 1976, in press).

D. Discussion

A photograph of Boom Lake illustrating its setting is provided by Baird (1967, p. 169).

Boom Lake had a heavy load of glacial silt in the late 1930's, having a Secchi depth of only 0.7 m on August 3, 1938 (Rawson 1939). Since then, there has been a striking decrease in the silt load. Recent observations are that Boom Lake is very clear (Ward personal communication), having Secchi transparency readings of 13.6 m and 16.6 m in July of 1973 and 1975, respectively (Fig. 2.17). The dramatic decline in siltation since 1938 suggests that the glacier feeding the lake is now much less active than it formerly was.

Temperature conditions in Boom Lake in July 1973 and 1975 (Fig. 2.17) are similar to those observed in mid-August 1936 and late August 1938 by Rawson (1939). Rawson, however, observed a distinct thermocline between 7.5 m and 10 m in 1936, whereas only a marked but regular thermal gradient existed in July 1973 and 1975. Rawson's observations of somewhat lower pH and dissolved oxygen values in deep water (20 m) relative to those at the surface are comparable to the slight chemical stratification found in 1975 (p. 40). The change in the degree of siltation since 1938 apparently has not affected these thermal and chemical attributes of the lake to any great extent.

The following species have been reported from Boom Lake in addition to those found in the present survey.

Cyanophyta	
Nostoc	Rawson (1939)
Pyrrophyta	
Ceratium hirundinella	"
Peridinium cinctum	"
Rotifera	
Conichilus unicornis	"
Filinia (as Triarthra)	"
Hirudinoidea	
Erpobdella punctata	"
Crustacea	
Daphnia longispina	Rawson (1939)
Diacyclops bicuspidatus thomasi	Reed (1959)*
Coleoptera	
Agabus inscriptus	Larson (1975, p. 454)
Agabus tristis	Rawson (1939)
Mollusca	
Lymnaea	"

The taxonomy of some groups has been greatly changed since 1939. With the exception of the above species, the plankton and shoreline fauna differed little in quality in the 1938 and 1973-75 samples.

Rawson (1939) collected 5 bottom samples from Boom Lake in August 1938. The mean number of organisms/m^2 and the mean wet weight of organisms/m^2 were both less than half of the comparable 1975 values. We are unable to say whether these differences, though large, really reflect differences in the quantity of bottom fauna in the two years because there are too few samples, the samples were not taken from the same places, the samples were taken in different months, and Rawson did not adequately specify his methods, particularly the mesh size of his seive.

Rawson (1939) presented age, length range and weight range statistics for a sample of 125 cutthroat trout he collected from Boom Lake in August 1938, using scales for age determination. Because trout ages determined from scales may be in error by a year or more (Smiley 1976), it is not clear whether the apparent higher growth rate of the 1938 cutthroats relative to that of the fish collected in 1975 is real or an artifact of the different methods of age determination used. It does appear that the trout in the 1938 sample were heavier than the 1975 cutthroats at any given length (that is, they were in "better condition"), because substitution of the 1938 length data into the length-weight equation calculated for the 1975 sample (Fig. 2.22) gave weights consis-

* from Rawson's samples

tently lower than the observed weights of the 1938 fish.

Rawson (1939) found that cutthroat trout in Boom Lake used mainly Chironomidae pupae as food in August samples. Our results indicate that Chironomidae were unimportant in the diet in an October sample. The difference probably reflects a seasonal difference in availability of food organisms, rather than a change in food preference.

Rainbow trout (Salmo gairdneri) were introduced into Boom Lake in 1937 (National Parks stocking records) and, although they were said to reproduce naturally (Ward 1974), have not been reported since (Rawson 1939, Ward 1974, present study). Mountain whitefish (Prosopium williamsoni) and Dolly Varden trout (Salvelinus malma) were said to have occurred in the lake (Vick 1913, in Paetz and Nelson 1970), but they too have not been reported for many years (Rawson 1939, Ward 1974, present study). The present population of cutthroat trout is maintaining itself by natural recruitment, probably using the outlet as a spawning area.

Although National Parks stocking records show that cutthroats were stocked in Boom Lake only from 1915 to 1936, this species was recorded from the lake as early as 1913 (Vick 1913, in Paetz and Nelson 1970). It may be that this species, as well as mountain whitefish and Dolly Varden, were native to the lake. Unfortunately, there have been many instances of fish stocking by individuals or companies acting on their own initiative, particularly near the turn of the century (Ward 1974). We can therefore never be sure if early observations of species occurrences, such as those of Vick, indicate native populations.

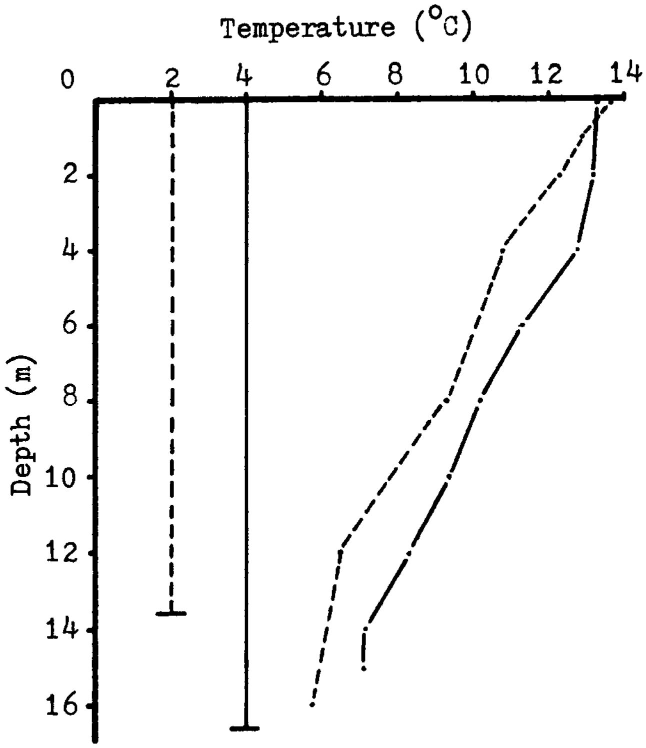


Figure 2.17. Temperature profiles and Secchi transparency readings (⊥), Boom Lake.

16 vii 73 ----

23 vii 75 ———

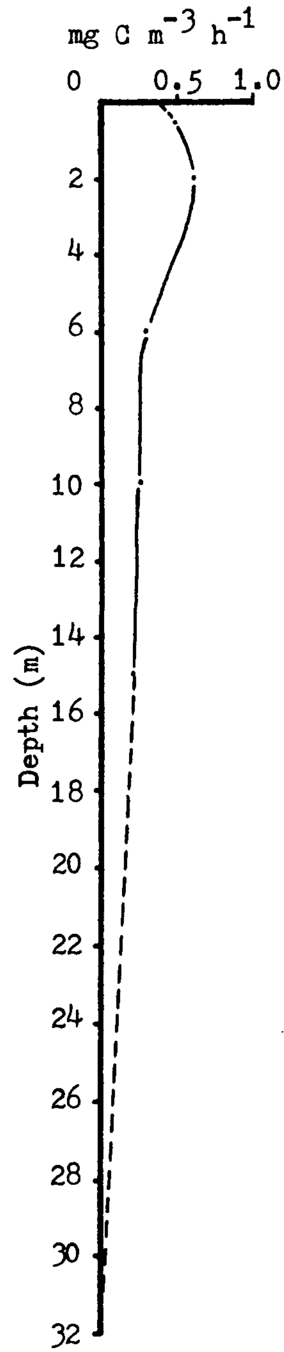
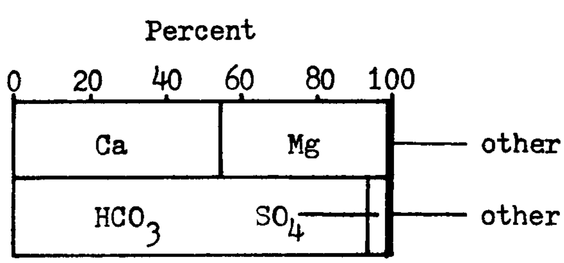


Figure 2.18. Profile of primary productivity, Boom Lake, 23 vii 75. Points are net figures (light minus dark). Samples were collected from discrete depths using a student sampler. Incubations 0935 - 1335 h MST

Figure 2.19. Percent ionic composition of surface water calculated on the basis of equivalent weights, Boom Lake, 16 vii 73.



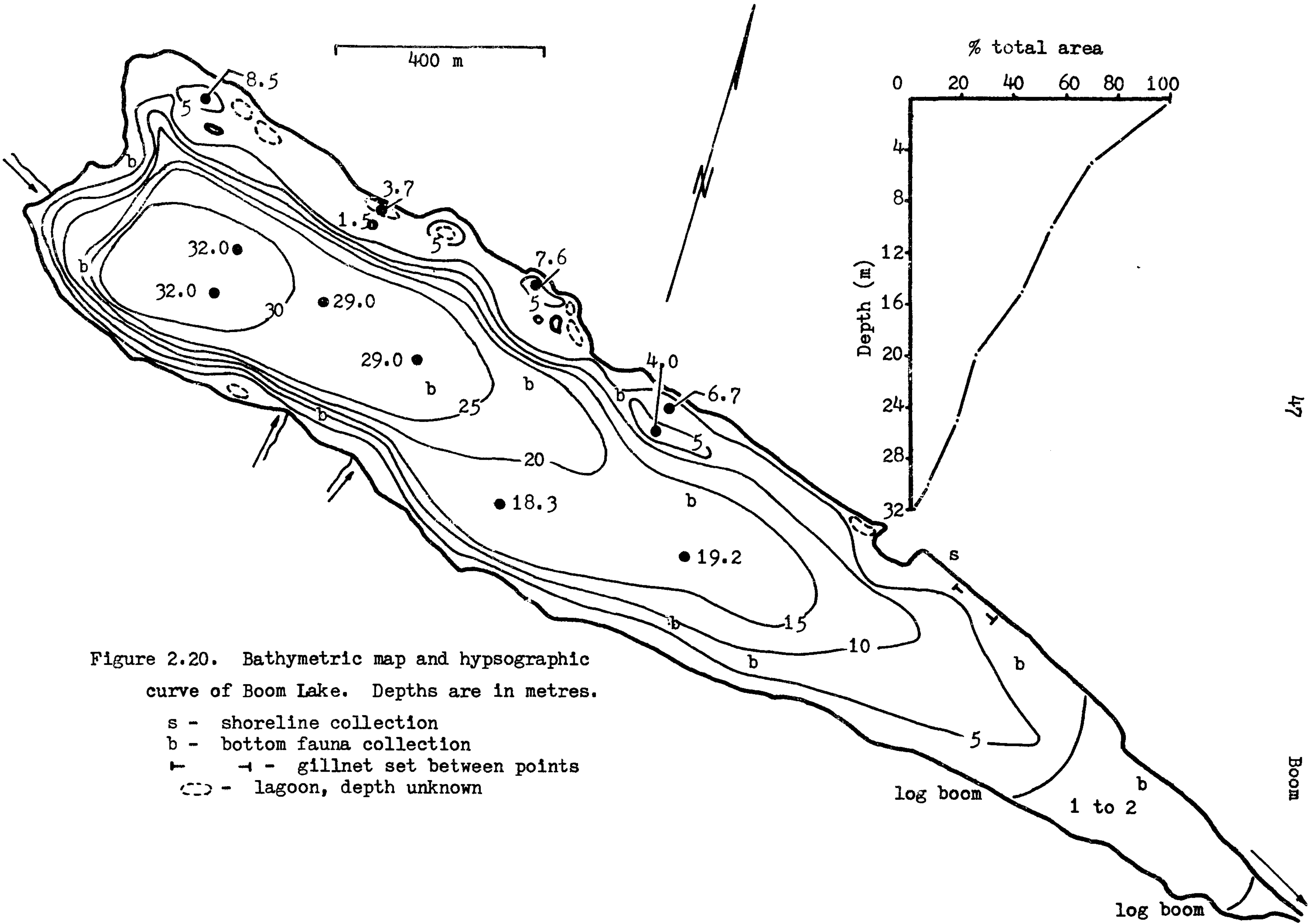


Figure 2.20. Bathymetric map and hypsographic curve of Boom Lake. Depths are in metres.

s - shoreline collection
b - bottom fauna collection
⊢ ⊣ - gillnet set between points
(⁻⁻) - lagoon, depth unknown

Boom

Figure 2.21. Growth diagram of cutthroat trout in Boom Lake, 6-7 x 75.

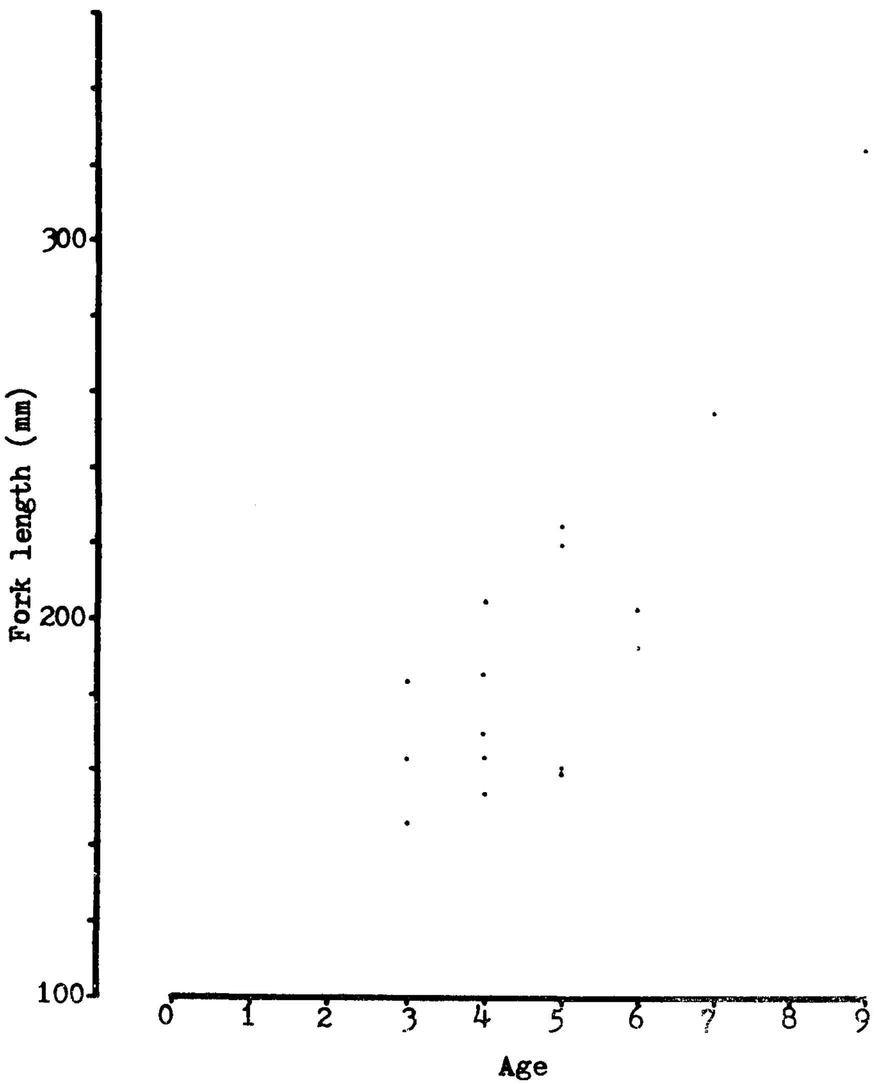
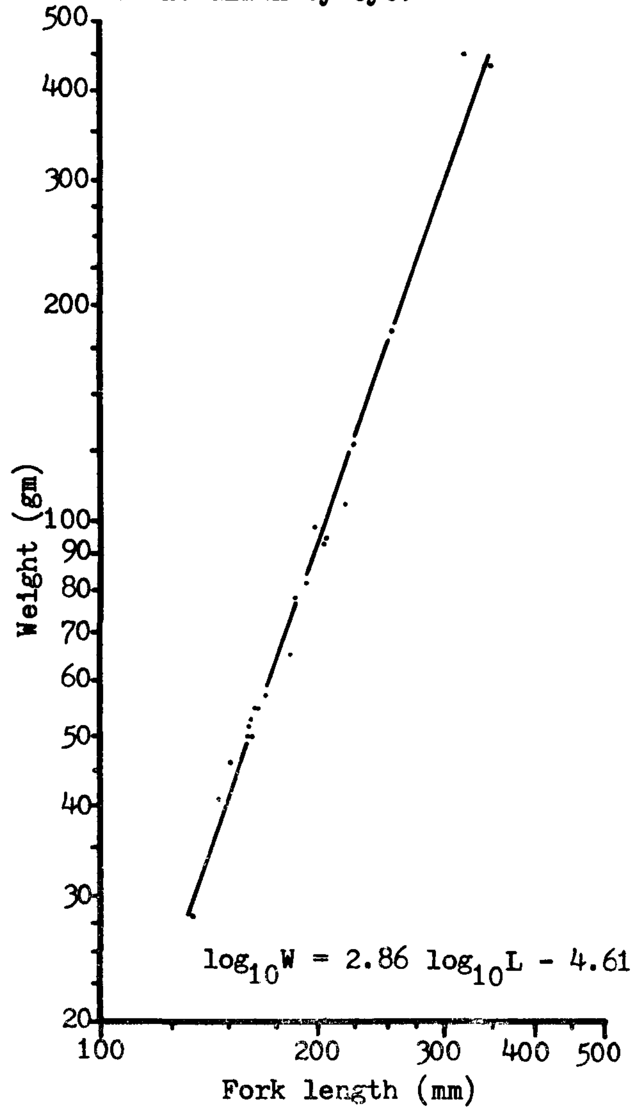


Figure 2.22. Length - weight relationship of cutthroat trout, Boom Lake, 6-7 x 75. The line was drawn by eye.



BRACHIOPOD LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NH 677034, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: restricted road to Temple Lodge, then by trail approximately 10.8 km (6.7 mi)

Elevation: 2271 m

Altitudinal zone: alpine

Basin type: depression between base of Anthozoan Mountain and upturned edges of rock strata

Length: 265 m

Mean width: 79 m

Area: 2.1 ha

Maximum depth: 3.0 m

Mean depth: 1.5 m

Volume: $3.1 \times 10^4 m^3$

Shoreline length: 714 m

Shoreline development: 1.39

Volume development: 1.48

Mean depth/max. depth: 0.50

Area/mean depth: 1.40

Water level fluctuation: extreme - high water marks and aerial photographs indicate the water level drops 2 m or more through the summer

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 1	1.72	55.7
1 - 2	1.09	35.2
2 - 3	0.28	9.1

Water renewal time: less than 25 days (21 viii 75)

Open-water period: no observations

Catchment area: 57 ha

Bedrock composition of catchment area: 100% Devonian carbonate rocks

Catchment area coverage: 100% exposed rock and low plants

(Catchment area - lake area)/ lake area: 26

Human activities in catchment area: hiking (probably infrequent)

Bottom composition: 100% medium-brown silt

Secchi depth: frequently clear to bottom (air photos, 21 viii 75), sometimes turbid (19 viii 66)

Surface temperature: 7.2°C (19 viii 66), 8.5°C (21 viii 75)

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

Date: 19 viii 66 pH: 7.8 units

Total alkalinity as $CaCO_3$: 64.8

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 68.4

Total acidity: 3.42

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 21 viii 75 Depth: surface

Turbidity: 2 JTU Colour: <5 HU

pH: 8.3 units Sum of constituents: 76.7

Conductivity: 141 µmho/cm @ 25C Sum const./cond: 0.54

Total alkalinity as $CaCO_3$: 71.1

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 77.0

Total inorganic carbon: 15 Total organic carbon: 3

Major constituents
Calcium: 18.0 Magnesium: 7.8 Sodium: 0.2 Potassium: 0.1
Bicarbonate: 86.7 Carbonate: 0 Sulphate: 2.3 Chloride: 0.2

Minor constituents
Nitrogen (nitrate + nitrite): 0.09 Nitrogen (Kjeldahl): 0.2
Phosphorus (total): 0.005

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 21 viii 75

Depth: surface

Chrysophyta		Diatomaceae (continued)	
Chrysophyceae		*Cymbella* sp.	8
Chrysochromulina parva	3	*Fragilaria brevistriata*	6
Diatomaceae		*Gomphonema* sp.	6
Achnanthes lanceolata	3	*Hannea arcus*	3
Achnanthes spp.	81	*Navicula* sp.	25
Cyclotella sp.	8	*Nitzschia* sp.	6
Cymbella ventricosa	3	*Synedra* sp.	3
		Total	155

b. Zooplankton (collections: 19 viii 66, 29 viii 67, 21 viii 75)
Units are maximum numbers per litre.

Rotifera		Cladocera	
Filinia longiseta	<0.1	*Chydorus sphaericus*	0.326

b. Zooplankton (continued)

Copepoda		Copepoda (continued)	
Diaptomus arcticus	3.31	immature cyclopoid	0.02
D. tyrrelli	42.65	maximum crustacean standing crop: 46.3 animals/l	

2. Bottom and Shoreline Organisms

a. Macrophytes

There are no macrophytes in the lake.

b. Shoreline fauna

no collections

c. Bottom fauna

no collections

3. Fish

no collections (no fish seen in the lake in 2 visits -- 1974 and 1975)

D. Discussion

The most significant feature of Brachiopod Lake is the extreme fluctuation in water level. The lake may fill to a maximum depth of 3 m during spring runoff, but by the end of August it is only 1 m deep, and by freeze-up may be even shallower. It undoubtedly freezes to the bottom in winter.

According to National Park stocking records, Brachiopod was stocked 4 times with cutthroat and 3 times with brook trout since 1939 -- the last time in 1967 with 2000 brook trout. As has been discussed elsewhere (Anderson 1969a, p. 7; and p. 36 this report), possible confusion in naming Brachiopod, Little Baker and Tilted Lakes leads us to question the accuracy of the stocking records. We agree with Ward (1974) that no fish now exist in Brachiopod, since the lake must freeze solid in winter.

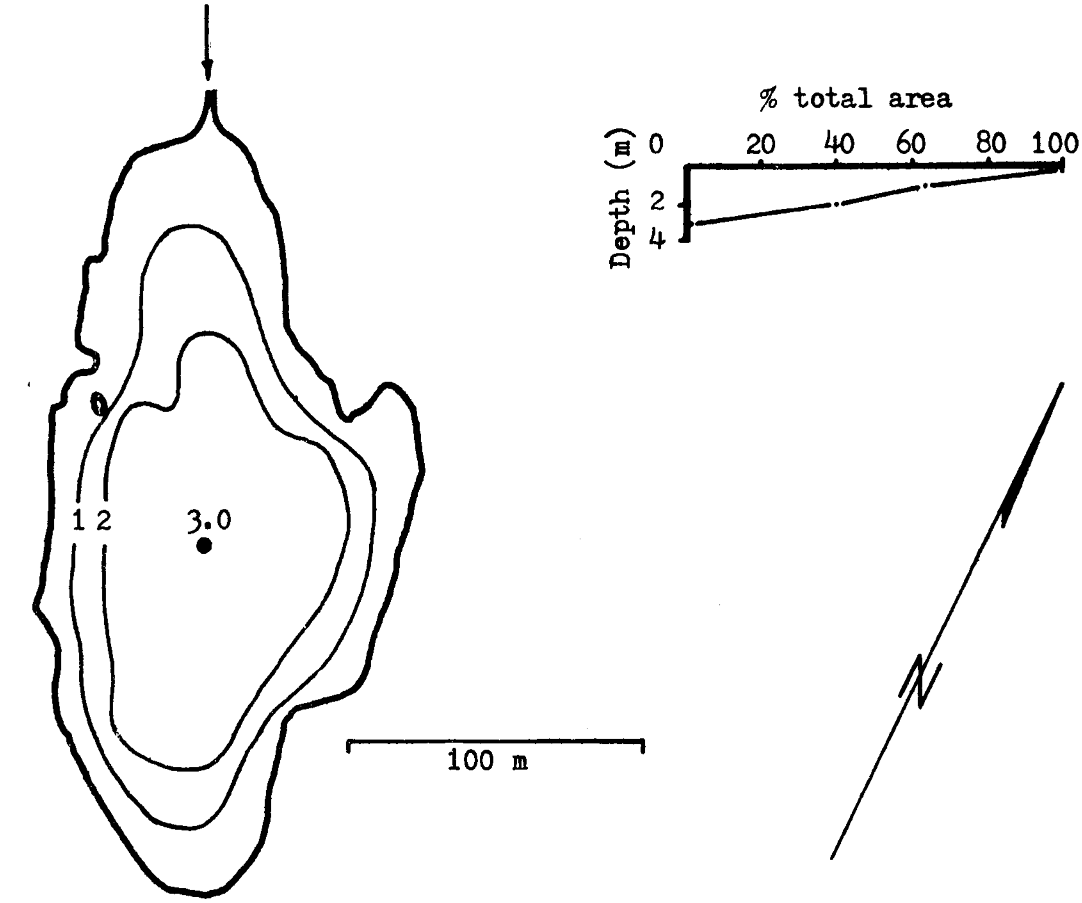
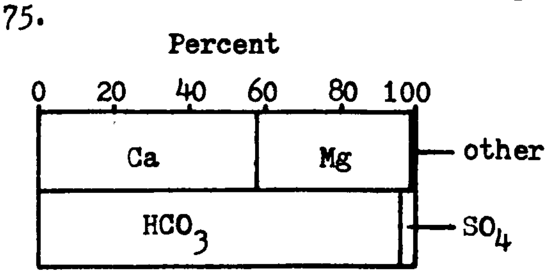


Figure 2.23. Bathymetric map and hypsographic curve of Brachiopod Lake. Depths are in metres.

Figure 2.24. Percent ionic composition of surface water calculated on the basis of equivalent weights, Brachiopod Lake, 21 viii 75.



LOWER CONSOLATION LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 592850, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Moraine Lake parking lot 2.9 km (1.8 mi)

Elevation: 1951 m

Altitudinal zone: upper subalpine

Basin type: valley basin formed by glacial corrasion and dammed by drift

Length: 709 m

Mean width: 204 m

Area: 14.5 ha

Maximum depth: 11.3 m

Mean depth: 5.9 m

Volume: $85.7 \times 10^4 m^3$

Shoreline length: 1885 m

Shoreline development: 1.40

Volume development: 1.57

Mean depth/max. depth: 0.52

Area/mean depth: 2.46

Water level fluctuation: water level can drop more than 30 cm through summer

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 2	26.09	30.4
2 - 4	21.28	24.7
4 - 6	17.50	20.4
6 - 8	13.09	15.3
8 - 10	6.91	8.1
10 - 11.3	0.82	1.1

Water renewal time: 7.4 days (n=3, summer 1974)

Open-water period: mid June/mid July to probably late October (100 - 130 ice-free days; no direct observations of freeze-up date)

Catchment area: 1006 ha

Bedrock composition of catchment area: 3% Miette Group, 78% quartzite, 19% Cambrian carbonate rocks

Catchment area coverage: 13% forest, 21% glaciers, 66% exposed rock and low plants

(Catchment area - lake area)/lake area: 68

Human activities in catchment area: hiking, angling, unauthorized camping

Bottom composition: Talus covers the bottom to near the maximum depth along the entire west shore. Elsewhere, the bottom in shallow water is covered by sandy sediments, except at the avalanche slope on the east shore, where large rock rubble covers the bottom. The bottom in the central portion of the lake is covered by dark green-brown mud having an organic content of 28.4%.

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

Date: 17 vii 73 pH: 7.9 units

Conductivity: 121 µmho/cm @ 25C

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 17 vii 73 Depth: surface

Turbidity: 0.3 JTU Colour: 0 HU

pH: 8.0 units Sum of constituents: 63.0

Conductivity: 115 µmho/cm @ 25C Sum const./cond: 0.55

Total alkalinity as $CaCO_3$: 52.0

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 62.0

Total inorganic carbon: 11 Total organic carbon: 1

Major constituents
Calcium: 15.0 Magnesium: 6.0 Sodium: 0.5 Potassium: 0.2
Bicarbonate: 63.4 Carbonate: 0.0 Sulphate: 6.8 Chloride: 0.3

Minor constituents
Copper: 0.005 Iron: < 0.05 Lead: < 0.004 Manganese: < 0.008
Zinc: 0.005
Fluoride: < 0.05 Nitrogen (nitrate + nitrite): 0.10
Phosphate (ortho): < 0.003 Phosphate (inorganic): < 0.003

Silica: 2.4

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 17 vii 73

Depth: 0.5 m

Chrysophyta		Chrysophyta (continued)	
Chrysophyceae		Diatomaceae	
Chrysochromulina parva	123	Achnanthes microcephala	2
Kephyrion spp.	18	Achnanthes spp.	4

Diatomaceae (continued)

Cymbella spp.	4	*Gomphonema* sp.	2
Fragilaria crotonensis	6	*Navicula* spp.	4

b. Zooplankton (collections: 17 vii 73, 12 vii 74, 14 viii 74, 19 ix 74)

Units are maximum numbers per litre.

Rotifera		Copepoda	
Keratella quadrata	0.1 - 1	*Diaptomus tyrrelli*	46.398
Polyarthra vulgaris	0.1 - 1	?*Acanthocyclops vernalis*	0.148
Synchaeta ?	1 - 10	maximum crustacean standing crop: 52.7 animals/l	

2. Bottom and Shoreline Organisms

a. Macrophytes

There are no macrophytes in the lake. Attached filamentous algae were conspicuously abundant on the large submerged boulders at the inlet and outlet ends of the lake.

b. Shoreline collections

Units are numbers collected.

collections:	17 vii 73 30 min.	12 vii 74 30 min.	14 viii 74 30 min.
Platyhelminthes			
Turbellaria	7		
Annelida			
Oligochaeta	2		3
Crustacea			
Cladocera			
Chydorus sphaericus	3		
Simocephalus vetulus	1		
Copepoda			
Acanthocyclops vernalis	7		
Eucyclops agilis		1	
Amphipoda			
Gammarus lacustris			4
Hyalella azteca	1		
Insecta			
Ephemeroptera			
Ameletus (nr. *celer* and *celeroides*)	2	8	2
Siphlonurus	11	4	4
Plecoptera			
Alloperla revelstoki adult	1		
Arcynopteryx (*Megarcys*)		1	
Isoperla (nr. *ebria*)		1	
Peltoperla mariana			1
Trichoptera			
unidentified pupae		1	
Limnephilidae	4	6	
Coleoptera			
Agabus tristis	2		
Hydroporus compertus		1	

	17 vii 73 30 min.	12 vii 74 30 min.	14 viii 74 30 min.
Insecta (continued)			
Diptera			
Chironomidae			
Tanypodinae larvae	14		
" pupae			2
Orthocladiinae	10		4
Arachnida			
Hydracarina			
Hygrobates	5		
Lebertia	4		
Mollusca			
Pelecypoda			
Sphaeriidae		1	1

c. Bottom fauna (collection: 11 vii 74, n = 3)
Units are mean numbers/m^2.

Nematoda	43
Insecta	
Diptera	
Chironomidae	
Procladius s. str.	1737
Psectrocladius	1234
" ? pupae	373
Chironomidae (continued)	
Phaenopsectra s. str. pupae	29
Tanytarsus	86
" pupae	57
Mollusca	
Pelecypoda	
Pisidium	57

Standing crop (mean preserved wet weight/m^2):

Chironomidae mainly	10.359 gm
Pisidium	0.235 gm (with shell)

3. Fish

Collection date: 11-12 vii 74 Set duration: 24 h 30 min

Gear: 20 m each of 3/4, 1½, 2, 3, 4-inch mesh green nylon multifilament gillnet set on bottom.

Catch: 28 cutthroat trout (*Salmo clarki*); 13 males, 12 females, 3 unsexed
44 brook trout (*Salvelinus fontinalis*); 24 males, 16 females, 4 unsexed

a. Cutthroat trout

Age:	3	4	5	7
Number:	1	21	5	1
Mean fork l. (mm):	107	151.1	176.6	259
Mean wt. (gm):	12	58.2	78.4	206

Maturity: Most males were mature by age 4, but none of the females were mature at that age. One of three age 5 females was mature. Only one cutthroat, an age 7 female, was ripe. Two males were approaching spawning condition. The remaining mature fish had developing gonads but were far from the gravid condition (stage 3 on Kesteven's scale -- Bagenal 1971).

a. Cutthroat trout (continued)

Food: 15 stomachs examined, 0 empty

Food item	% of fish with item	mean % total stomach contents by volume
Chironomidae pupae	100	93.7
" larvae	13	6.3

Parasites: The single cutthroat trout examined was infected with 8 Crepidostomum farionis (Mudry and Anderson, in press).

b. Brook trout

Age:	2	3	4	5	6	8	9
Number:	2	7	14	9	1	3	1
Mean fork l. (mm):	92	201.6	200.6	230.1	171	317	309
Mean weight (gm):	7.4	115.4	104.9	164.4	70	403.7	355

Maturity: Male and female brook trout were mature at age 3. Age 2 fish were immature. Only 3 of the 29 mature trout were judged to have relatively well-ripened gonads (stage 4 or higher on Kesteven's scale -- Bagenal 1971); the remainder, though mature, had small testes or ovaries.

Marks: Four brook trout were fin-clipped.

Age 8 male	both pectorals
Age 3 female	left pelvic
Age ? male	left pelvic
Age ? female	left pectoral

Food: 21 stomachs examined, 1 (4.8%) empty

Food item	% of fish with item	mean % total stomach contents by volume
Chironomidae pupae	67	48.6
Trichoptera pupae and larvae	76	38.3
Ephemeroptera	9.5	4.8
Gammarus lacustris	19	3.8
Chironomidae larvae	9.5	2.1
Dytiscidae	24	1.0
Plecoptera	4.8	1.0
Pisidium	4.8	~0

Parasites: Two brook trout were examined. Both were infected with Crepidostomum farionis (mean 143.5 per host, range 99 - 188) (Mudry and Anderson, in press).

D. Discussion

Photographs by Mathews (1943), Gardner (1970, fig. 7) and Kucera (1974) illustrate the setting of Lower Consolation Lake.

Rawson (1939) stated that the Consolation Lakes were incompletely separated, and did not specify where he took his samples. Maps drawn prior to Rawson's work (sheet no. 82 N/8, Topographical Survey of Canada 1927; Kootenay Park sheet 1928; Yoho Park sheet 1930; Banff Park sheet

1932) all show the lakes completely divided, as does the 1942 photograph by Mathews (1943). There is no evidence on the shorelines of either lake indicating much higher water levels in the past. In the following discussion, we have assumed that Rawson's observations were made on the lower lake only.

Rawson (1939) described Consolation Lake as "definitely silted," and estimated from shore that the Secchi depth was about 4 m. In recent years, the lake has been very clear (Thomasson 1962, present study). The change in the degree of siltation suggests there has been a reduction in the activity of the glaciers feeding the lake.

The surface temperatures observed by Rawson in August (9.0 and 7.8 °C in 1936 and 1938, respectively) are somewhat higher than those recorded in this survey, but were taken near shore where the water is usually warmer than it is near the centre.

The following species have been recorded from Lower Consolation Lake in addition to those found in the present study. All were collected from shore.

Algae[1]			
Campylodiscus hibernicus	R	*Mougeotia* sp.	R
Ceratium hirundinella	R	*Pediastrum boryanum*	R
Chroococcus limneticus	R	*P. b.* var. *longicorne*	T
Cladophora sp.	R	*Staurodesmus cuspidatus*	T
Cocconeis pediculus	R	*Staurastrum muticum*	T
Cosmarium laeve	R	*Surirella biseriata*	R
Cymbella cuspida	R	*S. linearis*	R
Cymbella cymbiformis	R	*S. ovalis*	R
Dinobryon divergens	R, T	*S. spiralis*	R
Meridion circulare	T	*Tabellaria fenestrata*	R
Merismopedia tenuissima	R	*T. flocculosa*	R
Rotifera			
Cephalodella catellina	R	*Notholca foliacea*	R
Keratella cochlearis	R	(also as *Argonotholca* by T)	
K. hiemalis	T	*N. striata*	T
Lecane scobis	R	*Polyarthra dolicoptera*	T
Lepadella quadricarinata	R		
Crustacea			
Macrocyclops ater (as *Cyclops*)	R	*Alona costata*	R
Canthocamptus sp.	R	*Bosmina* sp.	R

R: Rawson (1939) T: Thomasson (1962)

Rawson (1939) also identified *Arcynopteryx* (*Megarcys*) *yosemite* (as *Perlodes yosemite*), a stonefly, from Consolation Lake. The specimens were apparently nymphs. This species is rare even in its described

1. Kristiansen (1976) also found *Mallomonas striata* (1 scale)

range of the Cascade and Sierra Nevada Mountains, at high elevations, Washington to California (Jewett 1959). Its occurrence in Lower Consolation Lake requires confirmation.

Rawson presented few data on the cutthroat trout he caught from the lake. They appear to have differed little in size from those caught in 1974, but had fed mainly on Trichoptera, Plecoptera and wasps. No data on the capture method, catch rate, age or number of fish in the sample were given.

National Parks stocking records show no stocking of the lower lake, but Rawson (1939) and Ward (1974) both state that cutthroats were stocked in 1922. The former author further states that there had been extensive stocking of cutthroats since that date.

Cutthroats have been recorded from Consolation Lake since at least 1913 (Vick 1913, in Paetz and Nelson 1970). Ward (1974) indicated that only cutthroats occurred in the lower lake. The stocking records state that only brook trout occur there, but that both cutthroat and brook trout have been stocked in the upper lake. It appears that at least some of the many stockings recorded for the upper lake were in fact placed in the lower lake, because we caught both species in 1974.

Most of the cutthroats caught in mid-July 1974, though mature, were far from spawning condition. We had expected these fish to be ripe, because June to mid-July is the typical spawning season for this species (Scott and Crossman 1973). Ripe cutthroats could have been spawning in the outlet creek, and so would have been unavailable to the gillnet. The findings suggest that cutthroat trout in Lower Consolation do not spawn every year, a phenomenon observed in some other cutthroat populations (Scott and Crossman 1973).

It is not clear whether brook trout in Lower Consolation Lake also fail to spawn every year. Most mature specimens had gonads that were at about the same stage of development as those of the cutthroats, but they would not be expected to spawn until autumn. September or October collections could reveal whether or not brook trout spawn annually in this lake.

The mix-up in the stocking records makes it impossible to know for certain if the trout populations are maintaining themselves by natural recruitment. The outlet of the lake appears to be an adequate spawning ground, however.

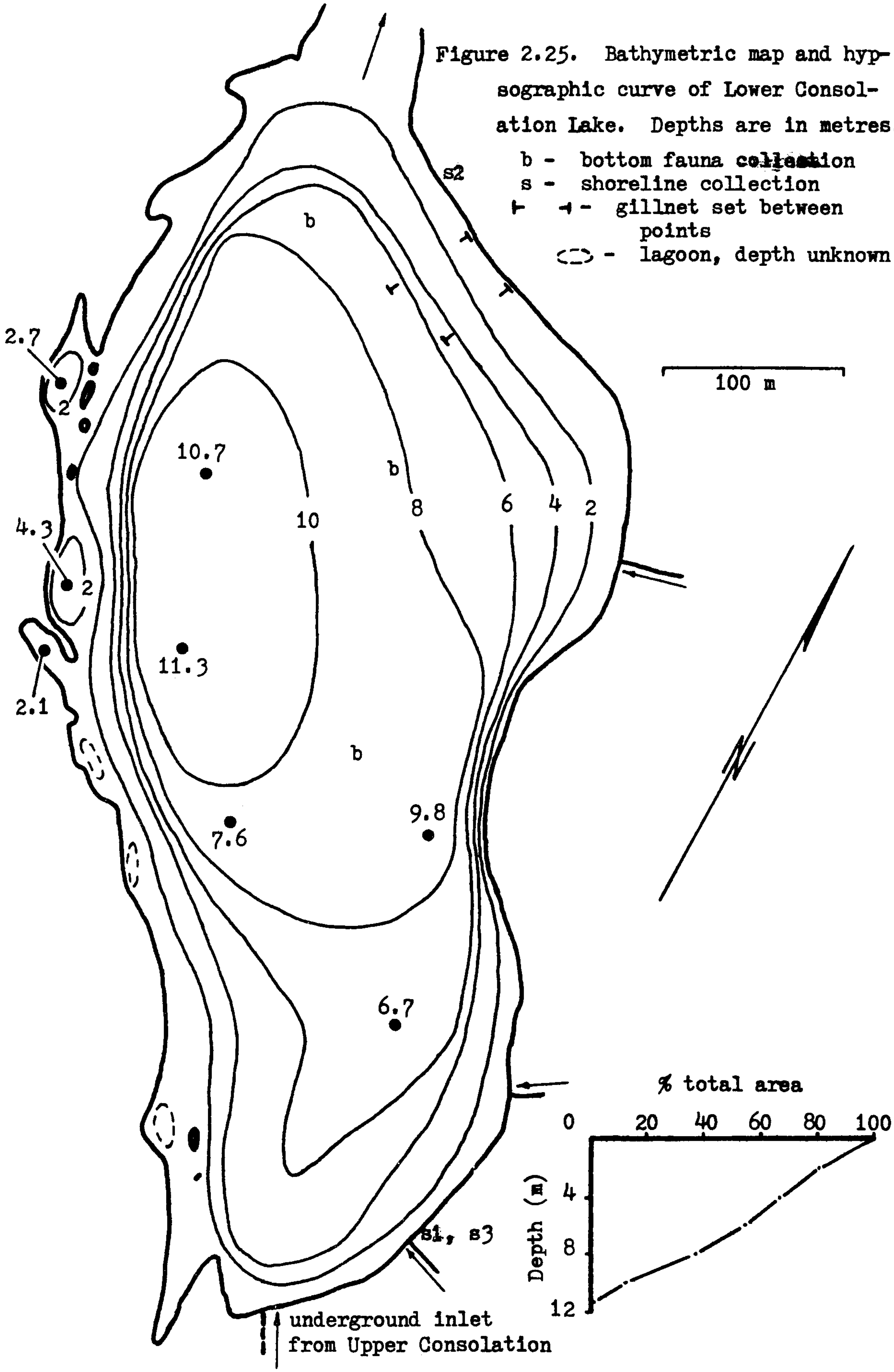


Figure 2.25. Bathymetric map and hypsographic curve of Lower Consolation Lake. Depths are in metres.

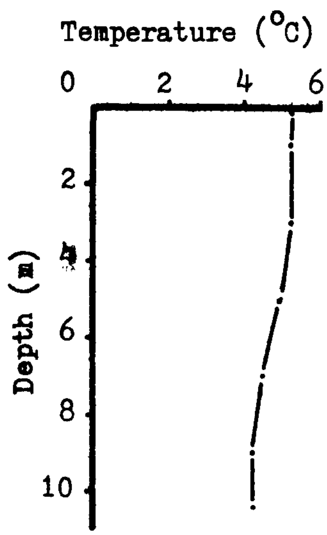


Figure 2.26. Representative temperature profile, Lower Consolation Lake, 15 viii 74.

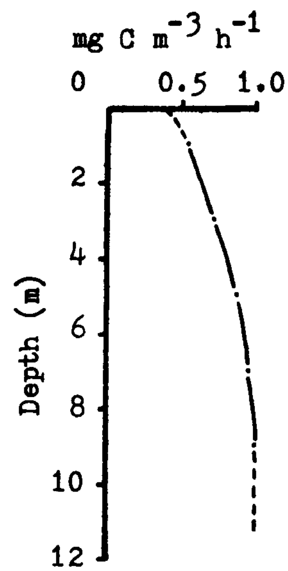


Figure 2.27. Profile of primary productivity, Lower Consolation Lake, 15 viii 74. Points are net figures (light minus dark). Samples were collected with a hose. Incubation 0925 - 1240 h MST

Figure 2.28. Percent ionic composition of surface water calculated on the basis of equivalent weights, Lower Consolation Lake, 17 vii 73.

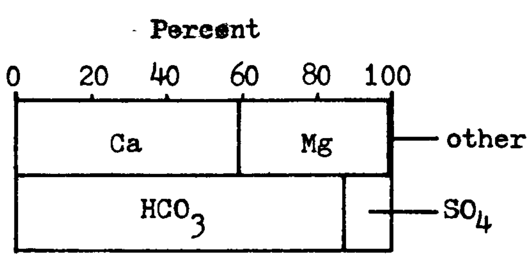


Figure 2.29. Fish growth diagram, Lower Consolation Lake, 11-12 vii 74.
Brook trout - simple points
Cutthroat trout - circled points

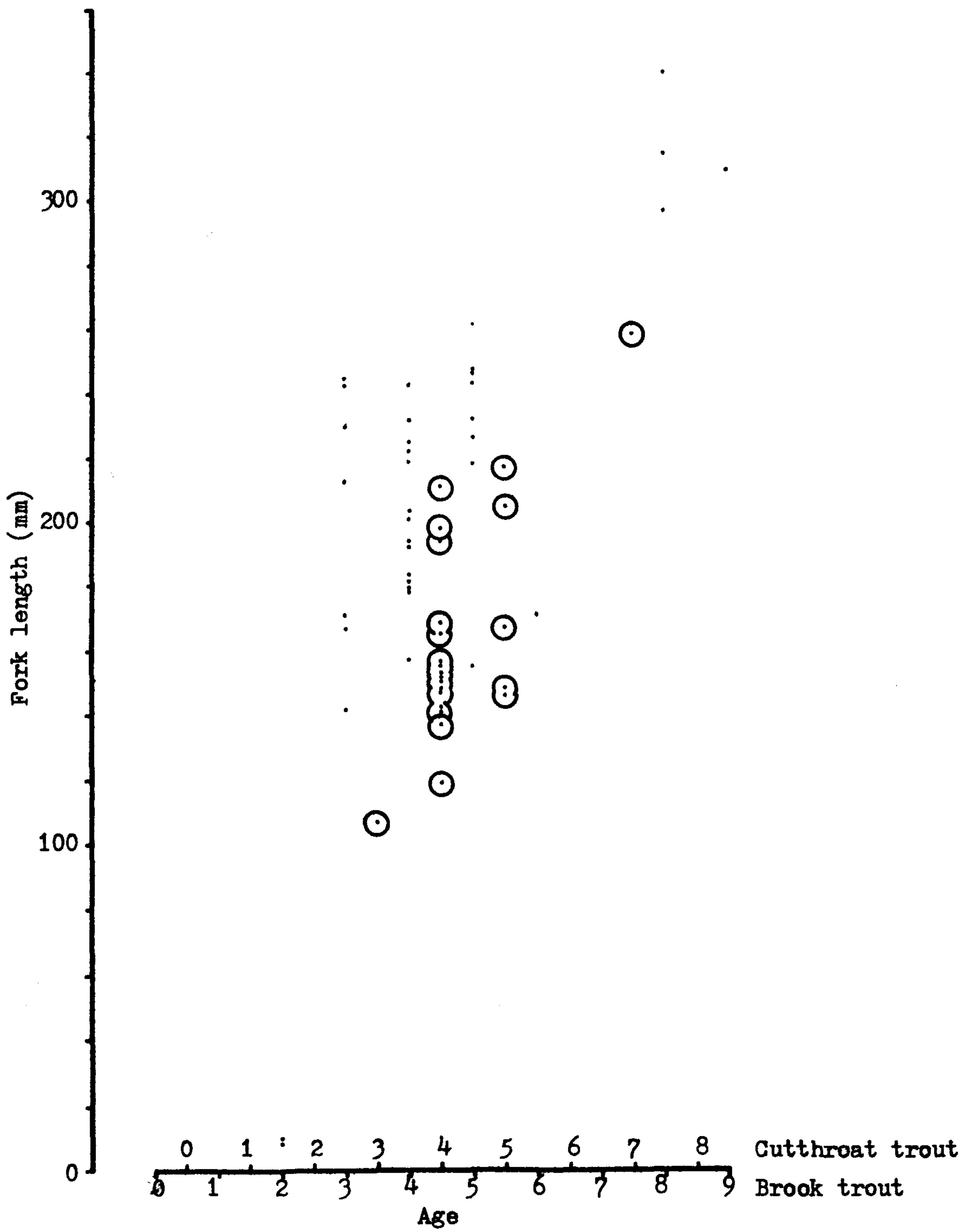
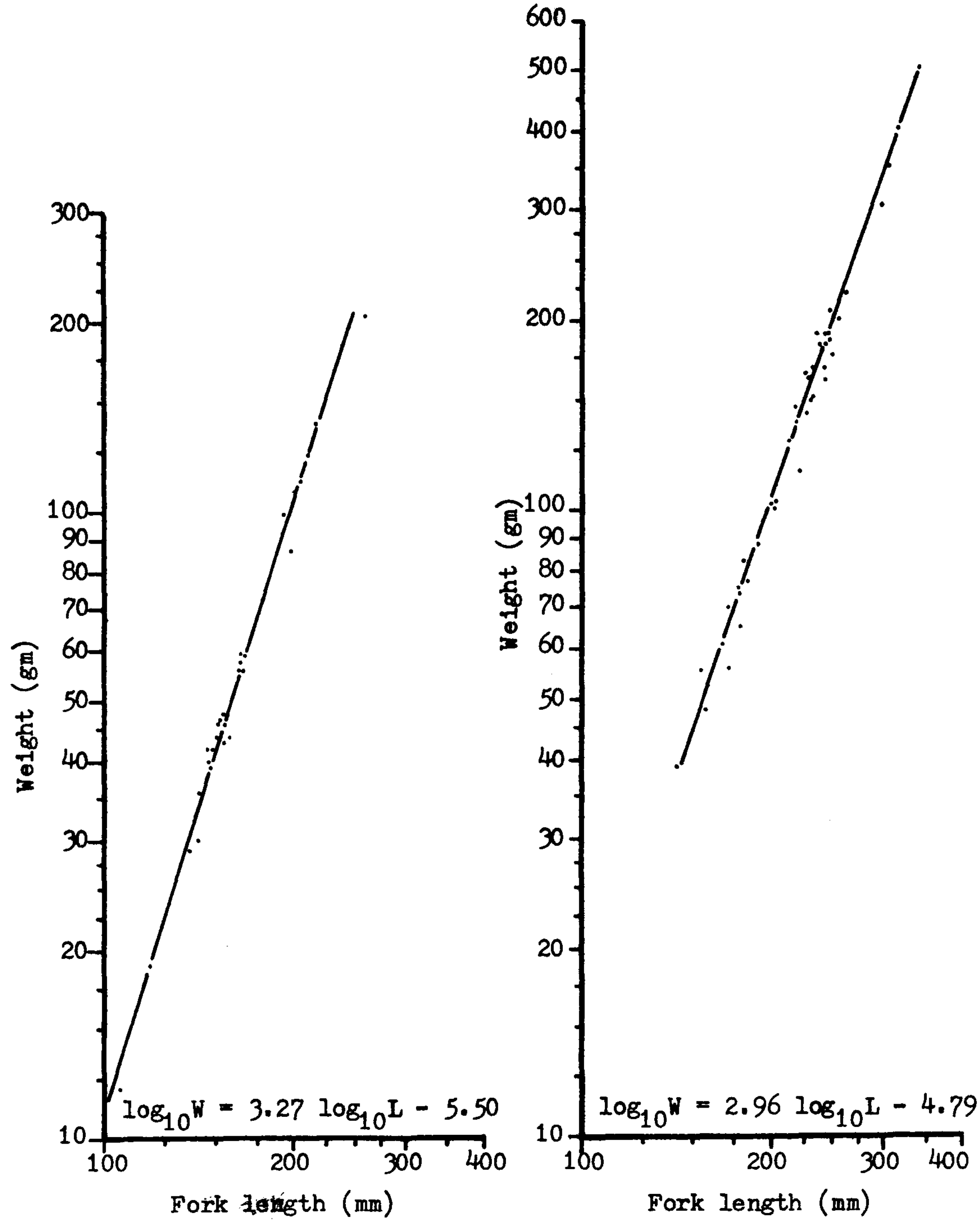


Figure 2.30. Length - weight relationship of cutthroat trout (left) and brook trout (right), Lower Consolation Lake, 11-12 vii 74. The lines were drawn by eye.



UPPER CONSOLATION LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 594843, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Moraine Lake parking lot approximately 3.8 km (2.3 mi)

Elevation: 1951 m

Altitudinal zone: upper subalpine

Basin type: valley basin dammed by a debris cone, which separates it from the lower lake (outlet is subsurface)

Length: 506 m

Mean width: 211 m

Area: 10.7 ha

Maximum depth: 16.2 m

Mean depth: 5.9 m

Volume: 63.5 x $10^4 m^3$

Shoreline length: 1665 m

Shoreline development: 1.44

Volume development: 1.10

Mean depth/max. depth: 0.36

Area/mean depth: 1.81

Water level fluctuation: water level can change quickly (drop of 5 - 8 cm 14 viii to 15 viii 74), probably drops more than 30 cm through summer

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 2	18.58	29.3
2 - 4	13.92	21.7
4 - 6	10.99	17.3
6 - 8	8.98	14.2
8 - 10	5.84	9.2
10 - 12	3.03	4.8
12 - 14	1.69	2.7
14 - 16.2	0.43	0.8

Water renewal time:

3 vii 74: 3.2 days 12 ix 74: 9.1 days
8 viii 74: 3.7 days 4 vii 74: 4.3 days
based on outflow rates from Lower Consolation; therefore these times are somewhat too low

Open-water period: late June/mid July to probably late October (approximately 100 - 115 ice-free days; no direct observations of freeze-up date) Break-up is about 1 week later than the lower lake in some years.

Catchment area: 780 ha

Bedrock composition of catchment area: 2% Miette Group, 74% quartzite, 24% Cambrian carbonate rocks

Catchment area coverage: 9% forest, 27% glaciers, 64% exposed rock and low plants

(Catchment area - lake area)/lake area: 72

Human activities in catchment area: hiking, angling, unauthorized camping

Bottom composition: organic content of sediments 6.3%

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

Conductivity: 102.8 µmho/cm @ 25C (n = 2) pH: 8.3 units (n = 3)

Total alkalinity as $CaCO_3$: 54.6

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 68.4

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 17 vii 73 — Depth: surface

Turbidity: 0.7 JTU — Colour: 0 HU

pH: 8.0 units — Sum of constituents: 57.7

Conductivity: 102 µmho/cm @ 25C — Sum const./cond: 0.57

Total alkalinity as $CaCO_3$: 52.0

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 53.0

Total inorganic carbon: 10 — Total organic carbon: 1

Major constituents
Calcium: 13.0 Magnesium: 5.0 Sodium: 0.4 Potassium: 0.2
Bicarbonate: 63.4 Carbonate: 0 Sulphate: 5.4 Chloride: 0.2

Minor constituents
Copper: < 0.002 Iron: < 0.05 Lead: < 0.004 Manganese: < 0.008
Zinc: 0.002
Fluoride: < 0.05 Nitrogen (nitrate + nitrite): 0.09
Phosphate: < 0.003 (ortho), < 0.003 (total)

Silica: 1.8

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date:	17 vii 73	15 viii 74
Depth:	0.5	0 - 9 m composite
Chlorophyta		
Chlamydomonas sp.		2

a. Phytoplankton (continued)

Date:	17 vii 73	15 viii 74
Depth:	0.5	0 - 9 m composite
Chrysophyta		
Chrysophyceae		
Chromulina sp.		23
Chrysochromulina parva	14	
Diatomaceae		
Achnanthes sp.	3	
Cymbella sp.		2
Fragilaria crotonensis	6	
Gomphonema olivaceum	2	
Navicula sp.	9	
Synedra ulna	2	5
Cryptophyta		
Rhodomonas minuta	2	475
Total	38	507

b. Zooplankton[1] (collections: 25 vii 66, 20 ix 67, 17 vii 73, 14 viii 74)

Units are maximum numbers per litre.

Rotifera		Cladocera	
Ascomorpha ?	<0.1	*Chydorus sphaericus*	0.011
Brachionus	<0.1	Copepoda	
Polyarthra vulgaris	10 - 100	*Diaptomus tyrrelli*	1.45

2. Bottom and Shoreline Organisms

a. Macrophytes

No macrophytes were found, but attached filamentous algae were conspicuously abundant on the large boulders in the outlet bay.

b. Shoreline fauna

Units are numbers collected.

Collections:	17 vii 73 30 min	14 viii 74 30 min
Platyhelminthes		
Turbellaria	3	
Annelida		
Oligochaeta	1	17
Crustacea		
Copepoda		
Eucyclops agilis	5	1
Insecta		
Ephemeroptera		
Ameletus nr. *celer* and *celeroides*	4	
Siphlonurus		1
Plecoptera		
Perlodidae (damaged)	1	

1. maximum crustacean standing crop: 1.5 animals/l

b. Shoreline fauna (continued)

Collections:	17 vii 73 30 min	14 viii 74 30 min
Insecta (continued)		
Trichoptera		
unidentified pupae		1
Diptera		
Chironomidae		
Orthocladiinae larvae	1	1
" pupae		1
<u>Phaenopsectra</u>		1
Ceratopogonidae		
<u>Palpomyia</u>, <u>Bezzia</u> or <u>Johannsenomyia</u>	1	
Arachnida		
Hydracarina		
<u>Lebertia</u>		1
unidentified nymphs	1	2

c. Bottom fauna (collection: 14 viii 74, n = 6)
Units are mean numbers/m^2.

Nematoda	43
Annelida	
Oligochaeta	14
Insecta	
Chironomidae	
<u>Procladius</u> s. str.	36
<u>Pseudodiamesa</u>	7
Orthocladiinae pupae	43
<u>Cricotopus</u> or <u>Orthocladius</u>	165
Chironomidae (continued)	
<u>Paracladius</u>	237
<u>Phaenopsectra</u> s.str.	1040
<u>Stictochironomus</u>	43
<u>Micropsectra</u>	409
<u>Tanytarsus</u>	50
Mollusca	
Pelecypoda	
<u>Pisidium</u>	660

Standing crop (mean preserved wet weight/m^2):

Oligochaeta	0.052 gm
Chironomidae	4.816 gm
<u>Pisidium</u>	1.467 gm

3. Fish

Collection date: 14-15 viii 74 Set duration: 20 h

Gear: 20 m each of 3/4, 1½, 2, 3, 4-inch mesh green multifilament nylon gillnet set on bottom

Catch: 23 brook trout (<u>Salvelinus fontinalis</u>); 6 males, 11 females, 6 unsexed

Age:	5	6	7	9	10
Number:	3	1	3	1	3
Mean fork l. (mm):	147.7	176	173.3	170	217.0
Mean weight (gm):	46.8	65	77.3	62	131.0

Twelve of the specimens (52%) could not be aged because the otolith checks were too obscure. All the remaining fish were very difficult to age because of their closely-spaced checks.

Maturity: Of the 3 fish judged to be immature which could be aged, two were age 7 and one was age 5. Five of the females judged to be mature nevertheless had ovaries containing relatively small eggs.

Food: 20 stomachs examined, 3 (15%) empty

Food item	% of fish with item	mean % total stomach contents by volume
Chironomidae	80	53.2
Trichoptera	40	14.1
unidentified insect parts	20	10.6
Hydracarina	30	6.6
conifer needles	10	5.3
terrestrial insects	20	3.7
Plecoptera	20	2.9
Ephemeroptera	10	2.1
Pisidium	5	~0

Parasites: Of three specimens examined for parasites, two were infected with *Crepidostomum farionis* (mean 6 per specimen, range 0 - 17) (Mudry and Anderson in press).

D. Discussion

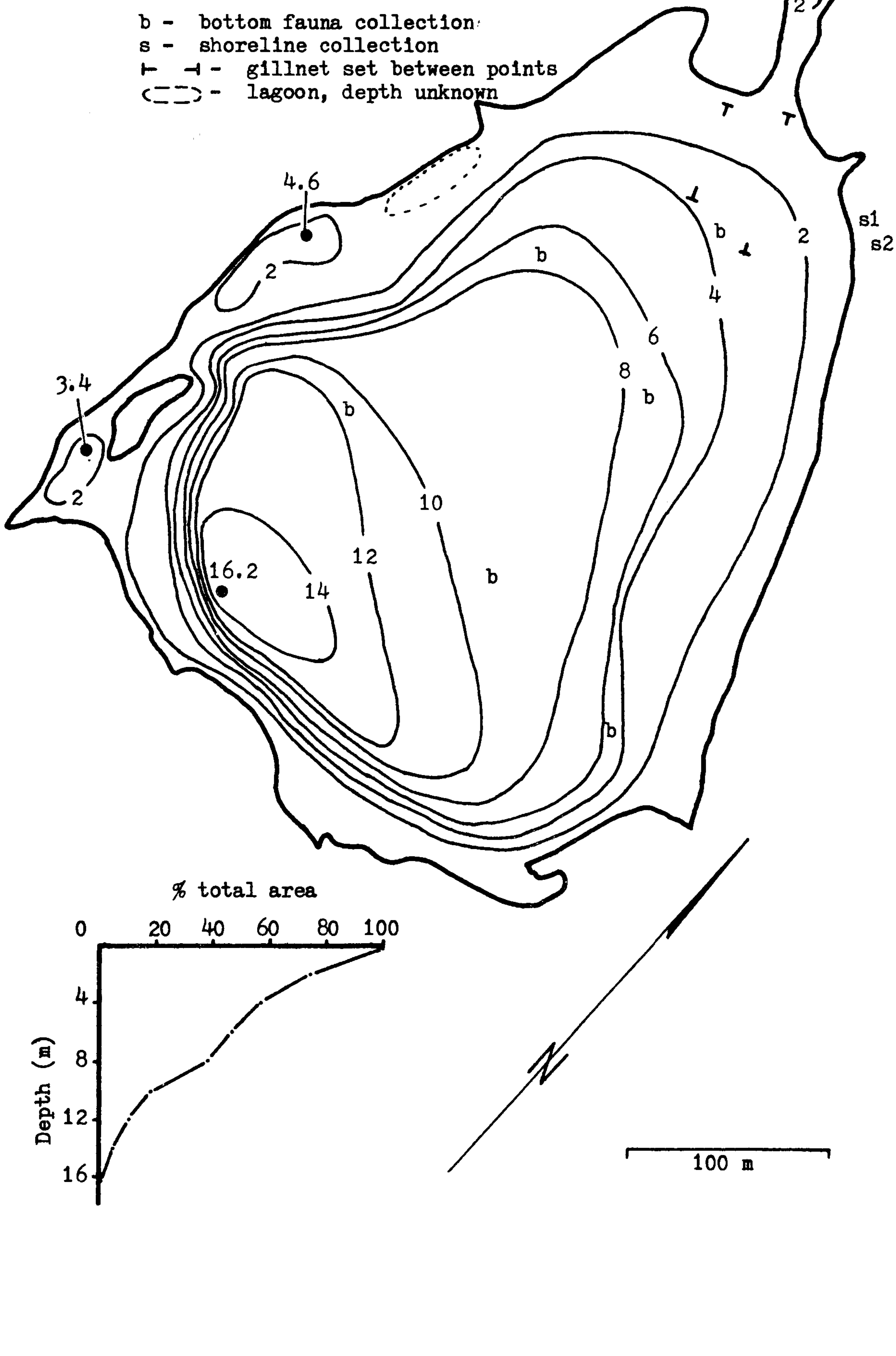
Although more than one-quarter of the drainage basin area of Upper Consolation is occupied by glaciers (p. 65), the lake is very clear (Fig. 2.32). The hanging glacier on Mounts Bident and Quadra is active. Before reaching the lake, meltwater from the glacier runs through an extensive area of moraine and disintegrating ice. The moraine evidently acts as an effective filter, removing silt from the meltwater before it enters the lake.

The age determinations presented for the brook trout are unreliable except as a rough indicator of relative age, because the checks on the otoliths were very obscure and closely spaced. Nevertheless, Upper Consolation brook trout clearly have a very low rate of growth (Fig. 2.35). This is to be expected in view of the low temperatures in the lake (Fig. 2.32). The mean annual temperature of the lake is less than 4°C, mainly because of the glacial source of the water and the high water renewal rate. Low water temperature could act to limit fish growth directly through its effect on metabolic rate, and indirectly by limiting the rate of production of food organisms.

The occurrence of mature, but far from ripe, fish in the mid-August catch suggests that brook trout do not spawn every year in Upper Consolation Lake. Suitable spawning areas are scarce, but some successful egg development might be possible in and near the outlet bay, where there is a slight but perceptible current. Some current is apparently necessary for successful natural reproduction of brook trout (Scott and Crossman 1973). To determine if there actually is any natural recruitment of brook trout in the lake, stocking would have to be stopped for a number of years, or all fish stocked would have to be marked.

Discussion relative to previous investigations and stocking records is presented in the section on Lower Consolation Lake (pp. 57-59).

Figure 2.31. Bathymetric map and hypsographic curve of Upper Consolation Lake. Depths are in metres.



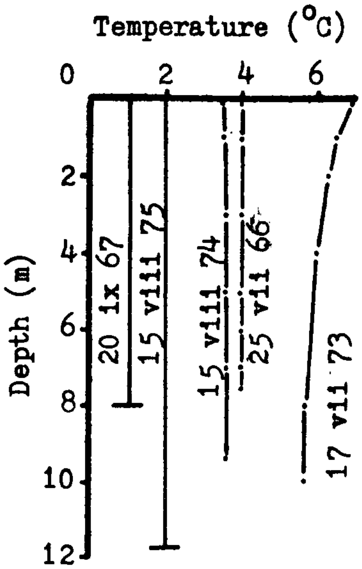


Figure 2.32. Selected temperature profiles and Secchi depth readings (⊥), Upper Consolation Lake.

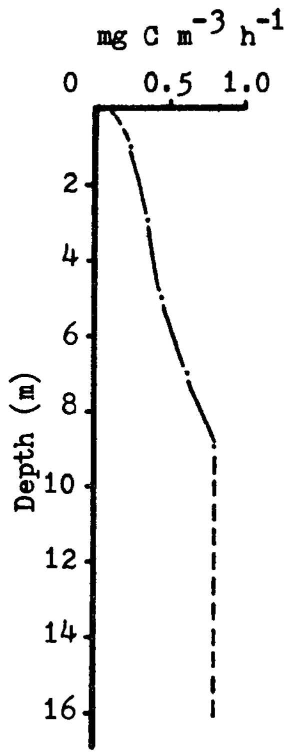


Figure 2.33. Profile of primary productivity, Upper Consolation Lake, 15 viii 74. Points are net figures (light minus dark). Samples were collected with a hose. Incubation 1035 - 1340 h MST

Figure 2.34. Percent ionic composition of surface water calculated on the basis of equivalent weights, Upper Consolation Lake, 17 vii 73.

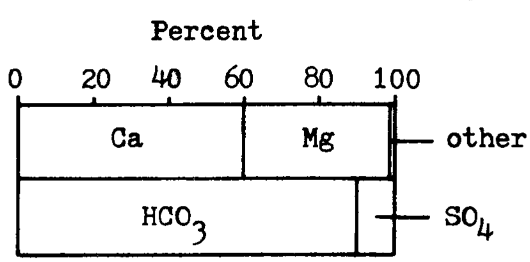


Figure 2.35. Growth diagram of brook trout from Upper Consolation Lake, 14-15 viii 75.

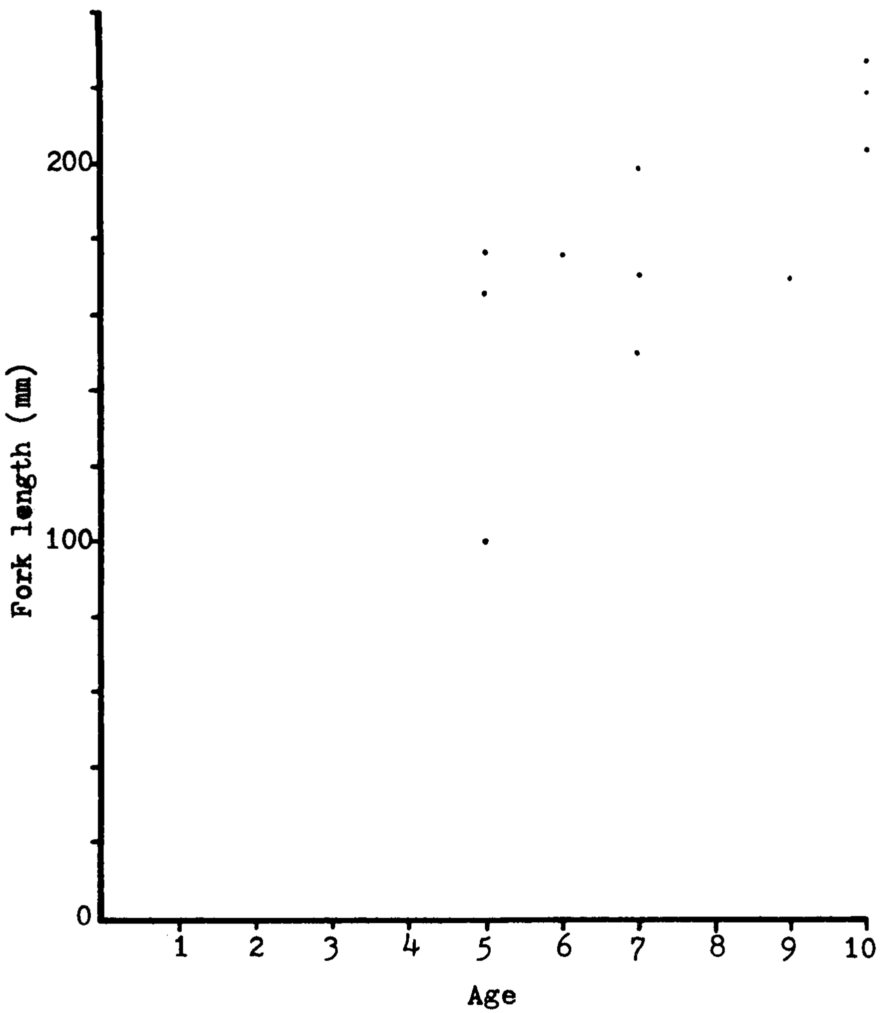
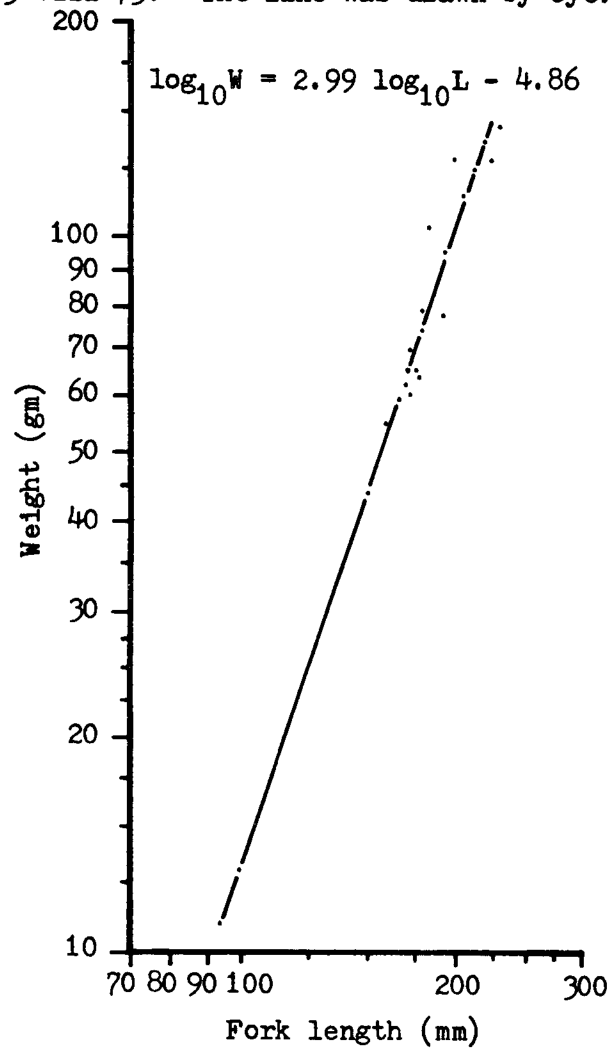


Figure 2.36. Length - weight relationship of brook trout, Upper Consolation Lake, 14-15 viii 75. The line was drawn by eye.



EIFFEL LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 528856, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Moraine Lake parking lot 5.7 km (3.5 mi)

Elevation: 2271 m

Altitudinal zone: treeline

Basin type: dammed against the base of Eiffel Peak by the Neptuak rockslide; partly in depression on rockslide (Kucera 1974)

Length: 570 m

Mean width: 237 m

Area: 13.5 ha

Maximum depth: 13.5 m

Mean depth: 6.0 m

Volume: 81.0 x $10^4 m^3$

Shoreline length: 1488 m

Shoreline development: 1.14

Volume development: 1.33

Mean depth/max. depth: 0.44

Area/mean depth: 2.25

Water level fluctuation: water level may drop 3 m through summer (Fabris 1966)

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 2	25.13	31.0
2 - 4	21.04	26.0
4 - 6	16.13	19.9
6 - 8	11.21	13.8
8 - 10	6.19	7.6
10 - 12	1.18	1.5
12 - 13.5	0.08	0.2

Water renewal time: not determined - no surface outlet, probably short

Open-water period: July 10 to October 11, 1965, or 92 ice-free days (Fabris 1966)

Catchment area: 360 ha

Bedrock composition of catchment area: 80% quartzite, 20% Cambrian carbonate rocks

Catchment area coverage: 100% bare rock and low plants

(Catchment area - lake area)/lake area: 26

Human activities in catchment area: hiking, occasional angling, unauthorized campsite used.

Bottom composition: Approximately 90% of the bottom is covered by very large rock rubble. Sediments in the deepest portion are gritty-black, with an organic content of 14.9%.

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 7 viii 66 — Depth: surface

pH: 7.5 units — Total alkalinity as $CaCO_3$: 41.0

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 51.3 — Total acidity: 4.56

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 7 viii 66 — Depth: 0.5 m

Turbidity: 0.1 JTU — Colour: 0 HU

pH: 7.8 units — Sum of constituents: 38.1

Conductivity: 69.3 µmho/cm @ 25C — Sum const./cond: 0.55

Total alkalinity as $CaCO_3$: 31.6

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 35.3

Major constituents
Calcium: 9.8 Magnesium: 2.6 Sodium: 0.1 Potassium: 0.1
Bicarbonate: 38.5 Carbonate: 0 Sulphate: 4.2 Chloride: 0.1

Minor constituents
Iron: 0.00 (both total and dissolved) Aluminum: 0.00
Manganese: 0.000 (both total and dissolved) Copper: 0.000
Zinc: 0.000
Fluoride: <0.01 Phosphate: <0.05 (total) Nitrate: 0.1

Silica: 2.1

Ammonia: 0.0

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)
Date: 4 ix 75
Depth: surface

Chlorophyta	
Cosmarium exiguum var. *subrectangulum*	1
Oocystis borgei	6
Chrysophyta	
Chrysophyceae	
Chromulina sp.	73
Chrysochromulina parva	6
Chrysophyceae (continued)	
Ochromonas sp.	21
Pseudokephyrion nr. *hyalinum*	6
Diatomaceae	
Achnanthes sp.	8
Cymbella microcephala	1
Cymbella sp.	4

Diatomaceae (continued)		Diatomaceae (continued)	
Cyclotella nr. kuetzingianum	1	Navicula sp.	3
Cyclotella sp.	8	Synedra sp.	6
Diatoma tenue	1	Cryptophyta	
Fragilaria pinnata	6	Rhodomonas minuta	92
Fragilaria spp.	14		
		Total	257

b. Zooplankton[1] (collections: 23 vi 66, 7 viii 66, 4 ix 75)
Units are maximum numbers per litre.

Cladocera		Copepoda	
Chydorus sphaericus	0.01	Diaptomus arcticus	2.83
Daphnia middendorffiana	0.10	Insecta	
		Chironomidae larvae	0.01

2. Bottom and Shoreline Organisms

a. Macrophytes

no macrophytes found

b. Shoreline fauna (collection: 4 ix 75, approximately 30 min)
Units are numbers collected.

Insecta			
Ephemeroptera		Coleoptera	
Siphlonurus	9	Agabus tristis	5

c. Bottom fauna (collection: 4 ix 75, n = 2)
Units are mean numbers/m^2.

Crustacea		Chironomidae (continued)	
Cladocera		Psectrocladius	1313
Daphnia middendorffiana	129	Phaenopsectra s. str.	151
Copepoda		Tanytarsus	23,767
Diaptomus arcticus	2648	Mollusca	
Insecta		Pelecypoda	
Diptera		Pisidium	108
Chironomidae			
Procladius s. str.	4973		

Standing crop (mean preserved wet weight/m^2):
Chironomidae mainly 16.927 gm Pisidium 0.118 gm (with shell)

3. Fish

no collections

D. Discussion

Kucera (1974) presented several photographs illustrating the setting of Eiffel Lake.

The primary productivity of Eiffel Lake has been studied by Fabris (1966) and Fabris and Hammer (1975). These authors also give additional information on the water chemistry, and the physical and biolo-

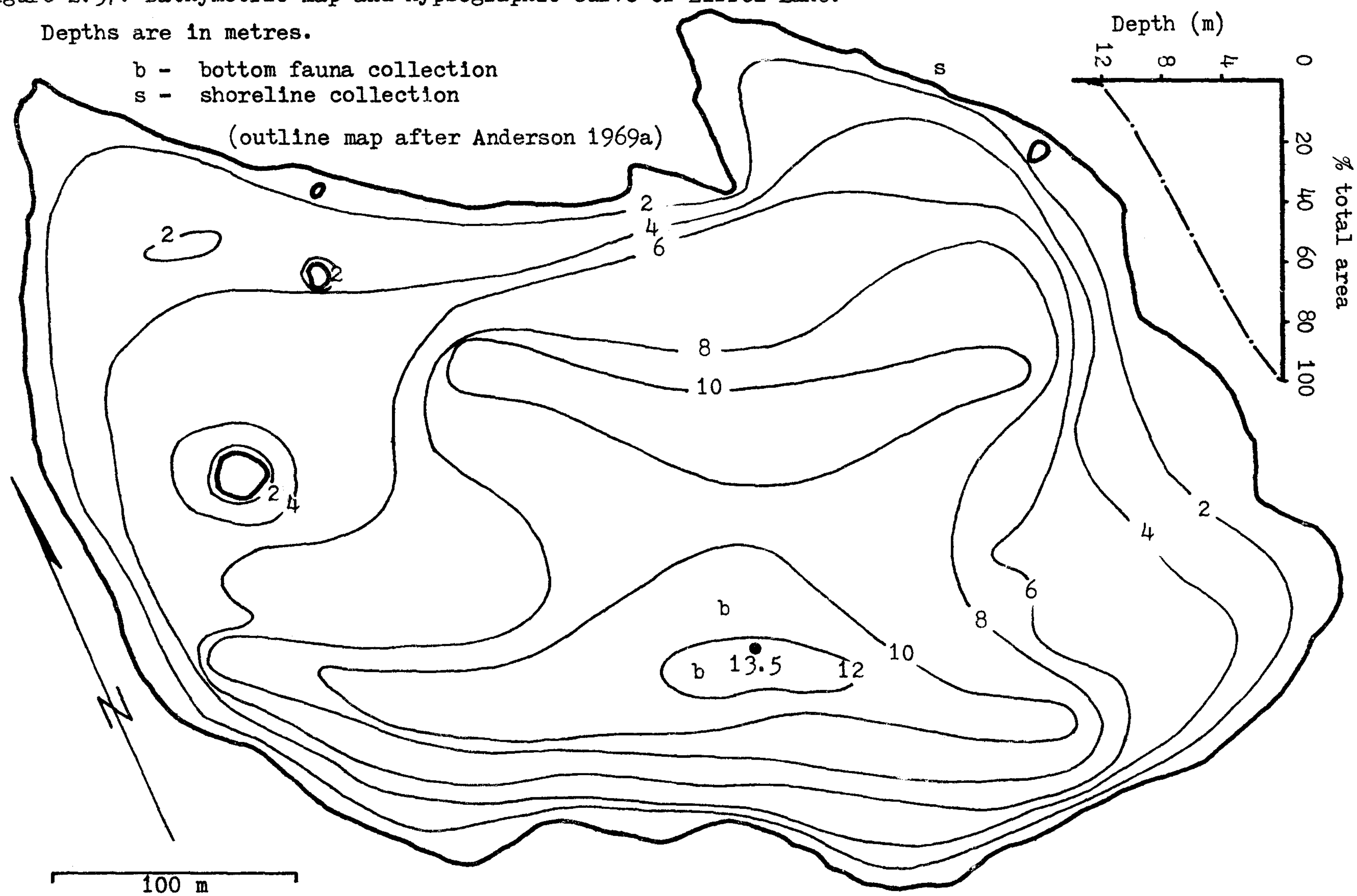
1. maximum crustacean standing crop: 2.8 animals/l

Figure 2.37. Bathymetric map and hypsographic curve of Eiffel Lake.

Depths are in metres.

b - bottom fauna collection
s - shoreline collection

(outline map after Anderson 1969a)



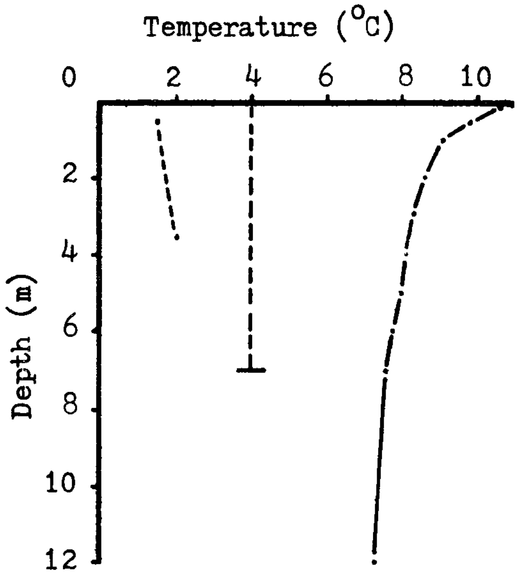


Figure 2.38. Selected temperature profiles and Secchi depth readings (⊥), Eiffel Lake.
23 vi 66 ----
7 viii 66 ——

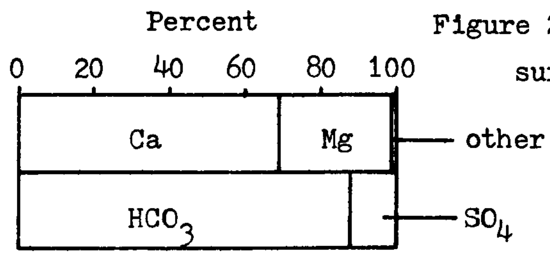


Figure 2.39. Percent ionic composition of surface water calculated on the basis of equivalent weights, Eiffel Lake, 7 viii 66.

gical attributes of the lake. Where data are comparable, our findings are in general agreement with theirs. The area of the lake given by them, which they determined from topographic maps, is certainly too small by a factor of about 1.7, however.

The only species reported from Eiffel Lake in addition to those found in this survey is the pyrrophyte Ceratium hirundinella, by Fabris (1966).

There is no record of fish being stocked in Eiffel Lake (National Parks stocking records, Ward 1974), nor did we see any sign of fish during our visits.

HERBERT LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NH 542010, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Transport corridor

Access: from the Banff-Jasper Parkway, which runs along the lakeshore.

Elevation: 1600 m

Altitudinal zone: lower subalpine

Basin type: drift basin of complex origin, determined partly by bedrock structure and partly by drift deposition

Length: 536 m

Mean width: 106 m

Area: 5.7 ha

Maximum depth: 13.3 m

Mean depth: 4.5 m

Volume: 25.4 x $10^4 m^3$

Shoreline length: 1360 m

Shoreline development: 1.61

Volume development: 1.00

Mean depth/max. depth: 0.34

Area/mean depth: 1.27

Water level fluctuation: minimal - less than 30 cm in summers of 1974 and 1975

Stratum (m)	Volume ($10^4 m^3$)	% Total Volume
0 - 1	5.21	20.5
1 - 3	7.98	31.4
3 - 5	5.51	21.7
5 - 7	3.76	14.8
7 - 9	1.96	7.7
9 - 11	0.74	2.9
11 - 13.3	0.25	1.0

Water renewal time: 1035 days (13 vi 74)

Open-water period: mid May to late October (approximately 150 ice-free days) (Anderson 1969b, 1970b)

Catchment area: Unknown. Lake fed largely by groundwater entering beneath surface (Anderson 1969b, 1970b)

Bedrock composition of catchment area: 100% Miette Group

Catchment area coverage: 100% forest

Human activities in catchment area: gravel pit north end of lake, Banff-Jasper Highway east shore, picnic site and pit toilets south shore, angling. No boats permitted.

Bottom composition: The deepwater sediments of Herbert Lake are medium to dark brown and flocculent (Anderson 1969b, 1970b). The mean organic content is 59.4% (n= 3).

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 29 vii 72

Depth:	0 m	2 m	4 m	6 m	10 m
Conductivity (μmho/cm @ 25C):	290	290	290	305	360
pH (units):	8.1	8.1	8.1	8.1	7.6
Total alkalinity as $CaCO_3$:	150	150	150	157	191

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 3 viii 66 Depth: 0.5 m

Turbidity: 0.1 JTU Colour: 1 HU

pH: 8.2 units Sum of constituents: 162

Conductivity: 305 μmho/cm @ 25C Sum const./cond: 0.53

Total alkalinity as $CaCO_3$: 149

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 159

Major constituents
Calcium: 39.8 Magnesium: 14.5 Sodium: 1.9 Potassium: 0.5
Bicarbonate: 182.0 Carbonate: 0 Sulphate: 4.4 Chloride: 8.2

Minor constituents
Iron: 0.00 (total and dissolved) Aluminum: 0.10
Manganese: 0.005 (total), 0.000 (dissolved) Copper: 0.005
Zinc: 0.003
Fluoride: 0.04 Phosphate: < 0.05 (total) Nitrate: < 0.05

Silica: 5.3

Ammonia: 0.0

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 29 vii 72 Depth: surface

Chlorophyta
- Carteria klebsii 5
- Chlamydomonas sp. 36
- Elaktothrix gelatinosa 7
- Nephrocytium agardhianum 7
- Oocystis parva 3

Cyanophyta
- Anabaena sp. 81

Chrysophyta
Chrysophyceae
- Bitrichia chodatii 22
- Dinobryon divergens 13
- D. pediforme 23
- Epipyxis sp. 2
- Mallomonas sp. 2

Chrysophyta (continued)		Cryptophyta	
Diatomaceae		*Chroomonas nordstedtii*	2
Cyclotella ocellata	2	*Cryptomonas erosa*	2
Navicula sp.	8	*Rhodomonas minuta*	50
unknown sp. 1	23		
" 2	55		
" 3	5		

b. Zooplankton[1] (semi-monthly in summer, monthly in winter, 1971-73; 19 samples 1968-1970, 1974)

Units are maximum numbers per litre.

Rotifera		Cladocera (continued)	
Ascomorpha	1 - 10	*Daphnia* (*galeata mendotae*?)	22.875 (all *Daphnia*)
Asplanchna	10 - 100	*D.* (*pulex*?)	
Conichiloides	0.1 - 1	*D. pulicaria*	
Conichilus	0.1 - 1	*D.* (*rosea*?)	
Filinia longiseta	100 - 1000	*Eurycercus lamellatus*	trace
Kellicottia longispina	10 - 100	*Polyphemus pediculus*	0.072
Keratella cochlearis	10 - 100	Copepoda	
K. quadrata	10 - 100	*Acanthodiaptomus denticornis*	1.782
Lecane	1 - 10	*Diaptomus sicilis*	21.808
Monostyla	trace	*Acanthocyclops vernalis*	trace
Polyarthra vulgaris	1 - 10	*Eucyclops agilis*	trace
Synchaeta oblonga	10 - 100	*Macrocyclops albidus*	0.042
Cladocera		*Orthocyclops modestus*	32.456
Alona rectangula	0.004	Insecta	
Bosmina longirostris	5.554	Diptera	
Ceriodaphnia affinis	trace	Chaoboridae	
C. quadrangula	12.531	*Chaoborus flavicans*	trace
Chydorus sphaericus	0.238		

2. Bottom and Shoreline Organisms

a. Macrophytes

No collections were made, but some plants were noted in the field. Emergent sedges (*Carex*) were frequent around the shoreline. An unidentified Characeae was common in dredge samples, and *Potamogeton* (*natans*?) occurred in shallow water in places -- particularly in the narrow north bay.

b. Shoreline fauna (collections: 5 vi 72, 14 viii 72, both 30 min)

Units are numbers collected. G. L. Scott data

Crustacea		Insecta (continued)	
Amphipoda		Hemiptera	
Hyalella azteca	21	*Gerris*	5
Insecta		Trichoptera	
Odonata		Phryganeidae	1
Zygoptera		*Mystacides* adult	5
Coenagrionidae	16	unidentified pupae	1
Anisoptera		Coleoptera	
Aeshna	4	*Amphizoa lecontei*	1
Somatochlora	3		

1. maximum crustacean standing crop: 107.6 animals/l

b. Shoreline fauna (continued)

Insecta (continued)	
Diptera	
Chironomidae	
Tanypodinae	11
Orthocladiinae or Diamesinae	1
Chironominae	1
unidentified larvae	5
Mollusca	
Gastropoda	
<u>Lymnaea</u>	1

c. Bottom fauna (collections: 5 vi 72, 23 viii 72; n = 18)
Units are mean numbers/m^2. (G. L. Scott data)

Annelida	
Oligochaeta	36
Hirudinoidea	
<u>Helobdella stagnalis</u>	10
Crustacea	
Amphipoda	
<u>Gammarus lacustris</u>	68
<u>Hyalella azteca</u>	445
Insecta	
Odonata	
Zygoptera	
Coenagrionidae	12
Trichoptera	
<u>Mystacides</u>	7
<u>Oecetis</u>	5
Insecta (continued)	
Diptera	
Tipulidae	2
Chaoboridae	
<u>Chaoborus flavicans</u>	5
Chironomidae	
Tanypodinae	38
Orthocladiinae or Diamesinae	22
Chironominae	109
unidentified larvae	5
Ceratopogonidae	53
Mollusca	
Gastropoda	
<u>Gyraulus</u>	2
Pelecypoda	
Sphaeriidae	3884

Standing crop (mean preserved wet weight/m^2):
All organisms 18.4082 gm (n = 18)

3. Fish (B. D. Smiley data)

Collection dates: 26 vi 73 and 31 vii 73 Set duration: unknown

Gear: 7.6 m each of 3/4, 1, 1½, 2, 3, 4-inch mesh green monofilament nylon gillnet. One gang set on 26 vi 73, 3 gangs set 31 vii 73.

Catch: 1 brook trout (<u>Salvelinus fontinalis</u>); unsexed } 26 vi
4 rainbow trout (<u>Salmo gairdneri</u>); 2 males, 2 females }

31 brook trout; 17 males, 12 females 2 unsexed } 31 vii
17 rainbow trout; 5 males, 12 females }
1 whitefish (species unknown); female }

also 2 longnose sucker (<u>Catostomus catostomus</u>); unsexed, date of collection not known

a. Brook trout

Age:	1	2	3	4	5	6
Number:	2	10	11	2	1	2
Mean fork l. (mm):	160.0	157.8	208.6	319.5	320	217.0
Mean weight (gm):	48.0	50.3	108.2	335.5	382	113.0

a. Brook trout (continued)

Maturity: Most males were mature at age 2 or 3, but some age 3 males were still immature. Females were mature at age 3 or 4. These ages may be in error because of difficulties in reading the otoliths (see discussion).

Food: 31 fish examined, 3 (9.7%) empty stomachs

Food item	% of fish with item	mean % total stomach contents by volume
Chironomidae (mainly pupae)	61	40.0
Trichoptera	43	16.2
Zygoptera adults	18	9.8
Amphipoda (both spp.)	25	8.6
Diptera adults	14	8.6
Anisoptera nymphs (mainly Aeshnidae)	11	6.4
Cladocera	11	3.6
Coenagrionidae nymphs	7	2.5
Coleoptera (terrest.)	7	0.9
Orthoptera (terrest.)	4	0.4

Parasites: Five brook trout were examined for parasites. Four were infected with Crepidostomum farionis (mean 189.8 per specimen, range 0 - 513), and one was infected with 9 Diphyllobothrium sp. larvae (Mudry and Anderson, in press).

b. Rainbow trout

Age:	2	3	4	5	6
Number:	1	11	4	4	1
Mean fork l. (mm):	189	203.1	242.0	225.2	297
Mean weight (gm):	84	91.8	154.5	120.0	272

Maturity: Males were mature at age 3 or 4. Females less than age 6 were either immature or were judged to be maturing virgins. The otoliths of these fish were difficult to read, so the ages given may be wrong.

Food: 17 fish examined, none had empty stomachs

Food item	% of fish with item	mean % total stomach contents by volume
Chironomidae (mainly pupae)	71	64.4
Coenagrionidae nymphs	18	13.5
Amphipoda (both spp.)	24	7.9
unidentified material	6	2.9
Coleoptera (terrest.)	12	2.3
Diptera adults	12	1.5
Trichoptera	6	0.6
Zygoptera adults	6	0.6
Sphaeriidae	12	0.3
Ceratopogonidae larvae	6	~0

b. Rainbow trout (continued)

Parasites: Ten rainbow trout were examined for parasites. Seven of these were infected with Crepidostomum farionis (mean 3.9 per specimen, range 0 - 13), and 9 were infected with Diphyllobothrium sp. larvae (mean 9.1 per specimen, range 0 - 42) (Mudry and Anderson, in press).

c. "Whitefish"

fork length 427 mm, weight 1180 gm, no age determination
stomach contents Diptera larvae and pupae (both abundant), and Mollusca (common)

d. Longnose sucker

Specimen 1: fork length 211 mm, weight 100 gm
Specimen 2: fork length 225 mm, weight 113 gm

Age, sex and stomach contents were not determined for either specimen. No parasites were found in either specimen (Mudry and Anderson, in press).

D. Discussion

Several aspects of the physical and chemical limnology of Herbert Lake have been treated in detail elsewhere (Anderson 1969b, 1970b). Because of its importance to fish survival, we elaborate only on the dissolved oxygen data here.

Herbert Lake has a prolonged period of circulation to the bottom in autumn, during which the water column becomes nearly saturated (70 - 80%) with oxygen. From February to April, under a cloudy ice and snow cover reaching a thickness of more than 1 metre, dissolved oxygen levels below 4 metres are at 40% saturation or less. During the same period, dissolved oxygen levels are at 60% saturation or less below 2 metres, and temperatures below 2 metres are 3 to 4 ^{o}C. Circulation in the spring is incomplete, so that the deeper water (below 8 or 9 metres) does not become fully charged with oxygen. Thus, low winter oxygen levels in deep water are carried over into summer.

Based on an extensive review of the literature, Davis (1975, Table 10) provided a useful guide to the quality of salmonid habitat with respect to dissolved oxygen. According to Davis' criteria, a large portion of a freshwater salmonid population subjected to the temperatures and dissolved oxygen levels found below 4 m in late winter in Herbert Lake would suffer severe hypoxic effects. Probably some mortalities could be expected if fish remained in this zone for more than a few days.

The region below 4 m in Herbert Lake constitutes about 37% of the lake volume (p. 78). When it is considered that a further 20.5% of the lake volume (the 0 to 1 m stratum, p.78) is frozen, it is apparent that only about 43% of the volume is at all habitable by fish during the three-month period of lowest dissolved oxygen concentrations. Again using Davis' criteria, it can be shown that about another 28% of the lake volume is unfavourable for long-term habitation by trout, if not lethal to a small portion of the population. Thus, only 15% of the lake volume is completely suitable for year-round habitation by trout in terms of its dissolved oxygen levels.

Considering the above discussion, some winterkill is to be expected in Herbert Lake, at least in some years. This is particularly true if the fish population is so large that some members of the population are forced to live below 4 metres. In fact, fishery workers have suspected that partial winterkills have occurred in Herbert Lake in the past (A. C. Colbeck and J. C. Ward, personal communication).

The following species have been recorded from Herbert Lake in addition to those found in the present survey.

Cyanophyta	
Anabaena circinalis	R
Aphanocapsa elachista	R
Chroococcus limneticus	R
Gomphosphaeria aponina	R
Lyngbya limneticum	R
Merismopedium glaucum	R
Chlorophyta	
Bulbochaete sp.	R
Closterium aciculare	R
C. kutzingii	R
Crucigenia irregularis	R
Mougeotia sp.	R
Pediastrum boryanum	R
Pleurotaenium trabecula	R
Spirogyra sp.	R
Volvox sp.	F
Chrysophyta	
Chrysophyceae	
Chrysosphaerella longispina	F
Diatomaceae	
Amphora ovalis	R
Cyclotella compta	R
Epithemia argus	R
Navicula peregrina	R
Nitzschia sigma	R
Diatomaceae (continued)	
Nitzschia sigmoidea	R
Pinnularia interrupta	R
Rhopalodia gibba	R
Stauroneis phoenicentron	R
Stephanodiscus sp.	F
Tabellaria fenestrata	R
T. flocculosa	R
Pyrrophyta	
Ceratium hirundinella	R,F
Peridinium cinctum	R
Rotifera	
Asplanchna priodonta	R
Collotheca sp.	R
Polyarthra trigla	R
Copepoda	
Diaptomus arcticus	Re
D. tyrrelli	R
Odonata	
Enallagma boreale	R
E. cyathigerum	R

R: Rawson (1939)
F: Fabris (1966)
Re: Reed (1959), Rawson's samples

Reed's (1959) noted occurrence of _D_. _arcticus_ in Herbert Lake may have been an error in transcription. Although he notes its occurrence in a discussion (p. 95), he does not mention Herbert Lake as a site record in his list of _D_. _arcticus_ collection sites. Neither this species nor _D_. _tyrrelli_ has been found in the 60 to 70 collections made since 1968.

Rawson (1939) provided data on the number and biomass of bottom organisms based on 6 Ekman grab samples. Our bottom fauna data are not comparable, because critical details of Rawson's methods were not specified.

The primary productivity of Herbert Lake has been studied by Fabris (1966) and Fabris and Hammer (1975). These authors also give additional information on the water chemistry, and the physical and biological attributes of the lake. Where data are comparable, our findings are in general agreement with theirs. Their estimates of primary productivity were somewhat higher than ours, however (see Part 4).

The ages of Herbert Lake brook trout reported here may be inaccurate. The otoliths were very difficult to read, in part because both yearling and fingerling brook trout have been stocked in recent years (National Parks stocking records). Depending on hatchery conditions, the trout may have formed supernumary checks, or no checks at all. Because the fish ages are uncertain, the growth and maturity data are likewise questionable. The same data for rainbow trout are similarly suspect, because the specimens examined were probably stocked fish also (see below).

According to National Parks stocking records, rainbow trout were last stocked in Herbert Lake in 1949. Ward (1974) noted only brook trout to occur in the lake, yet a number of individuals were caught in 1973 which were apparently of several age classes. Rainbows were still being caught by anglers in 1975 (Damm 1975).

Potential spawning areas in the lake are few and of poor quality, being limited to the two small inlets, one of which becomes nearly dry at times. It seems unlikely that these areas could support even a small naturally-recruiting trout population. More probably Herbert Lake has received unrecorded plantings of rainbow trout in recent years.

The occurrence of whitefish and longnose suckers in Herbert Lake is also noteworthy. These species were not found by Rawson (1939), and could not be native to the lake because there is an impassable waterfall on the outlet creek. They were probably introduced accidentally, or by anglers using "minnows" as live bait.

Fishing in Herbert Lake is presently poor. Damm (1975) interviewed 38 fishermen who had fished an average of 1.55 hours each, and had caught a total of 4 rainbow and 2 brook trout. The average catch per angler-hour was therefore 0.10, or 9.8 hours per fish. Damm estimated the total catch for the season to be about 154 fish.

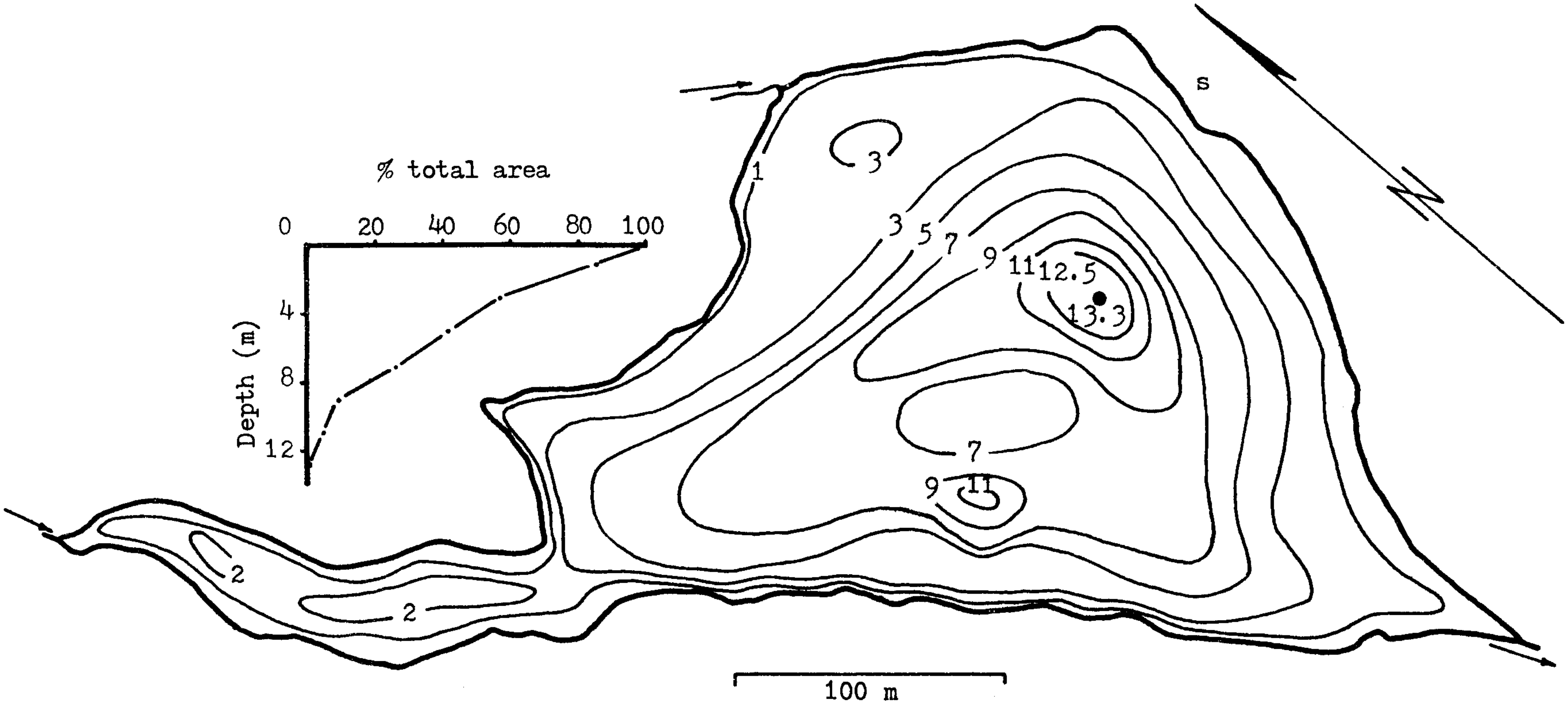


Figure 2.40. Bathymetric map and hypsographic curve of Herbert Lake. Depths are in metres.
s - shoreline collection (after Anderson 1969b)

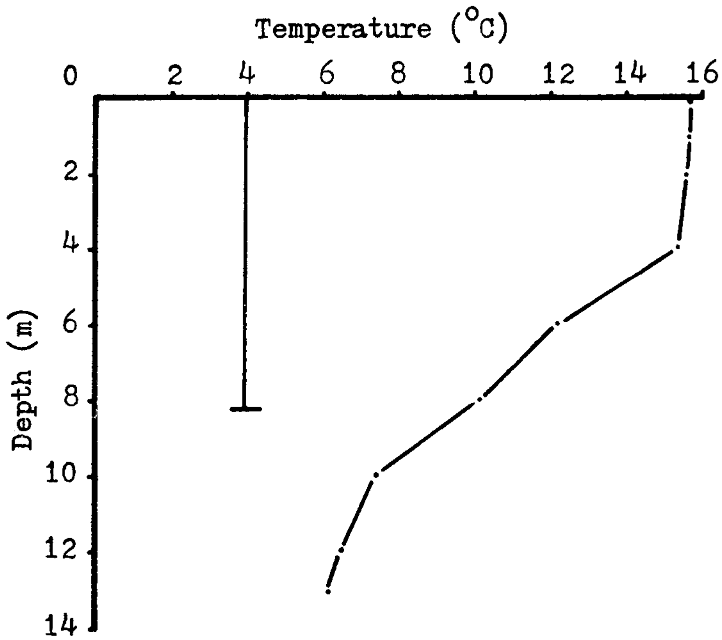


Figure 2.41. Representative mid-summer temperature profile and Secchi depth reading (⊥), Herbert Lake, 29 vii 72.

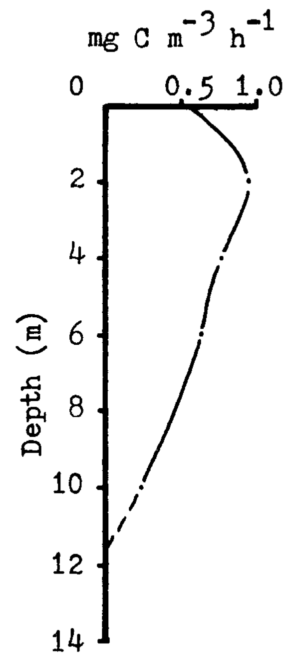


Figure 2.42. Representative mid-summer profile of primary productivity, Herbert Lake, 29 vii 72. Points are net figures (light minus dark). Samples were collected with a van Dorn sampler from discrete depths. Incubation 0805 - 1125 h MST

Figure 2.43. Percent ionic composition of surface water calculated on the basis of equivalent weights, Herbert Lake, 3 viii 66.

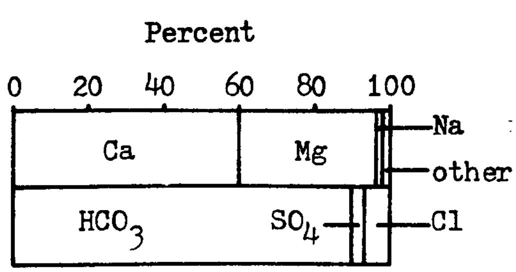
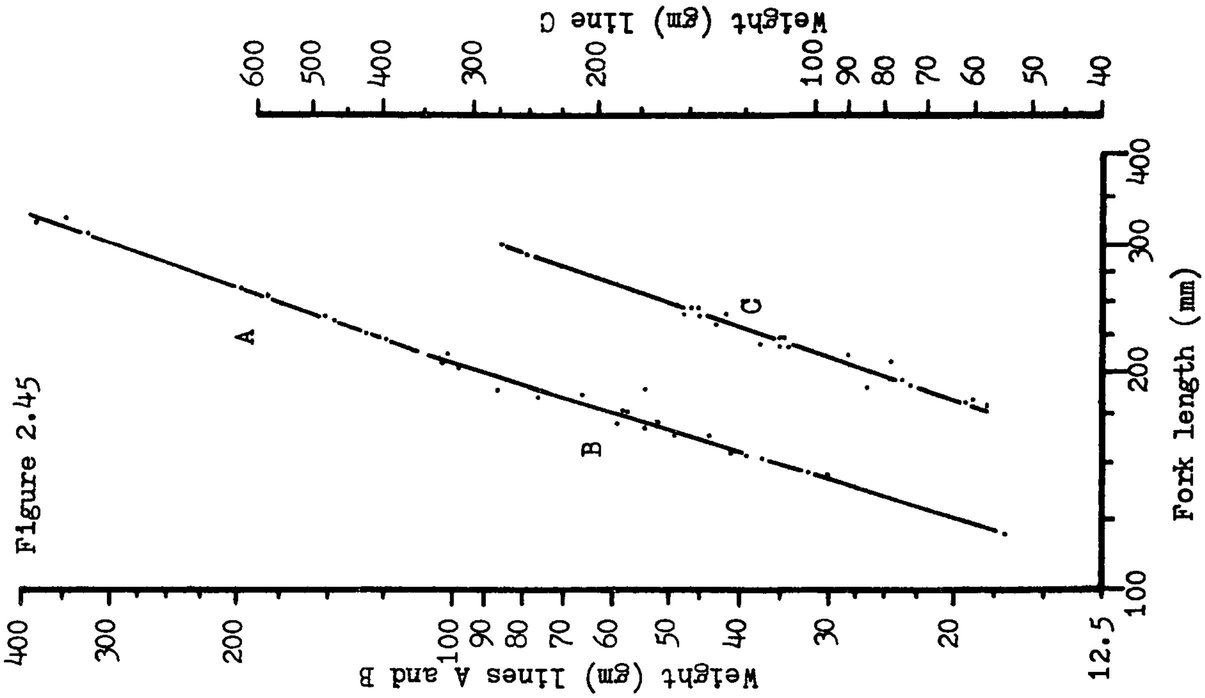
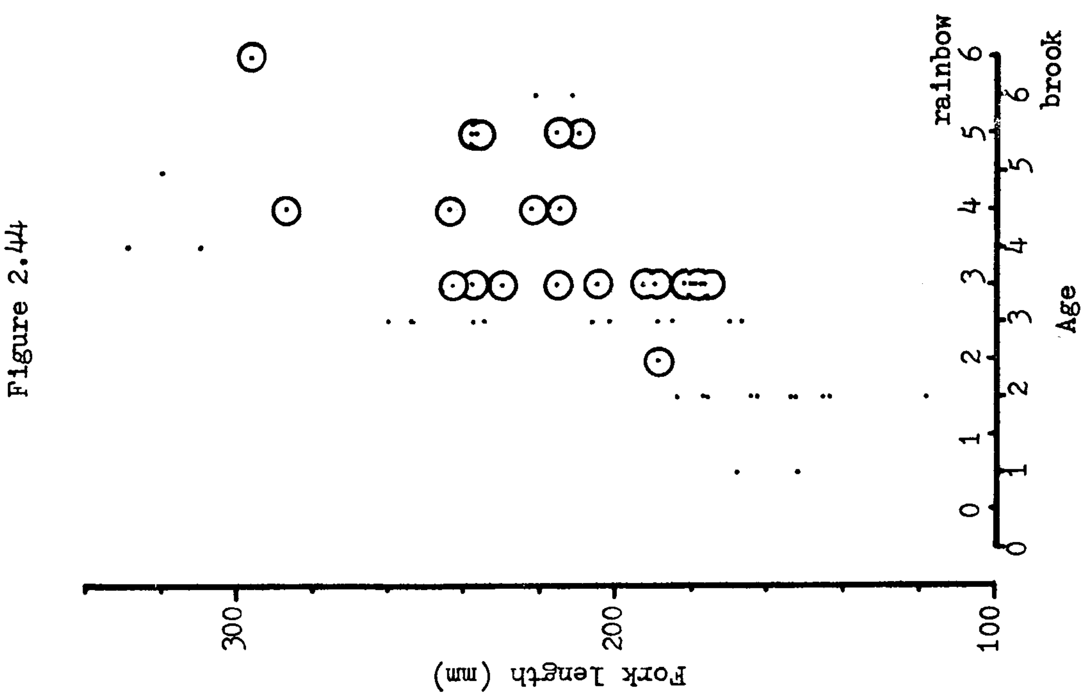


Figure 2.44. Growth diagram of fish from Herbert Lake, June and July 1973. brook trout, simple points; rainbow trout, circled points

Figure 2.45. Length - weight relationship of fish, Herbert Lake, June and July 1973.

Line A: brook trout log W = 2.91 log L - 4.73
Line B: brook trout log W = 3.27 log L - 5.57
Line C: rainbow trout log W = 2.97 log L - 4.91
The lines were drawn by eye.





LITTLE HERBERT LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NH 546001, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Transport corridor

Access: from the Banff-Jasper Parkway which runs along the lakeshore

Elevation: 1570 m

Altitudinal zone: lower subalpine

Basin type: basin of complex origin, partly determined by bedrock structure and drift deposition

Length: 146 m

Mean width: 41 m

Area: 0.6 ha

Maximum depth: 8.2 m

Mean depth: 3.8 m

Volume: 2.2 x $10^4 m^3$

Shoreline length: 346 m

Shoreline development: 1.26

Volume development: 1.34

Mean depth/max. depth: 0.46

Area/mean depth: 0.16

Water level fluctuation: minimal - less than 30 cm drop through the summer

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 2	0.96	43.7
2 - 4	0.66	30.1
4 - 6	0.42	19.1
6 - 8	0.15	7.0
8 - 8.2	0.002	0.1

Water renewal time: 41 days (15 v 74), 134 days (13 vi 74), or approximately once per year

Open-water period: mid May to late October (approximately 160 ice-free days)

Catchment area: Unknown. Includes catchment area of Herbert Lake.

Bedrock composition of catchment area: 100% Miette Group

Catchment area coverage: 100% forest

Human activities in catchment area: includes Herbert Lake catchment area. Banff-Jasper Highway east shore, angling.

Bottom composition: fine black mud having an organic content of 69.4%

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 29 vii 72

Depth:	surface	2 m	4 m
Conductivity (µmho/cm @ 25C):	325	330	335
pH (units):	7.8	7.8	7.6
Total alkalinity as $CaCO_3$:	171	171	178

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 14 ix 67 Depth: 0.5 m

Turbidity: 0.1 JTU Colour: 0 HU

pH: 8.2 units Sum of constituents: 193.6

Conductivity: 369 µmho/cm @ 25C Sum const./cond: 0.52

Total alkalinity as $CaCO_3$: 174

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 188

Major constituents
Calcium: 51.7 Magnesium: 14.3 Sodium: 3.3 Potassium: 0.6
Bicarbonate: 212 Carbonate: 0 Sulphate: 8.3 Chloride: 2.9

Minor constituents
Iron: 0.16 (total), 0.11 (dissolved) Manganese: 0.144 (total), $<$0.005 (dissolved) Copper: 0.013 Zinc: $<$0.005
Fluoride: 0.05 Phosphate: 0.07 (total), 0.01 (dissolved)
Nitrate: 0.1

Silica: 9.0

Ammonia: 0.4

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 29 vii 72 Depth: 0.5 m

Chlorophyta	
Chlamydomonas sp.	40
Kirchneriella lunaris	13
Oocystis parva	38
Sphaerocystis schroeteri	27
Cyanophyta	
Chroococcus spp.	10
Oscillatoria sp.	50
Chrysophyta	
Chrysophyceae	
Bitrichia chodatii	3
Dinobryon divergens	2
D. pediforme	18
Chrysophyceae (continued)	
Kephyrion nr. *planctonicum*	22
Kephyriopsis crassa	45
Pseudokephyrion inflatum	3
Diatomaceae	
Achnanthes lanceolata	2
Navicula spp.	3
Nitzschia palea	2
Pyrrophyta	
Gyrodinium sp.	5
Cryptophyta	
Chroomonas nordstedtii	23
Rhodomonas minuta	142

b. Zooplankton (46 samples, all seasons, 1967 to 1973)

Units are maximum numbers per litre.

Rotifera	
Ascomorpha?	10 - 100
Asplanchna	1 - 10
Asplanchnopus?	1 - 10
Brachionus	0.1 - 1
Conichilus (*unicornis*?)	10 - 100
Filinia longiseta	10 - 100
Kellicottia longispina	10 - 100
Keratella cochlearis	10 - 100
Keratella quadrata	10 - 100
Lecane (*lunaris*?)	0.1 - 1
Monostyla	0.1 - 1
Polyarthra vulgaris	10 - 100
Synchaeta oblonga	10 - 100
Cladocera	
Alona sp.	trace
Bosmina longirostris	17.61
Ceriodaphnia quadrangula	0.087
Cladocera (continued)	
Chydorus sphaericus	0.075
Daphnia rosea	15.37
Eurycercus lamellatus	trace
Polyphemus pediculus	1.86
Copepoda	
Acanthodiaptomus denticornis	19.28
Diaptomus sicilis	0.543
Acanthocyclops vernalis	0.178
Eucyclops speratus	trace
Macrocyclops albidus	0.102
Orthocyclops modestus	45.10
Insecta	
Chaoborus sp.	trace

maximum crustacean standing crop: 110.4 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

No collections were made, but incidental note was taken of some plants during other field work. A submergent Characeae species was found in several Ekman grab samples, and *Potamogeton* (*natans*?) grows near the outlet. Emergent sedges (*Carex*) occur in places along the shoreline.

b. Shoreline fauna (collections: 5 vi 72, 14 viii 72; both 30 min)
Units are numbers collected. (G. L. Scott data)

Crustacea	
Amphipoda	
Hyalella azteca	30
Insecta	
Ephemeroptera	1
Odonata	
Zygoptera	
Coenagrionidae	23
Anisoptera	
Aeshna	2
Leucorrhinia	1
Somatochlora	1
Insecta (continued)	
Hemiptera	
Gerris incognitus	4
Gerris sp.	3
Diptera	
Tipulidae	1
Chironomidae	
Tanypodinae	5
Orthocladiinae or Diamesinae	1
Mollusca	
Gastropoda	
Gyraulus	6
Valvata	11

c. Bottom fauna (collections: 5 vi 72, 14 viii 72; n = 7)
Units are mean numbers/m^2. (G. L. Scott data)

Annelida	
Oligochaeta	1913
Crustacea	
Cladocera	
Eurycercus lamellatus	6

Crustacea (continued)		Insecta (continued)	
Copepoda		Diptera	
Acanthodiaptomus denticornis	6	Tipulidae	6
Amphipoda		Chironomidae	
Hyalella azteca	12	Tanypodinae	360
Ostracoda	6	Orthocladiinae or Diamesinae	6
Insecta		Chironomini	180
Odonata		Tanytarsini	25
Zygoptera		unidentified larvae	6
Coenagrionidae	6	Ceratopogonidae	12
Anisoptera			
Somatochlora	6	Mollusca	
Trichoptera		Pelecypoda	
Oecetis	6	Sphaeriidae	723

Standing crop (mean preserved wet weight/m^2):
all organisms 10.8065 gm (n = 7)

3. Fish (B. D. Smiley data)

Collection dates: 26 vi 73, 30 vii 73 Set duration: unknown

Gear: 7.6 m each of 3/4, 1, 1½, 2, 3, 4-inch mesh green nylon monofilament gillnet, also angling gear

Catch:
1 brook trout (*Salvelinus fontinalis*); female } gillnet
1 rainbow trout (*Salmo gairdneri*); female } gillnet
2 brook trout; 2 females } angling
14 rainbow trout; 9 males, 4 females } angling

a. Brook trout

Specimen 1: fork length 234 mm, 110 gm, age 4, mature female
Specimen 2: fork length 278 mm, no weight, no age, mature female
Specimen 3: fork length 204 mm, 108 gm, no age, female

The stomach of one specimen was examined. Ninety percent (by volume) of the contents were unidentifiable, 5% were chironomid larvae and pupae, and 5% were Planorbidae.

b. Rainbow trout

8 age 2 (scales), 4 age 3 (2 scales, 2 otoliths), 1 age 5 (otoliths)

Age:	2	3	5
Number:	8	4	1
Mean fork l. (mm):	203.2	191.5	267
Length range (mm):	186-233	155-230	

no weights taken, 2 not aged

Food: 3 stomachs examined, none empty

Food item	% of fish with item	mean % total stomach contents by volume
Hyalella azteca	67	36.7
Chironomidae	67	31.7
Planorbidae	67	8.3
Coleoptera (aquatic)	33	6.7
Cladocera	67	5.0
Ceratopogonidae	33	3.3
Copepoda	33	3.3

D. Discussion

The water strider Gerris incognitus recorded from Little Herbert Lake in this survey is not listed for Alberta by Brooks and Kelton (1967), and may be a new record for the province. Its occurrence in the mountains of Alberta is not unexpected: Usinger (1956) gives its range as northern and western North America. Brooks and Kelton may have missed this species because their collecting included few sites in the mountains. This species will key to G. cognatus in their key. Records of G. cognatus from the Alberta mountains may in fact be G. incognitus if Brooks and Kelton's key was used for the identification.

G. incognitus was also found in McNair Pond.

Rainbow trout were first stocked in Little Herbert Lake in 1945, and brook trout were introduced in 1959. Annual plantings of one or both species have been made since the latter date (National Parks stocking records). Natural recruitment is unlikely and at least partial winterkill is probable. The limited age data gathered in this survey indicate there has been some overwinter survival.

Data provided by Damm (1975) suggest that angling success was good in 1975, although the sample size was small. Angling pressure was evidently low. The four fishermen interviewed by Damm had caught 5 fish for an average of 0.65 angler-hours per fish. Damm estimated the total 1975 harvest to be 55 fish.

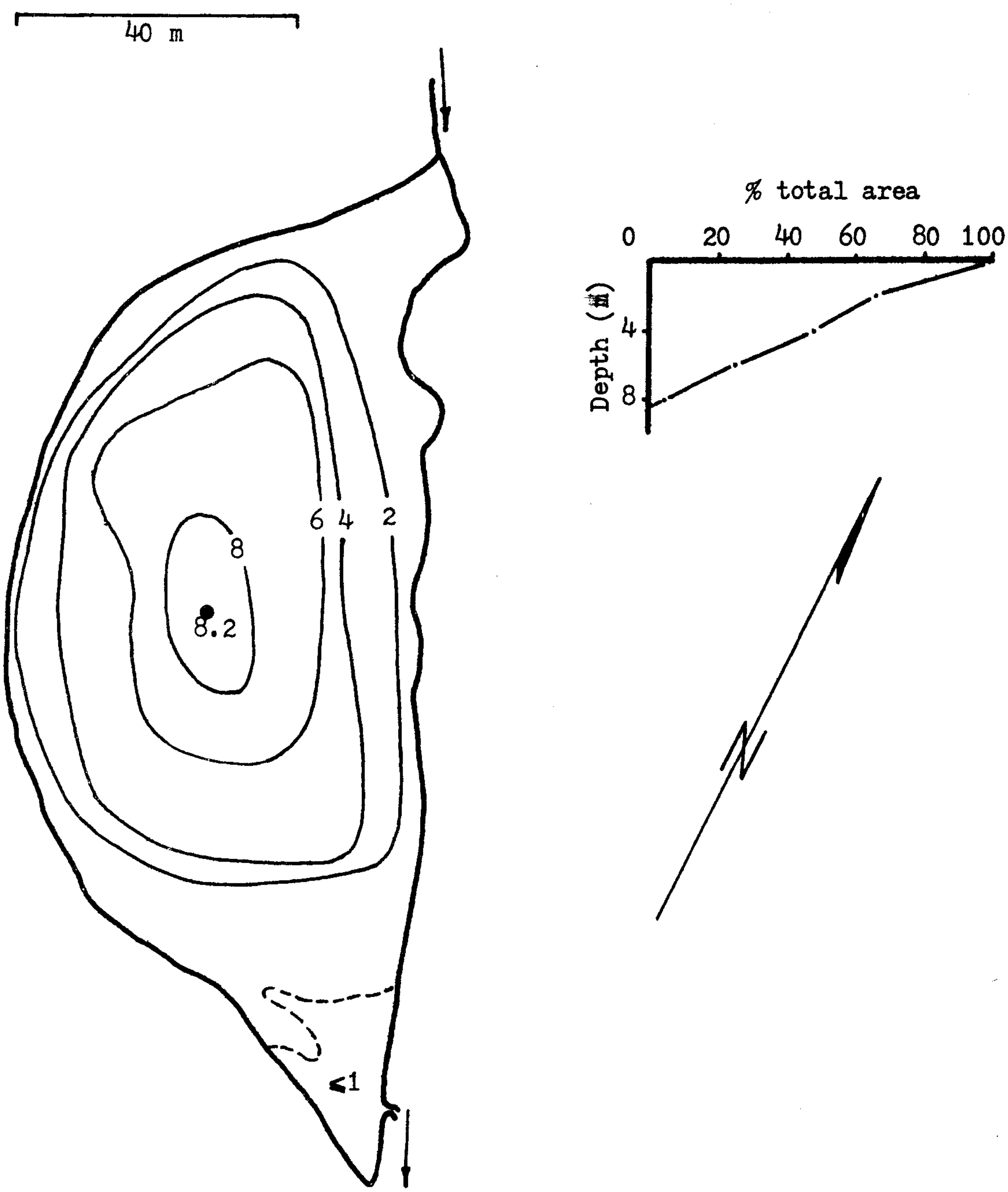


Figure 2.46. Bathymetric map and hypsographic curve of Little Herbert Lake. Depths are in metres.

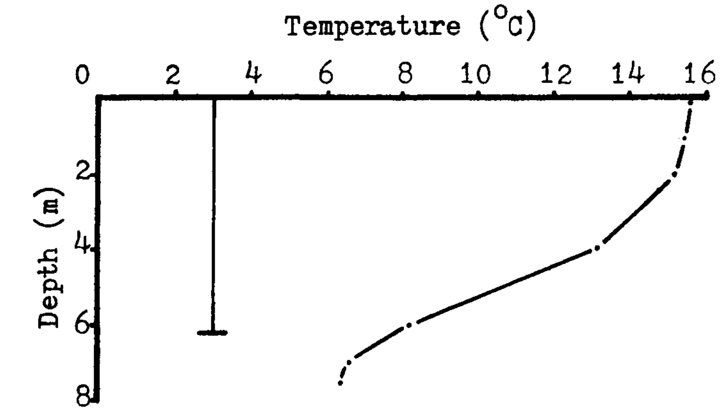


Figure 2.47. Representative temperature profile and Secchi depth reading (⊥), Little Herbert Lake, 29 vii 72.

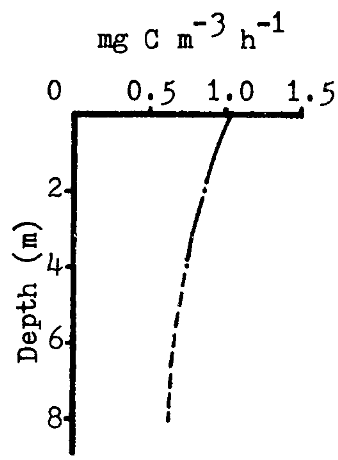
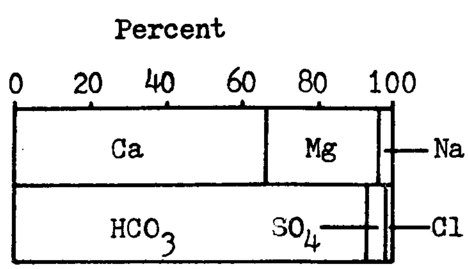


Figure 2.48. Representative mid-summer profile of primary productivity, Little Herbert Lake, 29 vii 72. Points are net figures (light minus dark). Samples were collected with a van Dorn sampler from discrete depths. Incubation 0640 - 1025 h MST

Figure 2.49. Percent ionic composition of surface water calculated on the basis of equivalent weights, Little Herbert Lake, 14 ix 67.



HERBERT POND

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NH 541007, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Transport corridor

Access: by trail from Herbert Lake picnic site 0.1 km (0.06 mi)

Elevation: 1600 m

Altitudinal zone: lower subalpine

Length: 121 m

Mean width: 33 m

Area: 0.4 ha

Maximum depth: 5.0 m

Mean depth: 1.4 m

Volume: $0.6 \times 10^4 m^3$

Shoreline length: 289 m

Shoreline development: 1.29

Volume development: 0.90

Mean depth/max. depth: 0.28

Area/mean depth: 0.29

Water level fluctuation: minimal - less than 30 cm drop through summer

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 2	0.48	80.8
2 - 4	0.11	18.0
4 - 5	0.007	1.2

Water renewal time: unknown - water gain and loss mainly subsurface

Open-water period: mid May to mid October (Anderson 1974b) (approximately 150 ice-free days)

Catchment area: Unknown - fed mainly by groundwater

Bedrock composition of catchment area: 100% Miette Group

Catchment area coverage: 100% forest

(Catchment area - lake area)/lake area: unknown

Human activities in drainage basin: abandoned roadbed east side

Bottom composition: light, flocculent greenish brown mud having an organic content of 46.5%

Secchi depth: very clear to bottom through summer

Surface temperatures: 6 vi 69: 17.5°C; 22 viii 69: 17°C; 2 vi 70: 17°C; 2 viii 72: 17°C; 23 viii 73: 18.2°C; 19 viii 75: 18°C

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 2 vi 70 Depth: surface

Conductivity: 231 µmho/cm @ 25C pH: 8.2 units

Total alkalinity as $CaCO_3$: 115

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 19 viii 75 Depth: surface

Turbidity: 1 JTU Colour: < 5 HU

pH: 8.6 units Sum of constituents: 111.7

Conductivity: 201 µmho/cm @ 25C Sum of const./cond: 0.56

Total alkalinity as $CaCO_3$: 108

Phenolphthalein alkalinity as $CaCO_3$: 0.9

Total hardness as $CaCO_3$: 116

Total inorganic carbon: 22 Total organic carbon: 14

Major constituents
Calcium: 26.2 Magnesium: 12.3 Sodium: 1.2 Potassium: 0.4
Bicarbonate: 129.5 Carbonate: 1.1 Sulphate: 1.5 Chloride: 0.2

Minor constituents
Nitrogen (nitrate + nitrite): < 0.01 Nitrogen (Kjeldahl): 0.6
Phosphorus (total): 0.008

C. Lake Biology

1. Plankton

a. Phytoplankton

no collections

b. Zooplankton (collections: 6 vi 69, 22 viii 69, 2 vi 70, 23 viii 72, 30 vii 74)

Units are maximum numbers per litre.

Rotifera	
Ascomorpha?	0.1 - 1
Asplanchna priodonta	1 - 10
Horaella	< 0.1
Kellicottia longispina	1 - 10
Keratella cochlearis	10 - 100
Keratella quadrata	1 - 10
Polyarthra vulgaris	1 - 10
Cladocera	
Chydorus sphaericus	< 0.1
Daphnia (pulex?)	2.96
Daphnia schoedleri	1
Polyphemus pediculus	1
Copepoda	
Acanthodiaptomus denticornis	2.097
Diacyclops bicuspidatus thomasi	4.933
Harpacticoida	1
Amphipoda	
Gammarus lacustris	1
Insecta	
Chaoboridae	
Chaoborus americanus	1.10
Chironomidae	1
Corixidae	< 0.1
Hydracarina	1

maximum crustacean standing crop: 25.0 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

Emergent sedges (*Carex*) occur in several places near shore, and *Menyanthes trifoliata* grows out from shore into the water. Submerged *Chara* beds also occur. *Potamogeton natans* is scattered throughout the lake, even near the deepest portion.

b. Shoreline fauna (collection: 19 viii 75, approx. 15 min)
Units are numbers collected.

Crustacea	
Cladocera	
Simocephalus vetulus	1
Amphipoda	
Hyalella azteca	9
Insecta	
Ephemeroptera	
Caenis	1
Odonata	
Zygoptera	
Coenagrionidae	3
Ishnura	2
Anisoptera nymphs	1
Insecta (continued)	
Hemiptera	
Gerris nymphs	1
Diptera	
Dixidae	
Dixa	1
Mollusca	
Pelecypoda	
Sphaeriidae	3

c. Bottom fauna (collection: 19 viii 75, n = 2)
Units are mean numbers/m^2.

Annelida	
Oligochaeta	22
Crustacea	
Amphipoda	
Gammarus lacustris	409
Hyalella azteca	947
Insecta	
Diptera	
Chironomidae	
Procladius s. str.	86
Pagastiella	65
Tanytarsus	237
" pupae	22

Standing crop (mean preserved wet weight/m^2):

Amphipoda	7.440 gm
Oligochaeta	0.422 gm
Chironomidae	0.235 gm

3. Fish

no collections

D. Discussion

Although there is no record of it, fish have been stocked in Herbert Pond in the past (W. McPhee, pers. comm.). We have seen no fish in any visits to this pond. Natural recruitment is unlikely, and winterkill is probable.

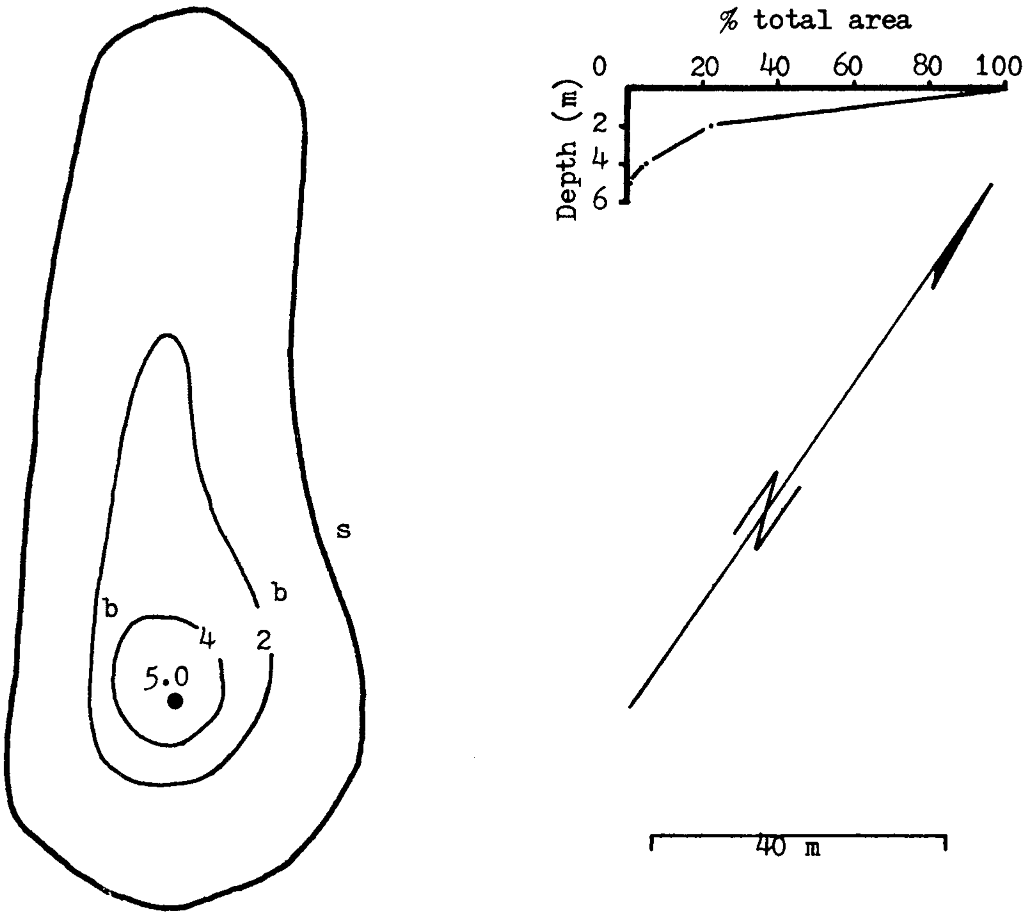
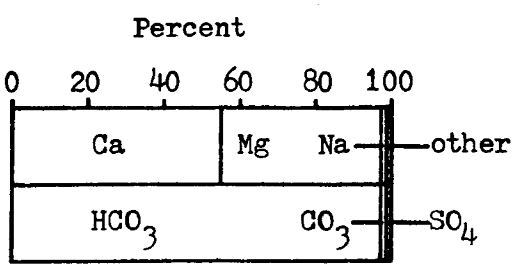


Figure 2.50. Bathymetric map and hypsographic curve of Herbert Pond. Depths are in metres.
b - bottom fauna collection s - shoreline collection

Figure 2.51. Percent ionic composition of surface water calculated on the basis of equivalent weights, Herbert Pond, 19 viii 75.



HIDDEN LAKE

A. General Attributes, Morphometry, and Drainage Basin Features

Location: Grid reference 11U/NH 620039, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: restricted road to Temple Lodge, then by trail 4.5 km (2.8 mi)

Elevation: 2271 m

Altitudinal zone: alpine

Basin type: cirque, dammed by drift

Length: 454 m

Mean width: 293 m

Area: 13.3 ha

Maximum depth: 32.3 m

Mean depth: 14.6 m

Volume: 194.7 x $10^4 m^3$

Shoreline length: 1398 m

Shoreline development: 1.08

Volume development: 1.36

Mean depth/max. depth: 0.45

Area/mean depth: 0.91

Water level fluctuation: very little

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 3	36.97	19.0
3 - 6	31.81	16.3
6 - 9	27.50	14.1
9 - 12	23.60	12.1
12 - 15	20.35	10.4
15 - 18	17.62	9.0
18 - 21	14.93	7.5
21 - 24	11.20	5.7
24 - 27	6.97	3.6
27 - 30	3.33	1.7
30 - 32.3	0.46	0.6

Water renewal time: 58.5 days (2 viii 74), or approximately 2 times per year

Open-water period: early July to early November (approximately 120 ice-free days)

Catchment area: 234 ha

Bedrock composition of catchment area: 58% quartzite, 42% Cambrian carbonate rocks

Catchment area coverage: 100% exposed rock and low plants

(Catchment area - lake area)/ lake area: 17

Human activities in catchment area: hiking, angling, unauthorized camping

Bottom composition: organic content of sediments 7.8%

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

pH: 8.0 units (n = 5) Total alkalinity as $CaCO_3$: 72.6 (n = 5)

Phenolphthalein alkalinity as $CaCO_3$: 0 (n = 5)

Total hardness as $CaCO_3$: 85.5 (n = 4) Total acidity: 4.56 (n = 5)

Variation with depth (2 viii 74):

	0 - 10 m composite	29 m
Conductivity (µmho/cm @ 25C):	159.5	203.5
pH (units):	7.8	7.4
Total alkalinity:	75.1	88.8

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 23 vii 66 | Depth: 0.5 m

Turbidity: 0.0 JTU | Colour: 3 HU

pH: 8.0 units | Sum of constituents: 74.4

Conductivity: 139 µmho/cm @ 25C | Sum const./cond: 0.54

Major constituents
Calcium: 19.3 Magnesium: 6.0 Sodium: 0.3 Potassium: 0.3
Bicarbonate: 83.7 Carbonate: 0 Sulphate: 5.4 Chloride: 0.2

Minor constituents
Iron: < 0.01 (both total and dissolved) Aluminum: 0.00
Manganese: < 0.05 (total), 0.000 (dissolved) Copper: 0.000
Zinc: < 0.005
Fluoride: 0.03 Phosphate: 0.10 (total) Nitrate: 0.2

Silica: 1.3

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 2 viii 74 | Depth: 0 - 10 m (29 m)

Chlorophyta
- *Ankistrodesmus falcatus* var. *acicularis* (16)
- *Chlamydomonas* spp. 3 (3)
- *Dictyosphaerium ehrenbergianum* 87 (167)

Pyrrophyta
- *Gymnodinium* sp. 3 (3)

Chrysophyta
Chrysophyceae
- *Bitrichia chodatii* 5 (6)
- *Chromulina* sp. 5

Chrysophyceae (continued)

Chrysochromulina parva	(15)
Chrysococcus sp.	2
Chrysoikos skujae	3 (56)
Chrysolykos planktonicus	3
Dinobryon cylindricum	9 (161)
Kephyrion sp.	3
Pseudokephyrion nr. *hyalinum*	27 (3)

Chrysophyta (continued)

Diatomaceae

Amphora ovalis	(3)
Achnanthes sp.	2
Cyclotella sp.	132 (245)
Synedra radians	104 (81)
Synedra sp.	2 (43)

Cryptophyta

Rhodomonas minuta	20 (31)

b. Zooplankton (collections: 23 vii 66, 20 viii 66, 14 ix 66, 2 viii 74)
Units are maximum numbers per litre.

Rotifera

Filinia longiseta	0.1 - 1
Kellicottia longispina	10 - 100
Keratella cochlearis	<0.1
Keratella quadrata	1 - 10
Lepadella ovalis	<0.1
Polyarthra	<0.1

Cladocera

Alona rectangula	<0.1

Copepoda

Diaptomus tyrrelli	21.9
Acanthocyclops vernalis	0.911

maximum crustacean standing crop: 21.9 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

no macrophytes seen

b. Shoreline fauna (collection: 2 viii 74)
Units are numbers collected.

Annelida	
Oligochaeta	64
Crustacea	
Amphipoda	
Gammarus lacustris	1
Insecta	
Coleoptera	
Hydroporus compertus adults	1
Hydroporus or *Hygrotus* larvae	6
Diptera	
Tipulidae	
Dicranota	2
Limnophila	1
Diptera (continued)	
Chironomidae	
Corynoneura	2
Paracladopelma	1
Orthocladiinae	2
unidentified	2
Arachnida	
Hydracarina	
Hygrobates	1
Lebertia	2
Mollusca	
Pelecypoda	
Sphaeriidae	1

c. Bottom fauna (collection: 2 viii 74, n = 4)
Units are mean numbers/m^2.

Platyhelminthes	
Turbellaria	22
Annelida	
Oligochaeta	118
Crustacea	
Ostracoda (mostly empty shells)	
Crustacea (continued)	
Amphipoda	
Gammarus lacustris	11
Insecta	
Trichoptera	
Limnephilidae	11

Insecta (continued)		Chironomidae (continued)	
Diptera		<u>Chironomus</u>	1335
Chironomidae		" pupae	54
<u>Procladius</u> s. str.	11	<u>Paracladopelma</u>	11
<u>Protanypus</u>	108	<u>Stictochironomus</u>	517
<u>Parakiefferiella</u>?	151	" pupae	22
Orthocladiinae pupae	11	<u>Micropsectra</u>	484
<u>Cricotopus</u>	65	Mollusca	
<u>Paracladius</u>	431	Pelecypoda	
		<u>Pisidium</u>	2465

Standing crop (mean preserved wet weight/m^2):

Chironomidae mainly	10.541 gm	<u>Gammarus</u>	0.090 gm
Sphaeriidae mainly	6.138 gm	Trichoptera	0.488 gm
Oligochaeta	0.279 gm		

3. Fish (B. D. Smiley data)

Collection date: 23 viii 73 Set duration: overnight

Gear: 7.6 m of 3/4, 1, 1½, 2, 3, 4-inch mesh green nylon monofilament gillnet; 3 gangs set

Catch: 95 brook trout (<u>Salvelinus fontinalis</u>); 60 males, 35 females
1 cutthroat trout (<u>Salmo clarki</u>); female

a. Brook trout

Age:	2	3	4	5	6	7	9
Number:	1	47	27	16	2	2	1
Mean fork l. (mm):	92	167.3	203.0	227.7	282.0	299.5	304
Mean weight (gm):	9	52.8	105.8	123.8	356.0	247.0	269

Maturity:
males - 33.3% mature @ age 3, 84.6% mature @ age 4, 90.0% mature @ age 5
females - 27.3% mature @ age 3, 90.0% mature @ age 4, 100% mature @ age 5
The stage of gonad development could not be assessed accurately enough to determine if individual fish spawn every year.

Food: 42 stomachs examined, none empty

Food item	% of fish with item	no. times item rated as R	C	A
Hydracarina	85.7	2	10	24
Chironomidae	61.9	5	10	11
Diptera (unident. imm.)	59.5	3	16	6
Diptera (unident. ad.)	38.1	8	8	
Hymenoptera	31.0	3	10	
plant material	40.5	15	2	
Trichoptera larvae	28.6	10	1	1
Sphaeriidae	21.4	4	5	
Coleoptera (terrest.)	21.4	8	1	
Hemiptera	11.9	3	2	
Amphipoda	4.8	1	1	
Homoptera	4.8	2		
Orthoptera	2.4	1		

b. Cutthroat trout

one specimen captured: fork length 175 mm, 50 gm, female, age 4, immature, stomach contents mostly Hydracarina

D. Discussion

As Smiley (1976) noted, there is no record of brook trout being stocked in Hidden Lake yet his gillnet catches yielded the species almost exclusively, and indicated a relatively dense population. Although these fish were of several age classes, it is unclear whether they were the result of natural recruitment because the stocking records are incomplete. The many small inlet streams might provide suitable (though limited) spawning sites at their mouths, as might a very short section of the outlet stream.

The re-analysis of Smiley's data in this survey revealed some errors in his report. Although Smiley stated that both sexes of brook trout mature at age 3, in fact only about one-third of them do. His raw data showed that the majority were not mature until age 4. Also, substitution into Smiley's length - weight equation reveals that it is incorrect. The portion of his discussion on the condition of the fish, which is based on the "condition index" (slope constant) of his equation is therefore invalid.

Rawson (1939) visited Hidden Lake (which he called Lost Lake), but provided little information on it. In contrast to our shoreline collection, he found mainly mayfly nymphs and caddisfly larvae along the shore. The cutthroats he caught by angling had eaten mayfly nymphs and aquatic beetles.

Present policy dictates no further stocking.

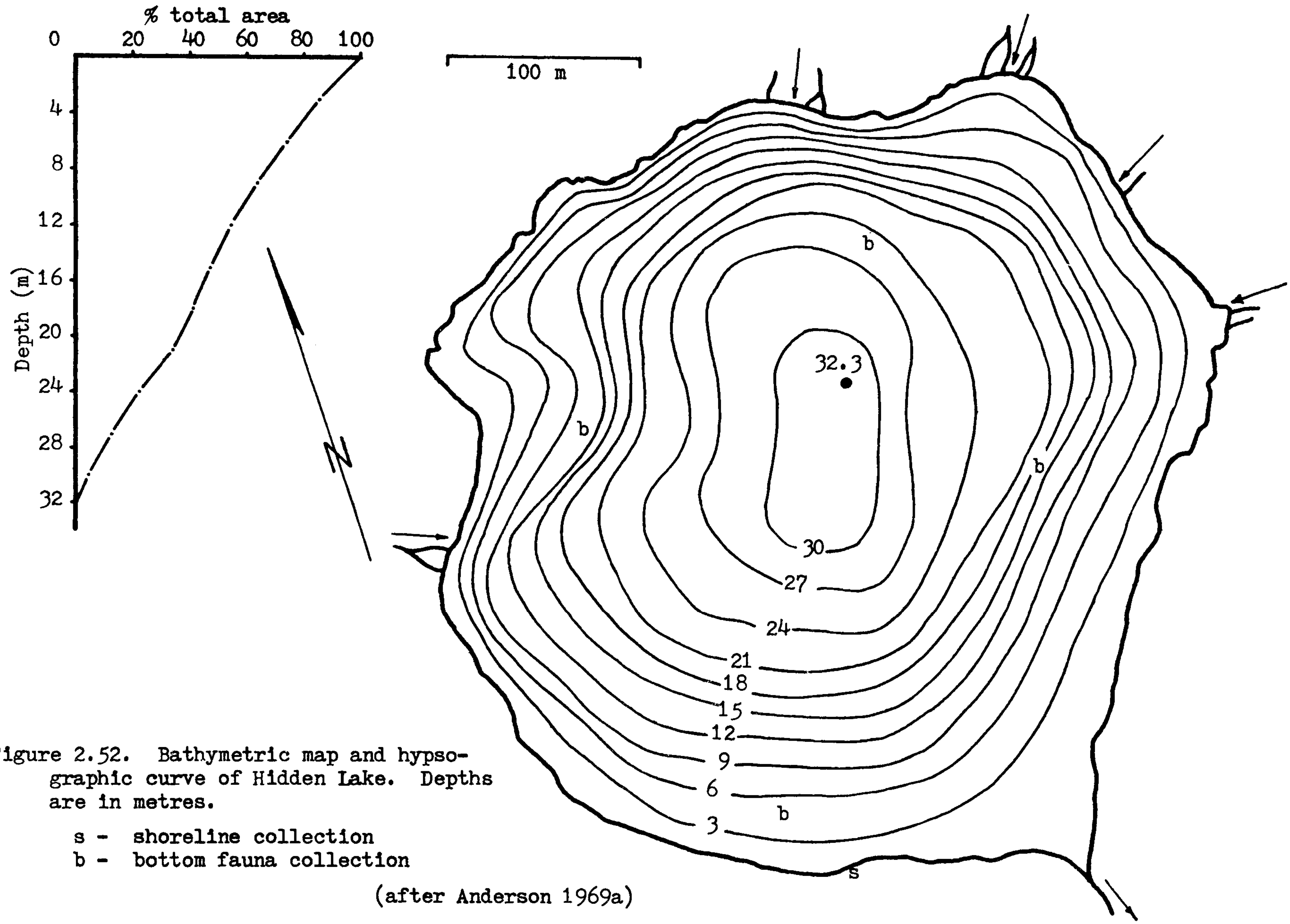
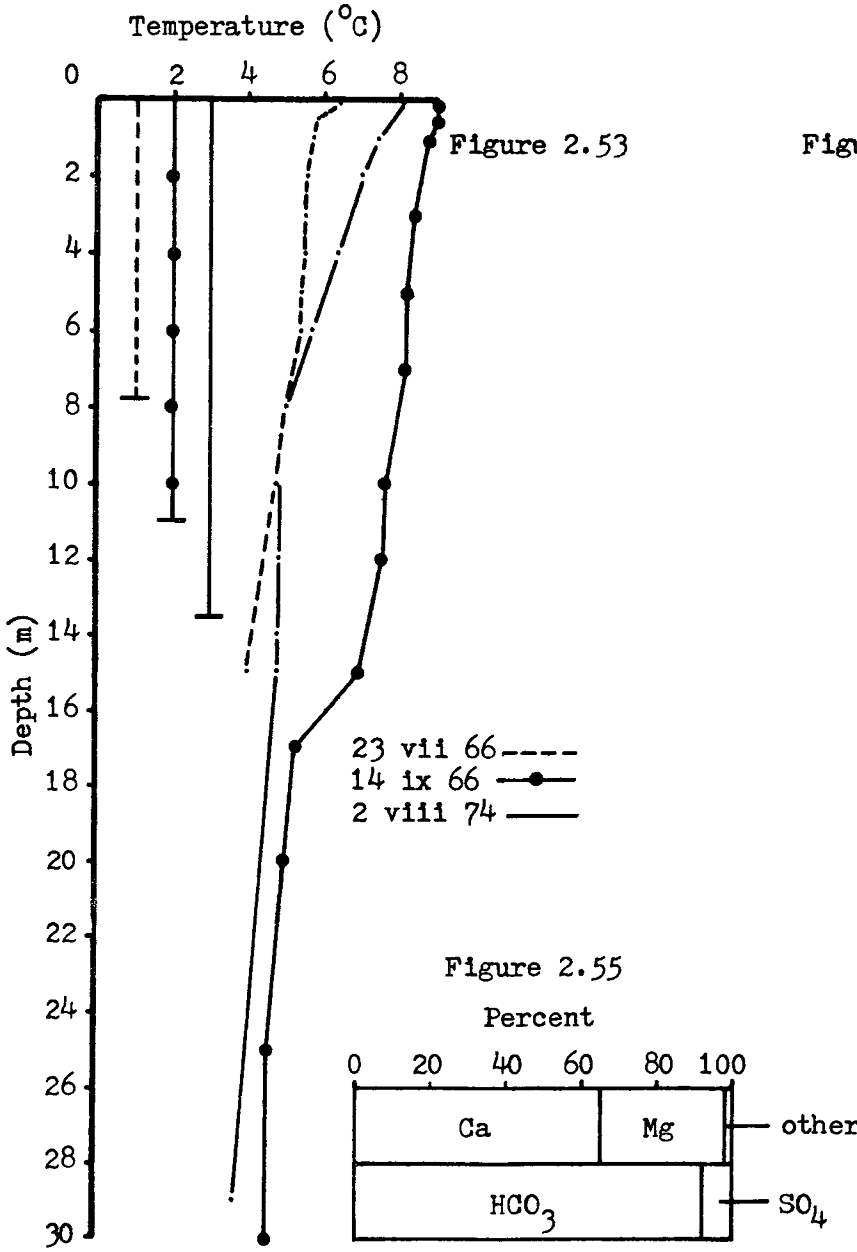


Figure 2.52. Bathymetric map and hypsographic curve of Hidden Lake. Depths are in metres.

s - shoreline collection
b - bottom fauna collection

(after Anderson 1969a)



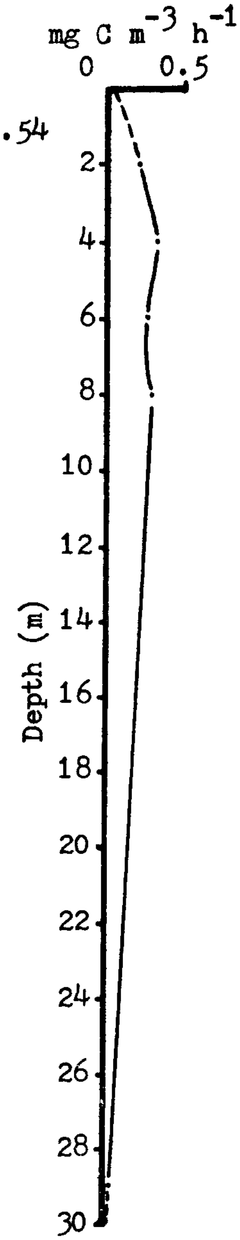


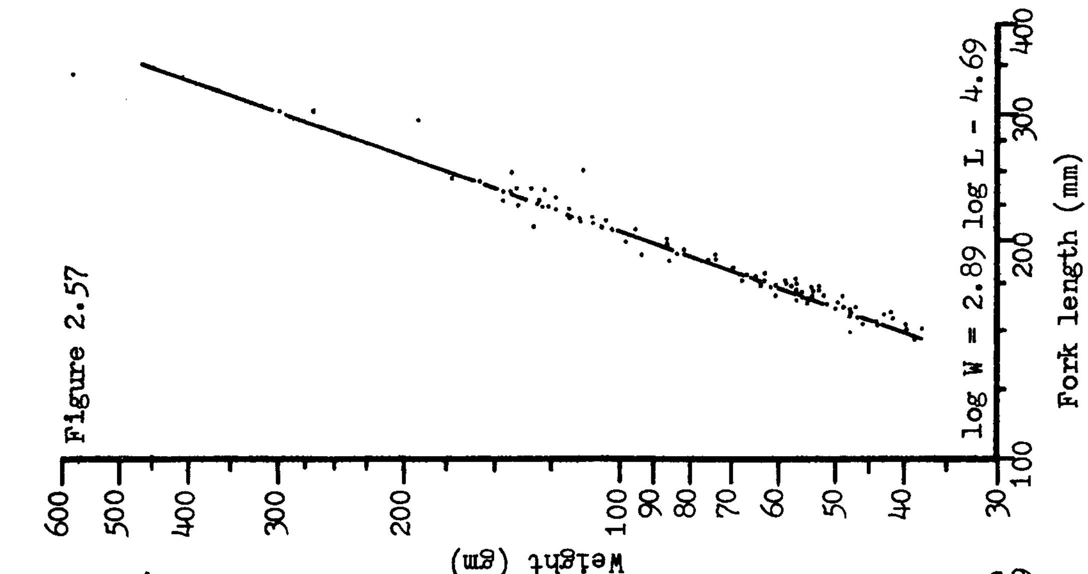
Figure 2.53. Temperature profiles and Secchi depth readings (⊥), Hidden Lake.

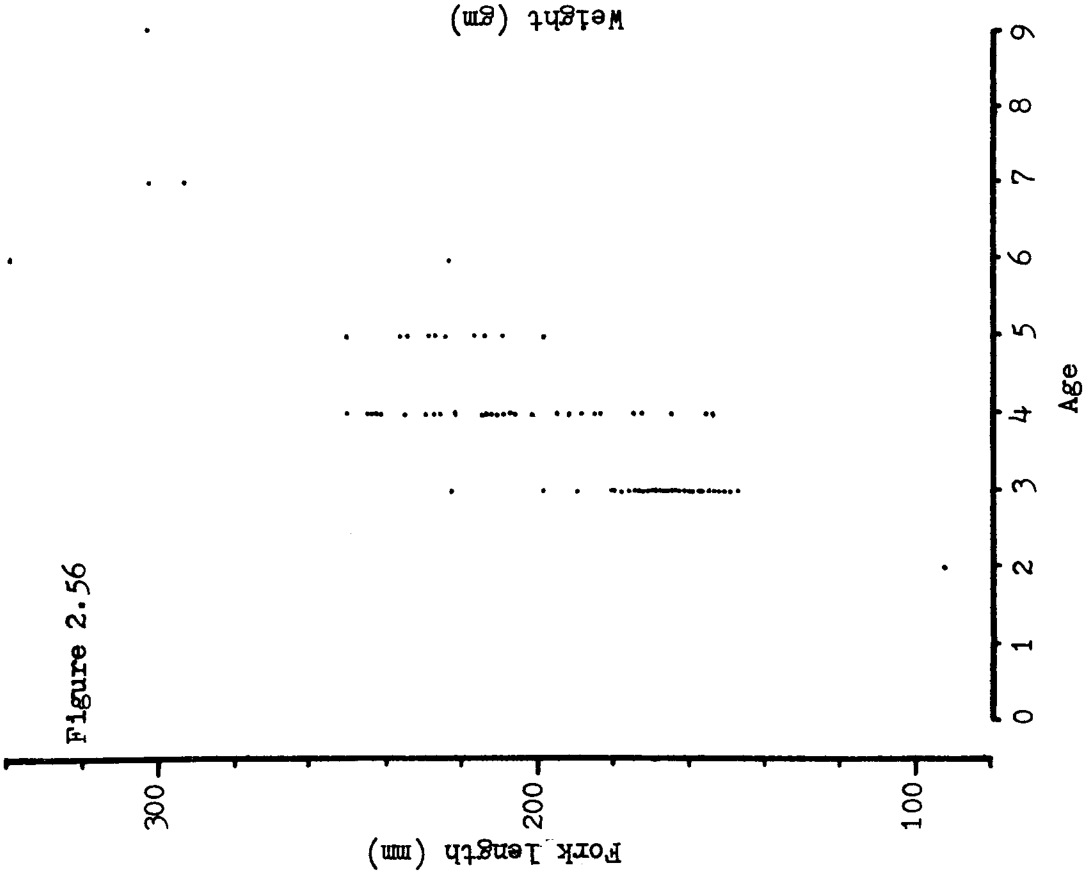
Figure 2.54. Profile of primary productivity, Hidden Lake, 2 viii 74. Points are net figures (light minus dark). Samples from 10 m to the surface were collected with a hose, and the 29 m sample was collected with a van Dorn sampler. Incubations 0840 - 1145 h MST

Figure 2.55. Percent ionic composition of surface water calculated on the basis of equivalent weights, Hidden Lake, 23 vii 66.

Figure 2.56. Growth diagram of brook trout, Hidden Lake, 23 viii 73.

Figure 2.57. Length - weight relationship of brook trout, Hidden Lake, 23 viii 73. The line was drawn by eye.





ISLAND LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 618935, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class III (Natural Environment Area)

Access: by game trail following outlet from 1-A Highway, approximately 1 km (0.6 mi)

Elevation: 1570 m

Altitudinal zone: lower subalpine

Basin type: depression in fluted ground moraine

Length: 775 m

Mean width: 192 m

Area: 14.9 ha

Maximum depth: 6.4 m

Mean depth: 0.5 m

Volume: $7.0 \times 10^4 m^3$

Shoreline length: 2147 m

Shoreline development: 1.57

Volume development: 0.22

Mean depth/max. depth: 0.08

Area/mean depth: 29.8

Water level fluctuation: minimal - less than 30 cm drop through summer (1975)

Stratum (m)	Volume ($10^4 m^3$)	% total volume
0 - 2	3.46	49.7
2 - 4	2.53	36.3
4 - 6	0.93	13.4
6 - 6.4	0.04	0.6

Water renewal time: Unknown --surface outflow only in spring, water gain and loss must be mainly subsurface

Open-water period: probably early May to mid October (approximately 150 ice-free days; no direct observation of dates)

Catchment area: unknown

Bedrock composition of catchment area: 100% Miette Group

Catchment area coverage: 100% forest

Human activities in catchment area: hiking, swimming (probably both rare)

Bottom composition: light-coloured, flocculent sediments cover the bottom of all but the deepest portion of the lake, and have an organic content of 49.9%.

Secchi depth: >6 m (29 viii 69)

Colour ($\frac{1}{2}$ Secchi): green (19 viii 75)

Surface temperature: 6 vi 69: 19°C
29 viii 69: 13.6°C

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

Conductivity: 193 µmho/cm @ 25C pH: 8.55 units (n = 2)

Total alkalinity as $CaCO_3$: 116 (n = 2)

Phenolphthalein alkalinity as $CaCO_3$: 0 (n = 2)

Total hardness as $CaCO_3$: 128.5 (n = 2)

Composite sample 0 - 3 m (24 v 75):
Conductivity: 209 µmho/cm @ 25C pH: 8.8 units
Total alkalinity as $CaCO_3$: 102.4

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 19 viii 75	Depth: surface
Turbidity: 2.0 JTU	Colour: < 5 HU
pH: 8.5 units	Sum of constituents: 120.4
Conductivity: 218 µmho/cm @ 25C	Sum const./cond: 0.55
Total alkalinity as $CaCO_3$: 113	
Phenolphthalein alkalinity as $CaCO_3$: 0.5	
Total hardness as $CaCO_3$: 123	
Total inorganic carbon: 23	Total organic carbon: 20

Major constituents
Calcium: 27.5 Magnesium: 13.2 Sodium: 2.4 Potassium: 0.8
Bicarbonate: 136.5 Carbonate: 0.6 Sulphate: 3.1 Chloride: 0.4

Minor constituents
Nitrogen (nitrate + nitrite): 0.01 Nitrogen (Kjeldahl): 1.0
Phosphorus (total): 0.035

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 24 v 75 Depth: 0 - 3 m composite

Chlorophyta		Chrysophyta	
Chlamydomonas sp.	152	Chrysophyceae	
Oocystis parva	14	*Chromulina* sp.	21
Scenedesmus denticulatus	14	*Chrysochromulina parva*	1090
Cyanophyta		*Chrysoikos skujae*	21
Oscillatoria tenuis	55	*Chrysolykos planktonicus*	21
Oscillatoria sp.	69	*Dinobryon attenuatum*	14
		D. crenulatum	62
Pyrrophyta		*D. sertularia*	248
Glenodinium sp.	28	*D. sociale*	69

Chrysophyceae (continued)		Diatomaceae (continued)	
Kephyrion sp.	359	Cymbella sp.	7
Mallomonas nr. acaroides	7	Nitzschia acicularis	7
Ochromonas sp.	40	N. sigma	14
Pseudokephyrion inflatum	262	Synedra sp.	35
Spiniferomonas sp.	28	Cryptophyta	
Diatomaceae		Cryptomonas ovata	14
Achnanthes minutissima	76	Rhodomonas minuta	48
Achnanthes sp.	207		
Cymbella microcephala	7		

b. Zooplankton[1] (collections: 6 vi 69, 29 viii 69, 24 v 75)
Units are maximum numbers per litre.

Rotifera		Copepoda	
Ascomorpha	0.1 - 1	Acanthodiaptomus denticornis	1 - 10
Asplanchna priodonta	1 - 10	Diacyclops bicuspidatus thomasi	0.1 - 1
Kellicottia longispina	1 - 10	Microcyclops varicans rubellus	0.04
Keratella cochlearis	1 - 10	Amphipoda	
Keratella quadrata	10 - 100	Gammarus lacustris	0.1 - 1
Monostyla	0.1	Insecta	
Polyarthra vulgaris	100 - 1000	Chaoborus americanus	1 - 10
Cladocera		Chironomidae	0.09
Chydorus sphaericus	< 0.1		
Daphnia pulex	1 - 10		
Polyphemus pediculus	< 0.1		

2. Bottom and Shoreline Organisms

a. Macrophytes

Emergent sedges (Carex spp.) occur near shore, sometimes in extensive beds. Sparganium sp. also grows near shore, just beyond the Carex beds in slightly deeper water. Two pondweeds, Potamogeton sp. (pectinatus or filiformis) and P. richardsonii grow at various places in the lake, but never in extensive beds. A large clump of Myriophyllum occurs near the north-central portion of the lake, and is clearly visible in aerial photographs. Chara is widespread throughout the lake, sometimes occurring in dense clumps. Total coverage of the lake bottom by macrophytes is approximately 10%.

b. Shoreline fauna (collection: 6 vi 75, approx. 40 min.)
Units are numbers collected.

Annelida		Insecta	
Oligochaeta	2	Ephemeroptera	
Hirudinoidea		Caenis	4
Helobdella stagnalis	1	Odonata	
Crustacea		Zygoptera	
Cladocera		unidentified nymphs	1
Simocephalus vetulus	2	Coenagrionidae	6
Amphipoda		Enallagma (cyathigerum?)	3
Hyalella azteca	43	Enallagma sp.	2

1. maximum crustacean standing crop: 13.2 animals/l

Odonata (continued)		Diptera (continued)	
Anisoptera		Chironomidae	
Aeshna	2	_Procladius_	1
Somatochlora albicincta	2	Orthocladiinae	2
Plecoptera		_Endochironomus_	1
Nemoura haysi adult	1	_Paratanytarsus_?	1
Hemiptera		Ceratopogonidae	
Arctocorisa	3	_Palpomyia_ pupae	1
Trichoptera		Arachnida	
Limnephilidae (2 spp.)	10	Hydracarina	
Coleoptera		_Eylais_	11
Haliplus sp.	1		
Diptera			
Chaoboridae			
Chaoborus americanus pupae	49		

c. Bottom fauna[1] (collection: 6 vi 75, n = 3)

Crustacea		Chironomidae (continued)	
Amphipoda		_Chironomus_	409
Hyalella azteca	22	_Cryptochironomus_	22
Insecta		Ceratopogonidae	
Diptera		_Palpomyia_, _Bezzia_ or _Johannsenomyia_	43
Chironomidae			
Procladius s. str.	86		

3. Fish

Collection date: 6 - 7 vi 75 Set duration: 22 h

Gear: 20 m each of 3/4, 1½, 2, 3, 4-inch mesh green multifilament nylon gillnet set on bottom.

Catch: nil

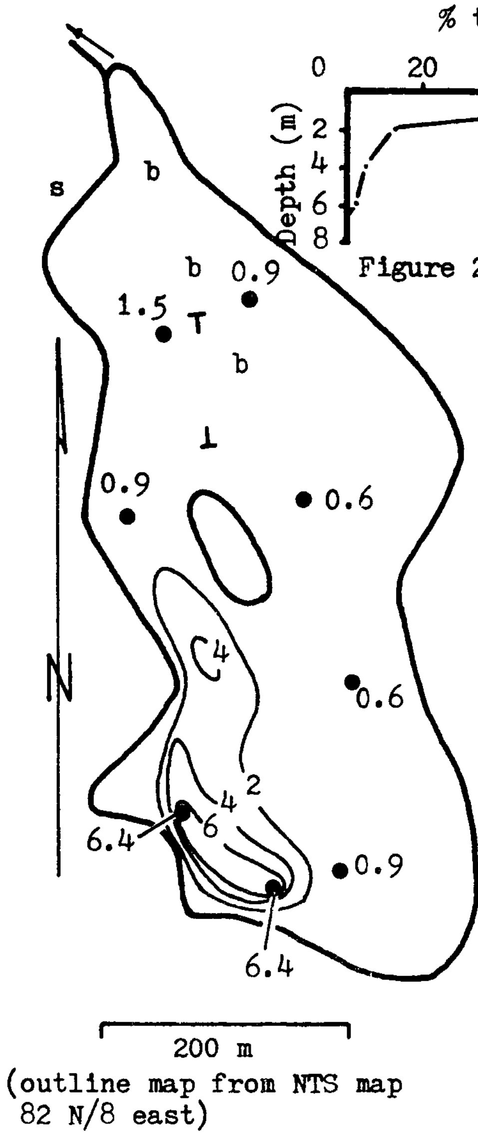
D. Discussion

Anderson and Raasveldt (1974) found _Gammarus lacustris_ in Island Lake, but it did not occur in the few 1975 samples.

The record of the stonefly _Nemoura haysi_ is surprising. Island Lake is rather atypical habitat for Plecoptera. It is possible that the specimen, an adult, flew to the lake from elsewhere.

Island Lake has been stocked several times with trout - the last time with brook trout in 1960 (National Parks stocking records). At least partial winterkill is likely, and natural recruitment would be limited at best. We saw no evidence of fish in several visits to the lake, but a note in the stocking records mentions that some small fish have been seen. The present policy is not to stock Island Lake.

1. Standing crop (mean preserved wet weight/m^2):
Hyalella azteca 0.158 gm Chironomidae 1.177 gm
Ceratopogonidae 0.029 gm



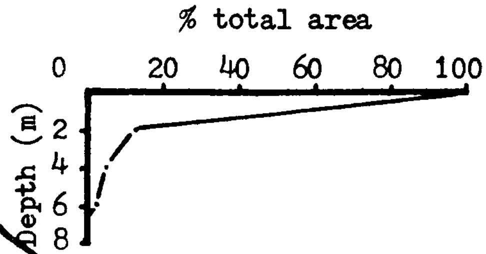


Figure 2.58

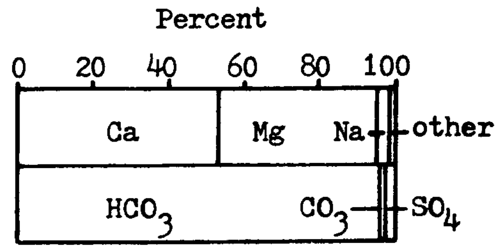


Figure 2.59

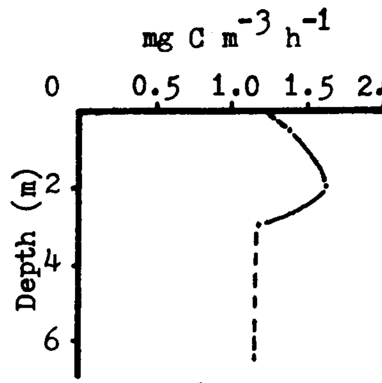


Figure 2.60

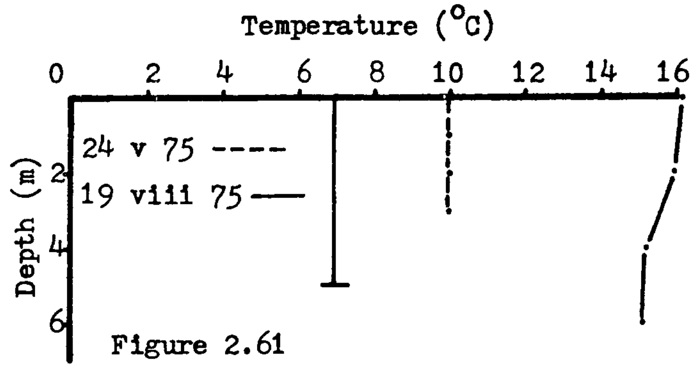


Figure 2.61

Figure 2.58. Bathymetric map and hypsographic curve of Island Lake.
Depths in metres.
b - bottom fauna collection
s - shoreline collection
⊢ ⊣ - gillnet set between points

Figure 2.59. Percent ionic composition of surface water calculated on the basis of equivalent weights, Island Lake, 19 viii 75.

Figure 2.60. Profile of primary productivity, Island Lake, 24 v 75. Points are net figures (light minus dark). Samples were collected with a hose. Incubations 0925 - 1235 h MST

Figure 2.61. Temperature profile and Secchi depth reading (⊥), Island Lake.

KINGFISHER LAKE*

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 583956, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class IV (General Outdoor Recreation)

Access: by trail from Trans-Canada Highway approximately 0.2 km (0.1 mi)

Elevation: 1539 m

Altitudinal zone: lower subalpine

Basin type: drift basin, type unknown

Length: 242 m

Mean width: 83 m

Area: 2.0 ha

Maximum depth: 7.2 m

Mean depth: 2.0 m

Volume: $4.0 \times 10^4 m^3$

Shoreline length: 577 m

Shoreline development: 1.15

Volume development: 0.83

Mean depth/max. depth: 0.28

Area/mean depth: 1.00

Water level fluctuation: level drops approximately 30 cm through summer

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 1	1.54	38.1
1 - 2	1.00	24.6
2 - 3	0.71	17.5
3 - 4	0.46	11.4
4 - 5	0.25	6.1
5 - 6	0.08	2.0
6 - 7.2	0.01	0.3

Water renewal time: unknown - very slight overflow in spring. Water gain and loss must be mainly subsurface.

Open-water period: mid May to late October (approximately 160 ice-free days)

Catchment area: unknown

Bedrock composition of catchment area: 100% Miette Group

Approximate coverage of catchment area: 100% forest

(Catchment area - lake area)/lake area:

Human activities in catchment area: angling, sometimes from canoes

* formerly Betty Lake

Bottom composition: The shallow 70% of the bottom (approximately 0-3 m) is covered by light-coloured flocculent sediments. The 30% of the bottom deeper than 3 m is covered by dark brown, flocculent or jelly-like mud having an organic content of 78.1%.

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 25 vi 70 — Depth: surface

Conductivity: 215 µmho/cm @ 25C — pH: 8.35 units

Total alkalinity as $CaCO_3$: 124

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 8 vii 75 — Depth: surface

Turbidity: 1.3 JTU — Colour: < 5 HU

pH: 8.4 units — Sum of constituents: 113.4

Conductivity: 221 µmho/cm @ 25C — Sum const./cond: 0.51

Total alkalinity as $CaCO_3$: 115

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 121

Major constituents
Calcium: 27.0 Magnesium: 13.0 Sodium: 1.1 Potassium: 0.6
Bicarbonate: 140.2 Carbonate: 0 Sulphate: 2.2 Chloride: 0.4

Minor constituents
Nitrogen (nitrate + nitrite): < 0.01 Nitrogen (Kjeldahl): 0.7
Phosphorus (total): 0.005

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 16 vii 73 — Depth: 0.5 m

Chlorophyta	
Ankistrodesmus sp.	32
Chlamydomonas sp.	6
Cosmarium sp.	3
Elaktothrix gelatinosa	12
Oocystis parva	15
Oocystis spp.	15
Scenedesmus sp.	6
Tetraëdron minimum	2
Cyanophyta	
Microcystis incerta	300
Oscillatoria rubescens	51
Chrysophyta	
Chrysophyceae	
Chrysolykos planktonicus	8
Dinobryon crenulatum	2
Kephyrion sp.	2
Pseudokephyrion spp.	2
Diatomaceae	
Achnanthes microcephala	2
Cyclotella sp.	177
Navicula radiosa	3
Navicula sp.	4
Cryptophyta	
Rhodomonas minuta	26

b. Zooplankton (collections: 25 vi 70, 9 xi 71, 25 vi 73, 16 vii 73, 15 ii 74, 24 v 74, 19 vi 74, 17 vii 74, 21 viii 74, 18 ix 74)

Units are maximum numbers per litre.

Rotifera	
Asplanchna	< 0.1
Conichiloides	0.1 - 1
Conichilus	1 - 10
Kellicottia longispina	1 - 10
Keratella cochlearis	0.1 - 1
Keratella quadrata	1 - 10
Monostyla lunaris	< 0.1
Polyarthra vulgaris	10 - 100
Cladocera	
Alona guttata	< 0.1
A. intermedia	< 0.1
A. quadrangularis	0.019
Alonella excisa	0.068
Bosmina longirostris	46.620

maximum crustacean standing crop: 228.2 animalx/l

Cladocera (continued)	
Ceriodaphnia (*affinis*?) } *C. quadrangula* }	88.800
Chydorus sphaericus	< 0.1
Daphnia (*galeata mendotae*/*rosea* group)	3.825
D. pulex	1 - 10
Polyphemus pediculus	0.1 - 1
Copepoda	
Acanthodiaptomus denticornis	1 - 10
Diaptomus leptopus	5.793
Acanthocyclops vernalis	21.830
Orthocyclops modestus	< 0.1
Arachnida	
Hydracarina	< 0.1

2. Bottom and Shoreline Organisms

a. Macrophytes

Emergent sedges (*Carex*) occur sparsely around the shoreline, as does *Sparganium* sp. There are two small, dense clumps of submerged macrophytes; one of *Chara* and one of *Myriophyllum*. *Potamogeton* (*pectinatus* or *filiformis*) is sparsely-distributed in shallow water, and *Menyanthes trifoliata* projects into the water from shore in places.

b. Shoreline fauna

Units are numbers collected.

collections:	16 vii 73 (30 min)	19 vi 74 (15 min)	16 vii 74 (30 min)
Coelenterata			
Hydrozoa			
Hydra			2
Ectoprocta			
Bryozoa			+
Annelida			
Oligochaeta			4
Crustacea			
Cladocera			
Eurycercus lamellatus		13	1
Simocephalus vetulus	35	25	15
Scapholeberis kingi	1	2	
Copepoda			
Diaptomus leptopus	3		
Ostracoda	2		1
Amphipoda			
Hyalella azteca	8	8	4

b. Shoreline fauna (continued)

collections:	16 vii 73 (30 min)	19 vi 74 (15 min)	16 vii 74 (30 min)
Insecta			
Ephemeroptera			
Caenis exuviae		1	
Odonata			
Zygoptera			
Lestes	4		
Coenagrionidae	24		
Enallagma boreale (adult)		1	(2)
Enallagma sp.		1	
Anisoptera			
Aeshnidae	18		
Aeshna	1	3	1
A. eremita	1		
Libellulidae	1	1	
Hemiptera			
Gerris notabilis			4
Trichoptera			
Limnephilidae	4	1	1
Oecetis		3	
" pupae			5
unidentified larvae, v. small			53
Diptera			
Chironomidae			
Tanypodinae	3	6	2
" pupae	2	1	
Orthocladiinae	5	9	1
" pupae		1	
Chironomini	9	1	4
" pupae	1		
Tanytarsini	12	56	
Ceratopogonidae			
Palpomyia pupae		1	
Mollusca			
Gastropoda			
Planorbidae (unident.)	1	1	
Gyraulus parvus		8	4
Pelecypoda			
Sphaeriidae	3		

c. Bottom fauna (collection: 16 vii 74, n = 12)
Units are mean numbers/m^2.

Nematoda	4
Annelida	
Oligochaeta (2 spp.)	50
Hirudinoidea	
Helobdella stagnalis	14
Crustacea	
Cladocera	
Eurycercus lamellatus	22
Cladocera (continued)	
Simocephalus vetulus	4
Copepoda	
Acanthocyclops vernalis	7
Amphipoda	
Hyalella azteca	872
Insecta	
Ephemeroptera	
Caenis	29

Insecta (continued)		Chironomidae (continued)	
Odonata		Tanypodinae pupae	7
Zygoptera		Diamesinae? pupae	4
Coenagrionidae	4	_Cryptocladopelma_	4
Anisoptera		_Dicrotendipes_	7
unidentified nymphs	4	_Harnischia_?	4
Aeshna	4	_Pagastiella_	144
Somatochlora	4	_Paratanytarsus_	11
Trichoptera		_Tanytarsus_	377
Oecetis	7	" pupae	14
" pupae	11	Ceratopogonidae	
Diptera		_Palpomyia_, _Bezzia_ or _Johannsenomyia_	111
Chironomidae			
Ablabesmyia	61	Mollusca	
Clinotanypus	4	Pelecypoda	
Procladius s. str.	18	_Pisidium_	4

Standing crop (mean preserved wet weight/m^2):

Aeshnidae	0.653 gm	_Caenis_	0.010 gm
Hyalella	1.581 gm	Chironomidae mainly	0.458 gm
Oligochaeta	0.267 gm	Libellulidae	0.408 gm
Ceratopogonidae (mainly)	0.067 gm	Coenagrionidae	0.024 gm
Trichoptera	0.129 gm	Hirudinoidea	0.023 gm

3. Fish

Collection dates: 13-14 vi 74, 16-17 vii 74, 20-21 viii 74

Set durations: 12.5 h, 12.5 h, and 14.5 h, respectively

Gear: 10 m each of 3/4, 1½, 2, 3, 4-inch mesh green multifilament nylon gillnet set on bottom; one set each date

Catch: 13-14 vi - 12 rainbow trout (_Salmo gairdneri_); 6 males, 6 females
16-17 vii - 10 rainbow trout; 2 males, 2 females, 6 unsexed
20-21 viii - 14 rainbow trout; 3 males, 2 females, 9 unsexed (gillnets vandalized)

June

Age:	2	4	5
Number:		4	5
Mean fork length (mm):		223.5	235.0
Mean weight (gm):		115.0	128.2
July			
Number:	2	4	
Mean fork length (mm):	85.0	238.0	
Mean weight (gm):	8.0	142.2	
August			
Number:	10		
Mean fork length (mm):	132.2		
Mean weight (gm):	48.0		

Maturity: Two males were mature at age 2, but only one female, an age 4 fish, was mature. Seventeen fish were either unsexed or their state of maturity was not recorded. The otoliths were very difficult to read, so the ages noted above are questionable.

Food: 12 stomachs examined (June collection), none empty

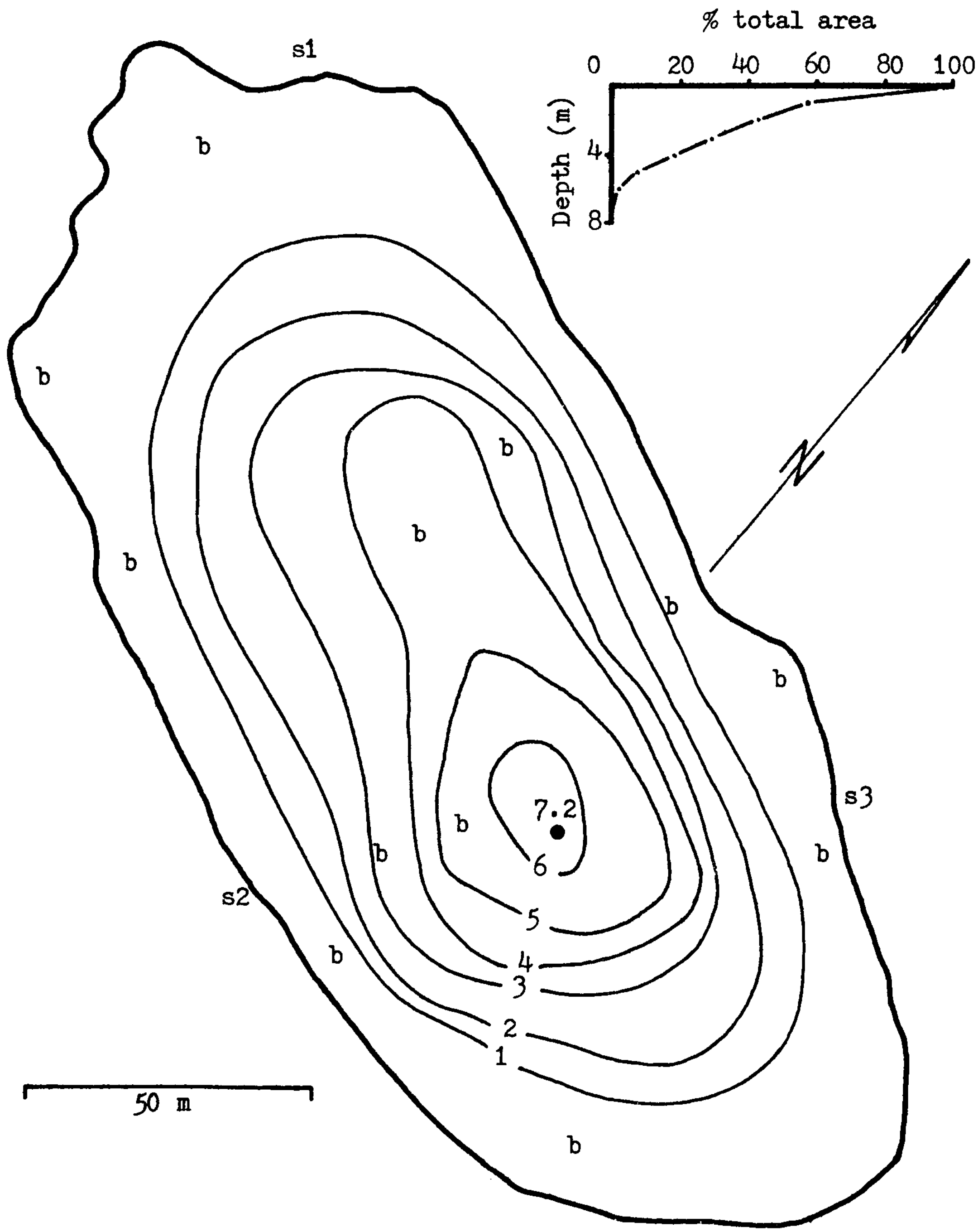
Food item	% of fish with item	mean % total stomach contents by volume
Hyalella azteca	100	79.6
unidentifiable insect parts	8.3	6.7
Coenagrionidae	8.3	5.0
Planorbidae	16.7	3.8
Anisoptera	16.7	1.7
Chironomidae	58.3	1.2
Ceratopogonidae	33.3	1.2
Trichoptera	8.3	0.8
Ephemeroptera	8.3	~0
Cladocera	8.3	~0

D. Discussion

The only additional species recorded from Kingfisher Lake of which we know is the damselfly *Enallagma cyathigerum*, by Walker (1953, p. 219).

Cutthroat trout and brook trout were stocked in Kingfisher Lake several years ago, but no longer occur (National Parks stocking records). Present policy is to continue the practice of planting small numbers of rainbow trout annually (National Park stocking records). Our present limited data suggest a fairly rapid growth rate for the youngest fish (from 85 mm to 132 mm fork length from July to August). Lake conditions are highly unfavourable for natural recruitment. At least partial winterkill may occur in some years, particularly if the population is dense.

Figure 2.62. Bathymetric map and hypsographic curve of Kingfisher Lake.
Depths are in metres.
b - bottom fauna collection
s - shoreline collection



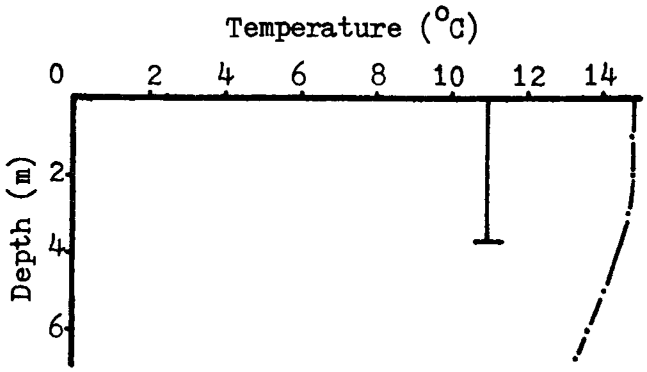


Figure 2.63. Representative mid-summer temperature profile and Secchi depth reading (⊥), Kingfisher Lake, 21 viii 74.

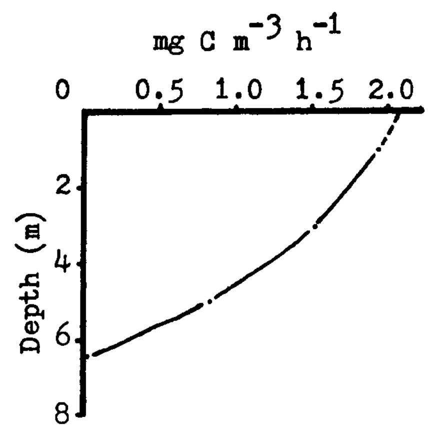
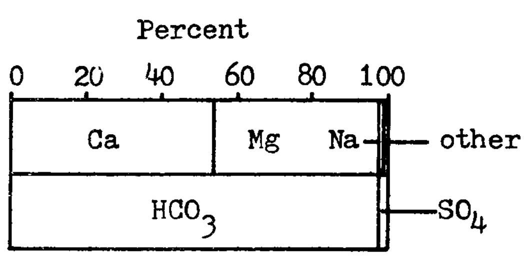


Figure 2.64. Representative profile of primary productivity, Kingfisher Lake, 21 viii 74. Points are net figures (light minus dark). Samples were collected with a hose. Incubations 0800 - 1125 h MST

Figure 2.65. Percent ionic composition of surface water calculated on the basis of equivalent weights, Kingfisher Lake, 25 vi 70.



KINGFISHER POND

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 581961, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class IV (General Outdoor Recreation)

Access: by blazed trail from Trans-Canada Highway, approximately 0.3 km (0.2 mi)

Elevation: 1600 m

Altitudinal zone: lower subalpine

Basin type: depression in ground moraine

Length: 104 m

Mean width: 48 m

Area: 0.5 ha

Maximum depth: 6.1 m

Mean depth: 2.7 m

Volume: $1.4 \times 10^4 m^3$

Shoreline length: 276 m

Shoreline development: 1.10

Volume development: 1.38

Mean depth/max. depth: 0.44

Area/mean depth: 0.18

Water level fluctuation: level dropped approximately 30 cm through summer of 1975

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 1	0.45	32.0
1 - 2	0.33	23.8
2 - 3	0.25	18.1
3 - 4	0.19	13.3
4 - 5	0.13	9.1
5 - 6.1	0.05	3.7

Water renewal time: unknown - very slight overflow only in spring; water exchange must be mainly subsurface

Open-water period: probably mid May to late October (approximately 160 ice-free days - no direct observations)

Catchment area: unknown

Bedrock composition of catchment area: 100% Miette Group

Catchment area coverage: 100% forest

Human activities in catchment area: angling (probably only locally known)

Bottom composition: dark brown flocculent or jelly-like mud having an organic content of 78.6%.

Secchi depth: > maximum depth (15 viii 73)

Colour (½ Secchi): green (25 v 75)

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 25 v 75 Depth: surface to 3 m composite

Conductivity: 231.0 μmho/cm @ 25C pH: 8.8 units

Total alkalinity as $CaCO_3$: 122.9

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 15 viii 73 Depth: surface

Turbidity: 0.9 JTU Colour: 20 HU

pH: 8.3 units Sum of constituents: 141.2

Conductivity: 240 μmho/cm @ 25C Sum const./cond: 0.59

Total alkalinity as $CaCO_3$: 136.0

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 141

Total inorganic carbon: 28 Total organic carbon: 14

Major constituents
Calcium: 46.0 Magnesium: 6.4 Sodium: 1.1 Potassium: 0.4
Bicarbonate: 165.8 Carbonate: 0 Sulphate: 2.3 Chloride: 0.9

Minor constituents
Copper: < 0.02 Iron: 0.03 Lead: < 0.004 Manganese: < 0.009
Zinc: 0.003
Nitrogen (nitrate + nitrite): 0.01 Phosphate: < 0.003 (both ortho- and inorganic)

Silica: 2.4

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 25 v 75 Depth: 0 - 3 m composite

Chlorophyta	
Chlamydomonas sp.	69
Dictyosphaerium pulchellum	83
Oocystis parva	21
Chrysophyta	
Chrysophyceae	
Bitrichia chodatii	48
Chromulina sp.	55
Chrysochromulina parva	248
Chrysoikos skujae	62
Dinobryon crenulatum	28
Chrysophyceae (continued)	
D. divergens	7
D. sertularia	35
Kephyrion sp.	97
Mallomonas sp.	7
Ochromonas sp.	14
Diatomaceae	
Achnanthes minutissima	28
Achnanthes spp.	97
Cyclotella kuetzingiana	7
Cyclotella sp.	166

Diatomaceae (continued)	
Cymbella microcephala	7
Navicula sp.	14
Pinnularia sp.	7
Synedra sp.	21
Cryptophyta	
Cryptomonas ovata	7
Rhodomonas minuta	48

b. Zooplankton (collections: 15 viii 73, 25 v 75)
Units are maximum numbers per litre.

Rotifera	
Conichilus	trace
Kellicottia longispina	0.1 - 1
Keratella quadrata	1 - 10
Polyarthra vulgaris	1 - 10
unidentified small sp.	0.1 - 1
Cladocera	
Ceriodaphnia (*quadrangula*?)	0.24
Cladocera (continued)	
Daphnia (*pulicaria*?)	1.60
Daphnia rosea	18
Scapholeberis kingi	0.02
Copepoda	
Acanthodiaptomus denticornis	7.265
Orthocyclops modestus	9.082
Insecta	
Chaoborus flavicans	0.061

maximum crustacean standing crop: 84.4 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

Chara, *Potamogeton natans* and *Utricularia intermedia*

b. Shoreline fauna (collection: 15 viii 73; 30 min)
Units are numbers collected.

Coelenterata	
Hydrozoa	
Hydra	4
Crustacea	
Ostracoda	
Notodromas monacha	75
Amphipoda	
Hyalella azteca	43
Insecta	
Ephemeroptera	
Caenis	2
Insecta (continued)	
Odonata	
Zygoptera	
Coenagrionidae	1
Anisoptera	
Aeshna eremita	1
Diptera	
Chironomidae	
unidentified	12
Orthocladiinae	2
Dixidae	
Dixa	1

c. Bottom fauna (collection: 25 v 75, n = 2)
Units are mean numbers/m^2.

Annelida	
Oligochaeta	22
Crustacea	
Amphipoda	
Hyalella azteca	43
Insecta	
Diptera	
Chironomidae	
Guttipelopia	22
Procladius s. str.	43
Chironomidae (continued)	
Psectrocladius	22
Dicrotendipes	237
Pagastiella	474
Tanytarsus	237
Ceratopogonidae	
Palpomyia, *Bezzia* or *Johannsenomyia*	43
Mollusca	
Pelecypoda	
Pisidium	194

c. Bottom fauna (continued)

Standing crop (mean preserved wet weight/m^2):

Hyalella	0.192 gm	Chironomidae mainly	0.654 gm
Sphaeriidae	0.396 gm		

3. Fish

Collection date: 6-7 vi 75 Set duration: 19 h 45 min

Gear: 10 m each of 3/4, 1½, 2, 3, 4-inch mesh green multifilament nylon gillnet set on bottom.

Catch: 1 Rainbow trout (Salmo gairdneri); male, fork length 492 mm, weight 1256 gm, stomach contents (by volume) Hyalella 50%, Odonata nymphs 50%, Tanypodinae larvae trace
See discussion also

D. Discussion

The ostracode Notodromas monacha found in this lake is said to be rare in North America (Delorme 1970). It was not identified from any other lakes in this survey.

Both brook trout and rainbow trout are said to occur in Kingfisher Pond (Ward 1974), although the stocking records do not record this. We caught single specimens of both species in 1975, but lost the brook trout when it fell out of the net during retrieval. A person who had emptied this net before we reached it told us he had removed several other specimens.

Winterkill could occur in this lake in some years, particularly if the population is dense. Natural recruitment is unlikely.

There is no stated stocking policy for this lake (National Parks stocking records).

Captions for figures page 126.

Figure 2.65. Bathymetric map and hypsographic curve of Kingfisher Pond. Depths are in metres.
b - bottom fauna collection
s - shoreline collection

Figure 2.66. Temperature profiles and Secchi depth reading (⊥), Kingfisher Pond. Solid lines, 25 v 75; broken line, 15 viii 73.

Figure 2.67. Profile of primary productivity, Kingfisher Pond, 25 v 75. Points are net figures (light minus dark). Samples were collected with a hose. Incubation 0900 - 1230 MST.

Figure 2.68. Percent ionic composition of surface water calculated on the basis of equivalent weights, Kingfisher Pond, 15 viii 73.

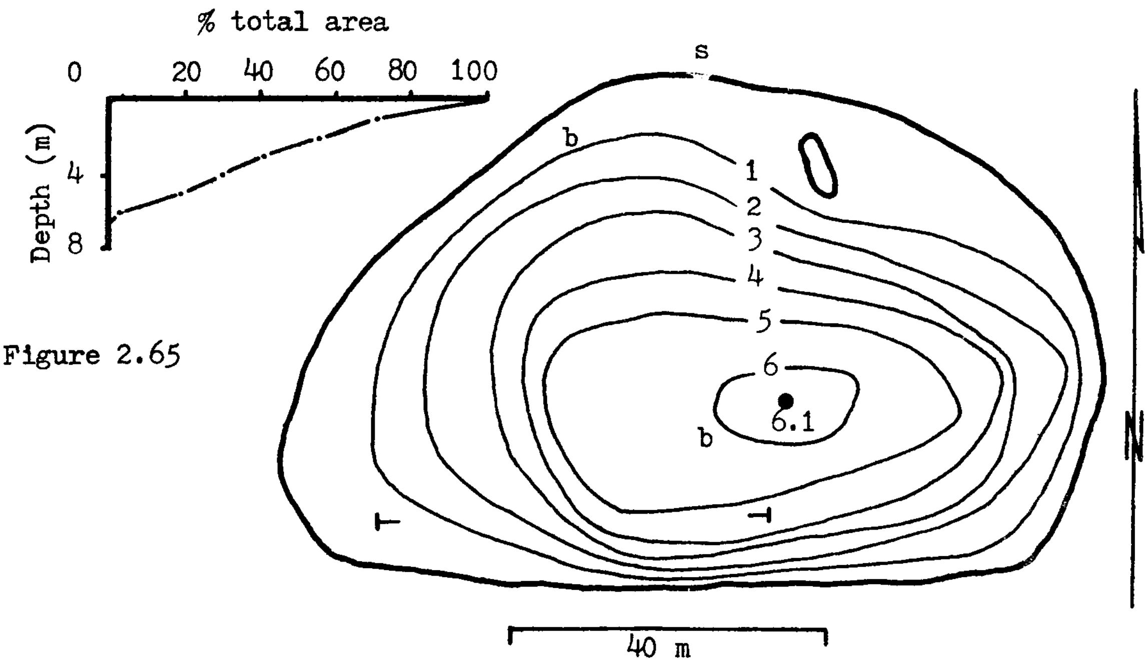


Figure 2.65

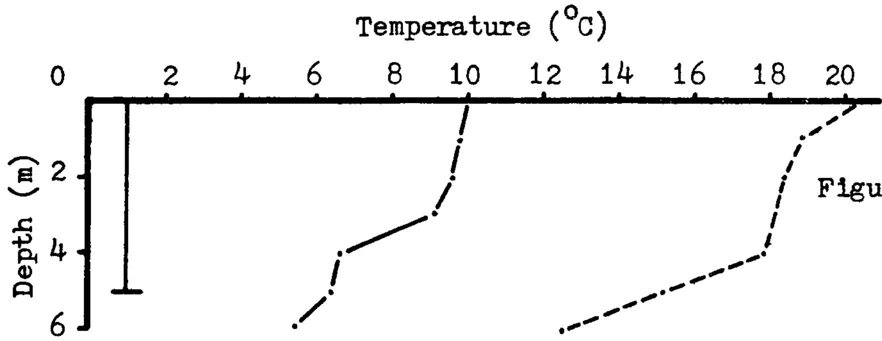


Figure 2.66

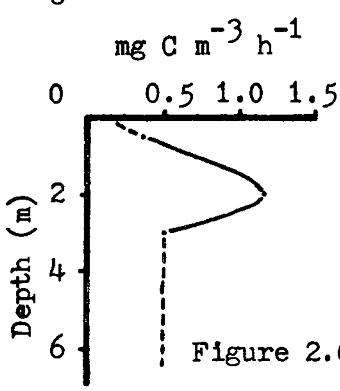


Figure 2.67

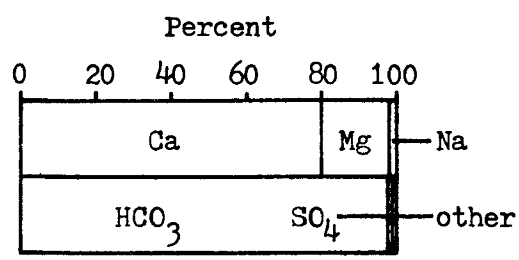


Figure 2.68

LARCH VALLEY POND EAST

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 548867, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Moraine Lake parking lot, approximately 3.2 km (2 mi)

Elevation: 2362 m

Altitudinal zone: alpine

Basin type: dammed by talus and moraine at junction between drift and base of Mt. Temple

Length: approx. 100 m

Mean width: approx. 40 m

Area: 0.4 ha

Maximum depth: 1.5 m

Mean depth: approx. 0.7 m

Volume: approx. $0.3 \times 10^4 m^3$

Mean depth/max. depth: approx. 0.47

Area/mean depth: approx. 0.57

Open-water period: unknown - certainly less than 100 days

Catchment area coverage: 100% exposed rock and low plants

Human activities in catchment area: hiking, unauthorized camping

Secchi depth: greater than maximum depth (2 viii 66)

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 2 viii 66

Depth: surface

pH: 8.26 units

Total hardness as $CaCO_3$: 85.5

2. Laboratory analysis

not done

C. Lake Biology

1. Plankton

a. Phytoplankton

no collections

b. Zooplankton (collection: 2 viii 66)
Units are maximum numbers per litre.

Rotifera	
Euchlanis (*dilatata*?)	0.04
Copepoda	
unidentified nauplii	0.04
Insecta	
Chironomidae	0.02

maximum crustacean standing crop: 0.1 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

no macrophytes in the pond

b. Shoreline fauna

no collections

c. Bottom fauna

no collections

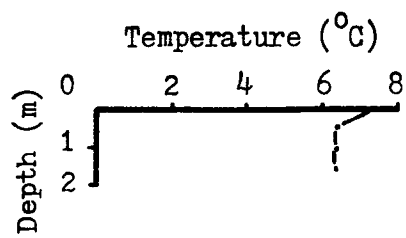
3. Fish

no collections

D. Discussion

This pond provides an inhospitable environment for most organisms, particularly fish. Most, if not all, of it must freeze to the bottom in winter. It could not support a sport fishery.

Figure 2.69. Temperature profile, Larch Valley Pond East, 2 viii 66.



LARCH VALLEY POND WEST

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 540866, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Moraine Lake parking lot, approximately 4.7 km (2.9 mi)

Elevation: 2393 m

Altitudinal zone: alpine

Basin type: dammed by drift and talus at the base of a spur of Eiffel Peak

Length: approx. 50 m | Mean width: approx. 40 m

Area: 0.2 ha | Maximum depth: 3.3 m

Mean depth: approx. 1.6 m | Volume: approx. $0.3 \times 10^4 m^3$

Mean depth/max. depth: approx. 0.48 | Area/mean depth: approx. 0.12

Open-water period: unknown - certainly less than 100 days

Catchment area coverage: 100% exposed rock and low plants

Human activities in catchment area: hiking

Secchi depth: greater than maximum depth (2 viii 66)

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 2 viii 66 | Depth: surface

pH: 8.30 units | Total hardness as $CaCO_3$: 68.4

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 2 viii 66 | Depth: 0.5 m

Turbidity: 0.0 JTU | Colour: 1 HU

pH: 8.0 units | Sum of constituents: 65.2

Conductivity: 123 µmho/cm @ 25C | Sum const./cond: 0.53

Total alkalinity as $CaCO_3$: 63.0

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 63.6

Major constituents
Calcium: 17.3 Magnesium: 5.0 Sodium: 0.2 Potassium: 0.1
Bicarbonate: 76.8 Carbonate: 0 Sulphate: 2.4 Chloride: 0.3

Minor constituents
Iron: 0.00 (both total and dissolved) Aluminum: 0.10

Minor constituents (continued)
Manganese: 0.000 (both total and dissolved) Copper: 0.000
Zinc: 0.000
Fluoride: 0.03 Phosphate (total): < 0.05 Nitrate: 0.1

Silica: 1.9

Ammonia: 0.0

C. Lake Biology

1. Plankton

a. Phytoplankton

no collections

b. Zooplankton (collection: 2 viii 66)
Units are maximum numbers per litre.

Rotifera		maximum crustacean standing crop: 0 animals/l
Euchlanis (*dilatata*?)	trace	
Insecta		
Chironomidae	trace	

2. Bottom and Shoreline Organisms

a. Macrophytes

no macrophytes in the pond

b. Shoreline fauna

no collections

c. Bottom fauna

no collections

3. Fish

no collections

Figure 2.70. Temperature profile, Larch Valley Pond West, 2 viii 66.

Figure 2.71. Percent ionic composition of surface water calculated on the basis of equivalent weights, Larch Valley Pond West, 2 viii 66.

Figure 2.70

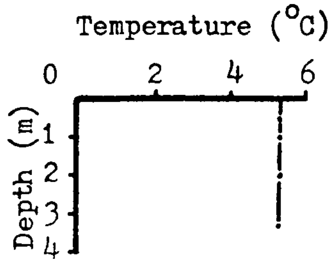
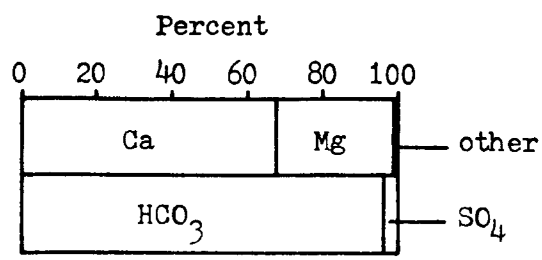


Figure 2.71



D. Discussion

Although this pond is deeper than its counterpart across the valley, it is much too small and clearly too unproductive to support a large biological community. It could not support a fishery.

LOST LAKE *

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NH 505026, NTS map No. 82 N/8 west (Lake Louise West map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Trans-Canada Highway culvert over Bath Creek, approximately 2.4 km (1.5 mi)

Elevation: 1692 m

Altitudinal zone: lower subalpine

Basin type: depression in former meltwater channel

Length: 185 m

Mean width: 22 m

Area: 0.4 ha

Maximum depth: 5.5 m

Mean depth: 2.0 m

Volume: 0.8 x $10^4 m^3$

Shoreline length: 411 m

Shoreline development: 1.83

Volume development: 1.09

Mean depth/max. depth: 0.36

Area/mean depth: 0.20

Water level fluctuation: less than 30 cm drop through the summer (1975)

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 1	0.33	40.6
1 - 2	0.21	26.2
2 - 3	0.15	18.3
3 - 4	0.09	10.7
4 - 5	0.03	3.9
5 - 5.5	0.002	0.3

Water renewal time: 9 days (5 vi 75)

Open-water period: probably mid May to late October (160 days - no direct observation of dates)

Catchment area: unknown

Bedrock composition of catchment area: 100% Miette Group

Catchment area coverage: 100% forest

Human activities in catchment area: hiking, angling, partly destroyed log cabin, abandoned garbage dump on south shore.

Bottom composition: light-coloured flocculent sediments having an organic content of 28.3%

Secchi depth: > maximum depth (25 vi 70)

* The lake shown as Lost Lake on map no. 82 N/8 west is not the Lost Lake referred to in the present report, which does not appear on the map. The Lost Lake treated here is at the location given for it in the 1974 Alberta Gazetteer.

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

	surface 25 vi 70	0 - 4 m composite 5 vi 75
Conductivity:	292 µmho/cm @ 25C	
pH:	8.2 units	7.8 units
Total alkalinity as $CaCO_3$:	166	150.3

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 25 vi 70 Depth: 0.5 m

Turbidity: 0.9 JTU Colour: 0 HU

pH: 8.2 units Sum of constituents: 162.8

Conductivity: 296 µmho/cm @ 25C Sum const./cond: 0.55

Total alkalinity as $CaCO_3$: 159

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 167

Major constituents
Calcium: 44.0 Magnesium: 13.9 Sodium: 0.8 Potassium: 0.3
Bicarbonate: 194 Carbonate: 0 Sulphate: 3.0 Chloride: < 0.1

Minor constituents
Iron: 0.03 Manganese: < 0.001 Copper: < 0.001 Lead: < 0.010
Zinc: 0.001
Fluoride: < 0.05 Nitrate: < 0.01 Phosphate: < 0.01 (ortho and total inorganic)

Silica: 5.8

Ammonia: 0.1

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 5 vi 75 Depth: 0 - 4.5 m composite

Chlorophyta	
Chlamydomonas sp.	140
Oocystis parva	3
Chrysophyta	
Chrysophyceae	
Bitrichia chodatii	11
Chromulina sp.	31
Chrysochromulina parva	92
Dinobryon attenuatum	17
D. crenulatum	95
D. sertularia	39
Kephyrion sp.	316
Chrysophyceae (continued)	
Monosiga varians var. *vagans*	3
Pseudokephyrion inflatum	109
Ochromonas sp.	8
Spiniferomonas bourrellii	22
Spiniferomonas sp.	6
Diatomaceae	
Achnanthes sp.	11
Cyclotella sp.	31
Cymbella microcephala	6
Cymbella sp.	3

Diatomaceae (continued)	
Navicula sp.	3
Synedra sp.	20
Cryptophyta	
Cryptomonas marsonii	6
Cryptomonas sp.	3
Rhodomonas minuta	25

b. Zooplankton[1] (collections: 25 vi 70, 5 vi 75)
Units are maximum numbers per litre.

Rotifera	
Kellicottia longispina	10 - 100
Keratella cochlearis	10 - 100
Keratella quadrata	1 - 10
Ploesoma hudsoni	0.1 - 1
Polyarthra vulgaris	100 - 1000
Cladocera	
Alona	trace
Bosmina longirostris	27
Cladocera (continued)	
Daphnia rosea	1
D. pulicaria	8.44
Polyphemus pediculus	10
Copepoda	
Acanthodiaptomus denticornis	27
Acanthocyclops vernalis	0.49
Macrocyclops albidus	<0.1

2. Bottom and Shoreline Organisms

a. Macrophytes

Emergent sedges (Carex) and horsetails (Equisetum sp.) occur near shore, and Menyanthes trifoliata grows out from shore into the water at several points. Submerged Chara beds are particularly dense in the west end.

b. Shoreline fauna (collection: 18 vii 75, 15 min)
Units are numbers collected.

Crustacea	
Amphipoda	
Hyalella azteca	34
Insecta	
Ephemeroptera	
Centroptilum	1
Odonata	
Zygoptera	
Enallagma (cyathigerum or boreale)	1
Coenagrionidae (unident.)	8
Odonata (continued)	
Anisoptera	
Aeshna	2
Trichoptera	
Limnephilidae	1
Diptera	
Chironomidae	
Tanypodinae	1
Ceratopogonidae	
Alluaudomyia	1
Culicoides?	1

c. Bottom fauna (collection: 5 vi 75, n = 3)
Units are mean numbers/m^2.

Annelida	
Oligochaeta	43
Hirudinoidea	
Helobdella stagnalis	43
Crustacea	
Amphipoda	
Gammarus lacustris	14
Amphipoda (continued)	
Hyalella azteca	775
Insecta	
Odonata	
Zygoptera	
Coenagrionidae (unident.)	14

1. maximum crustacean standing crop: 65.0 animals/l

Insecta (continued)		Chironomidae (continued)	
Trichoptera		Polypedilum s. str.	43
Mystacides?	14	Tanytarsus	43
Polycentropus	86	" pupae	57
Diptera		Chaoboridae	
Chironomidae		Chaoborus	14
Guttipelopia	158	Ceratopogonidae	
Procladius s. str.	244	Culicoides?	57
Corynoneura	57	Palpomyia, Bezzia or Johannsenomyia	29
Psectrocladius	43		
Chironomus	72		
Dicrotendipes	100	Mollusca	
Pagastiella?	1679	Gastropoda	
		Gyraulus	shell only
		Pelecypoda	
		Pisidium	14

Standing crop (mean preserved wet weight/m^2):

Chironomidae mainly	2.118 gm	Trichoptera	0.963 gm
Hirudinoidea	0.319 gm	Coenagrionidae	0.095 gm
Amphipoda	4.905 gm		

3. Fish

Collection date: 5-6 vi 75 Set duration: 18 h 30 min

Gear: 10 m each of 3/4, 1½, 2, 3, 4-inch mesh green multifilament nylon gillnet set on bottom

Catch: 1 brook trout (Salvelinus fontinalis); fork length 377 mm, 634 gm, stomach empty, female

D. Discussion

Rawson (1939) recorded the following additional species from Lost Lake ("Hidden Lake" in his report).

- Nostoc
- Coelosphaerium sp.
- Ceratium hirundinella
- Peridinium cinctum
- Chydorus sp.
- Daphnia pulex[1]
- D. longispina[1]
- Gerris sp.
- Planorbis

1. The taxonomy of this genus has been changed greatly since Rawson's survey. These species may now be the two we found in the present study.

The very low catch in our test nets suggests there is only a small population of fish in Lost Lake. We saw several rises while at the lake, but these were all in the same area. We saw no rises on our final 1975 visit.

Lost Lake was last stocked in 1972 with brook trout and cutthroat trout (National Parks stocking records). The inlet and outlet might provide a limited amount of successful spawning and egg hatching, but winterkill is a distinct possibility, especially when the population is dense.

Angling pressure is said to be almost nil, in spite of the fact that angling success was thought to be good in the recent past (National Parks stocking records). In our visits to the lake, we saw no anglers.

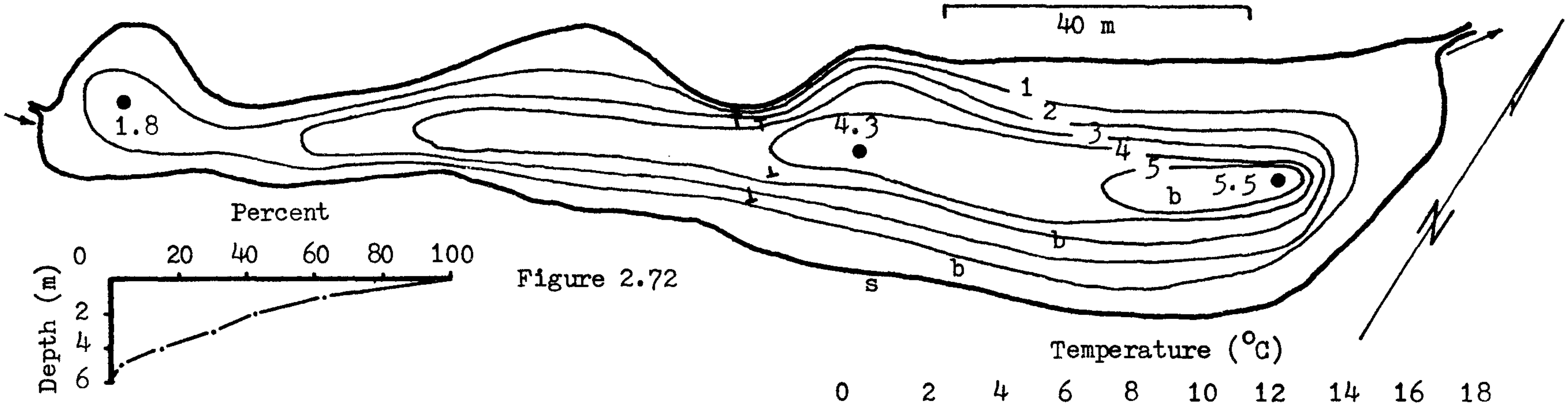


Figure 2.72

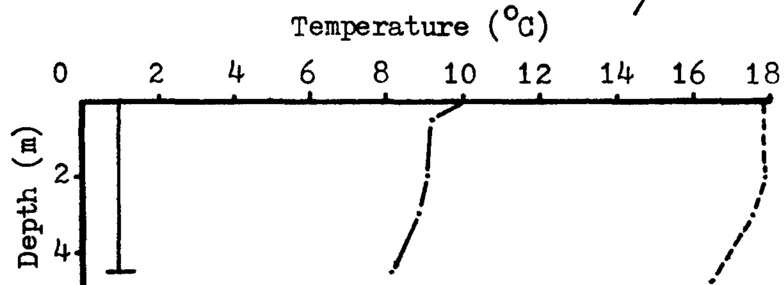


Figure 2.74

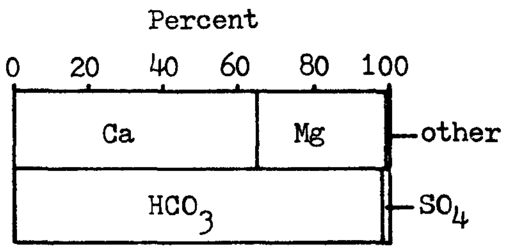


Figure 2.73

Figure 2.72. Bathymetric map and hypsographic curve of Lost Lake. Depths are in metres.
b - bottom fauna collection
s - shoreline collection
⊢ ⊣ - gillnet set between points

Figure 2.73. Percent ionic composition of surface water calculated on the basis of equivalent weights, Lost Lake, 25 vi 70.

Figure 2.74. Temperature profiles and Secchi depth readings (⊥), Lost Lake.
25 vi 70 ----
5 vi 75 ——

LAKE LOUISE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 540958, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class V (Intensive Use), most of lake Class II (Wilderness)

Access: by road from Lake Louise townsite

Elevation: 1731 m

Altitudinal zone: lower subalpine

Basin type: dammed by lateral moraine of Bow Valley (Wilcox 1899) rock basin scoured out by glacial corrasion

Length: 1990 m

Mean width: 425 m

Area: 84.5 ha

Maximum depth: 70.1 m

Mean depth: 36.5 m

Volume: $3084.7 \times 10^4 m^3$

Shoreline length: 4514 m

Shoreline development: 1.38

Volume development: 1.56

Mean depth/max. depth: 0.52

Area/mean depth: 2.32

Water level fluctuation: $<$1 m drop through the summer

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 10	779.31	25.3
10 - 20	672.16	21.8
20 - 30	563.94	18.3
30 - 40	457.32	14.8
40 - 50	356.21	11.5
50 - 60	211.03	6.8
60 - 70.1	44.74	1.5

Water renewal time: 187 days (4 vii 75), or approximately once per year

Open-water period: mid June to late November in both 1974 and 1975 (approximately 160 ice-free days)

Catchment area: 2500 ha

Bedrock composition of catchment area: 1% Miette Group, 58% quartzite, 41% Cambrian carbonate rocks

Catchment area coverage: 23% forest, 26% glaciers, 51% exposed rock and low plants

(Catchment area - lake area)/lake area: 29

Human activities in catchment area: includes Mirror and Agnes catchment areas. Large hotel, swimming pool (drains into lake near outlet via culvert), staff residences, tea house, canoeing (outboard motor boat for emergency purposes), mountaineering hut (Abbot Pass), horseback riding, hiking (very heavy use), angling (rare).

Bottom composition: Much of the bottom along the south shore is talus, and much of the near-shore bottom elsewhere is covered by large rocks. The central and western portions of the lake bottom are covered with greyish-white, very cohesive clay, having an organic content of 4.4%. The bottom near the eastern end is covered by darker, less cohesive sediments having a higher organic detritus content.

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

Conductivity: 139 µmho/cm @ 25C pH: 8.4 units (n = 3)

Total alkalinity as $CaCO_3$: 75 Total hardness as $CaCO_3$: 85.2 (n=2)

Variation with depth (20 vi 75):

	0 - 10 m composite	15 m
Conductivity:	159.5 µmho/cm @ 25C	159.5 µmho/cm @ 25C
pH:	8.0 units	8.0 units
Total alkalinity:	75.1	75.1

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 15 viii 73 Depth: surface

Turbidity: 2.5 JTU Colour: 10 HU

pH: 8.1 units Sum of constituents: 79.0

Conductivity: 137 µmho/cm @ 25C Sum const./cond: 0.58

Total alkalinity as $CaCO_3$: 68.0

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 77.0

Total inorganic carbon: 16 Total organic carbon: 0

Major constituents
Calcium: 23.0 Magnesium: 4.8 Sodium: 0.3 Potassium: 0.2
Bicarbonate: 82.9 Carbonate: 0 Sulphate: 6.9 Chloride: 0.5

Minor constituents
Copper: < 0.002 Iron: < 0.02 Lead: < 0.004 Manganese: < 0.009
Zinc: < 0.001
Fluoride: < 0.05 Nitrogen (nitrate + nitrite): 0.11 Phosphate: < 0.003 (both ortho- and inorganic)

Silica: 1.9

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 19 vi 75

Depth:	0 - 10 m composite	15.0 m
Chlorophyta		
Chlamydomonas sp.		6
Dictyosphaerium ehrenbergianum	17	17
Cyanophyta		
Chroococcus sp.		76
Chrysophyta		
Chrysophyceae		
Chrysococcus rufescens	1	
Dinobryon sociale		8
Mallomonas nr. *tonsurata* var. *alpina*		6
Diatomaceae		
Achnanthes sp.	1	4
Cyclotella sp.	10	18
Fragilaria sp.	4	
Synedra sp.		6

b. Zooplankton[1] (collections: 23 vi 66, 2 viii 66, 6 x 67, 15 viii 73, 27 x 74, 20 vi 75)

Units are maximum numbers per litre.

Rotifera	
Keratella cochlearis	0.1 - 1
Keratella quadrata	0.1 - 1
Polyarthra vulgaris	100 - 1000
Synchaeta (*oblonga*?)	1000 - 10000
Cladocera	
Daphnia pulex	0.011
Copepoda	
Acanthocyclops vernalis	4.366

2. Bottom and Shoreline Organisms

a. Macrophytes

a very few individual plants of *Myriophyllum* and emergent sedges (*Carex*) noted along the east shore, south of the outlet.

b. Shoreline fauna (collection: 19 vi 75, 30 min)

Units are numbers collected.

Annelida	
Oligochaeta	12
Insecta	
Ephemeroptera	
Siphlonurus	15
Trichoptera	
Limnephilidae	4
Diptera	
Tipulidae	
Dicranota	2
Tipula	5
Diptera (continued)	
Tanypodinae	1
Chironomini	5
Arachnida	
Hydracarina	
Lebertia	1
Mollusca	
Gastropoda	
Lymnaea (*arcticus*?)	10

1. maximum crustacean standing crop: 25.4 animals/l

c. Bottom fauna (collection: 20 vi 75, n = 6)
Units are mean numbers/m^2.

Annelida	
Oligochaeta	165
Insecta	
Diptera	
Chironomidae	
<u>Heterotrissocladius</u> (<u>oliveri</u>?)	983
Orthocladiinae sp.	7
<u>Parakiefferiella</u>?	330
Chironomidae (continued)	
<u>Paracladius</u>	36
<u>Chironomus</u>	280
" pupae	7
<u>Tanytarsus</u>	7

Standing crop (mean preserved wet weight/m^2):
Chironomidae mainly 2.334 gm

3. Fish

Collection date: 8-9 x 75 Set duration: 15 h 45 min

Gear: 20 m each of 3/4, 1½, 2, 3, 4-inch multifilament green nylon gillnet set on float

Catch: nil

D. <u>Discussion</u>

Wilcox (1899) described the probable origin of the Lake Louise basin, provided a bathymetric map of the lake, and estimated the sediments to be 2.6 m thick. He was unable to estimate the age of the lake by varve analysis because he could not obtain a complete sediment core. Our bathymetric map is substantially the same as that of Wilcox, but reveals less bottom detail in spite of the fact that it was based on 203 soundings, compared to the 137 soundings Wilcox made.

Johnston (1922) pointed out that surface water temperature increased from the inlet to the outlet end of the lake -- from about 2 to 3 °C at the inlet to 6 to 8 °C at the outlet in June 1921. Kucera (1974) remarked that midsummer temperatures range between about 6 to 9 °C. Our data and those of Rawson (1939) show that strong near-surface stratification can occur at times, with surface temperatures exceeding 14 °C. These relatively high temperatures are restricted to the upper 2 m of water when they occur. It may be that the heavy load of glacial silt in this lake, which greatly restricts light penetration, causes only the upper layer of water to heat up.

Scherzer (1907, in Johnston 1922) estimated the summer outflow of Lake Louise to be 2.49 m^3 sec^{-1}, and Johnston (1922) estimated the average annual outflow to be 1.42 $m^3\ sec^{-1}$. These data correspond to water renewal times of 143 and 251 days, or 1.12 and 0.64 times per year, respectively. Our estimates (187 days and once per year) are similar.

Rawson (1939) found no decline in dissolved oxygen with depth. In fact, oxygen concentrations were somewhat higher in deep water than at the surface on all three dates sampled.

The following additional species have been recorded from Lake Louise.

Cymbella ventricosa	R	*Conichilus unicornis*	T
Campylodiscus noricus var. *hibernia*	T	*Kellicottia longispina*[1]	R
Dinobryon sociale var. *americanum*	T	*Notholca striata*	R
Fragilaria crotonensis	T	*Alona costata*	R
Merismopedia glauca	T	*A. rectangula*	M
Synedra revaliensis	R	*Bosmina* sp.	R
Tabellaria fenestrata	R	*Daphnia longiremis*[2]	B
T. flocculosa var. *flocculosa*	T	*Eurycercus lamellatus*	M
		Scapholeberis kingi[3]	R,M
		Cyclops viridis americanus[4]	R
		Diaptomus arcticus[5]	Re

R: Rawson (1939)
T: Thomasson (1962)
M: McHugh (1940), in stomachs of mountain whitefish collected by Rawson
B: Brooks (1957), in Rawson's samples
Re: Reed (1959), in Rawson's samples

1. as *Notholca longispina*
2. found in only one other mountain lake in the region, Caladonia Lake in Jasper National Park (Anderson 1974b). Rawson's samples have been examined by many investigators and probably by students as well, with the consequent danger of contamination. We suspect that several anomalous occurences recorded from his samples, including this one, may be due to sample contamination.
3. as *S. mucronata*
4. *C. viridis* records in the older literature usually refer to *Acanthocyclops vernalis*, which Reed (1959) found in Rawson's Lake Louise samples.
5. almost certainly a contaminant of the sample. Rawson (1939) specifically remarked on the absence of *Diaptomus* from his Lake Louise samples.

Rawson collected 11 Ekman grab samples on 2 dates in summer, finding an average standing crop of 490 animals m^{-2} or 0.90 gm m^{-2}. These figures are notably lower than our comparable values. We are unable to say whether these differences reflect real differences in the benthic standing crops, because the samples were taken at different locations, and Rawson may have used a coarser seive than we did.

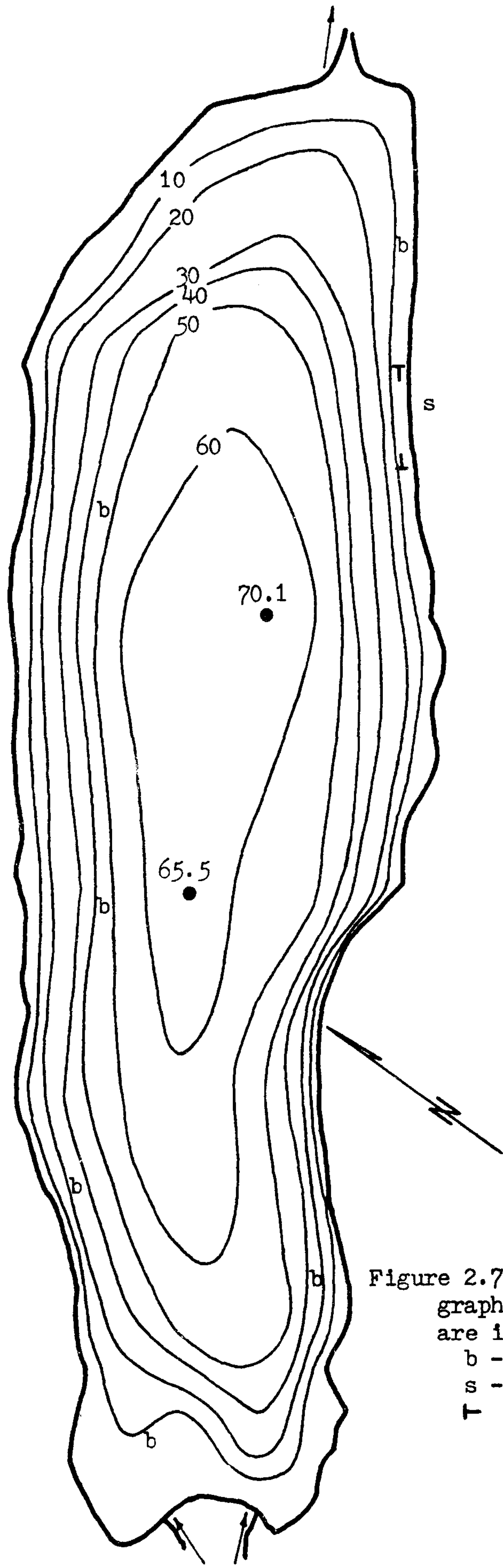
Rawson (1939) collected mountain whitefish (*Prosopium williamsoni*), Dolly Varden (<u>Salvelinus malma</u>) and cutthroat trout (<u>Salmo clarki</u>) from Lake Louise. Only the whitefish was abundant.

McHugh (1940, 1941) examined Rawson's mountain whitefish collection from this lake. He found that both age 1 and older fish ate mainly Chironomidae and Cladocera, and that Lake Louise whitefish had the second lowest growth rate (next to that of Bow Lake whitefish) of more than 20 mountain whitefish populations from throughout its range. Mountain whitefish reached an age of 9 in Lake Louise, at which age they averaged only 198 mm standard length (roughly 210 mm fork length).

Ward (1974) lists the following additional fish species for Lake Louise: rainbow trout (<u>Salmo gairdneri</u>), brook trout (<u>Salvelinus fontinalis</u>), and splake (<u>Salvelinus namaycush</u> X <u>S</u>. <u>fontinalis</u>). Lake Louise was last stocked with an unknown species, designated MT in the stocking records, in 1962. Present policy calls for no further stocking (National Parks stocking records).

Additional sampling would be required to adequately assess the present status of fish populations in Lake Louise. Mountain whitefish may have been missed in this survey because the collection was made in October, when the whitefish were probably spawning in the inlet creek.

Damm (1975) found that angling pressure on the lake was essentially nil in 1975.



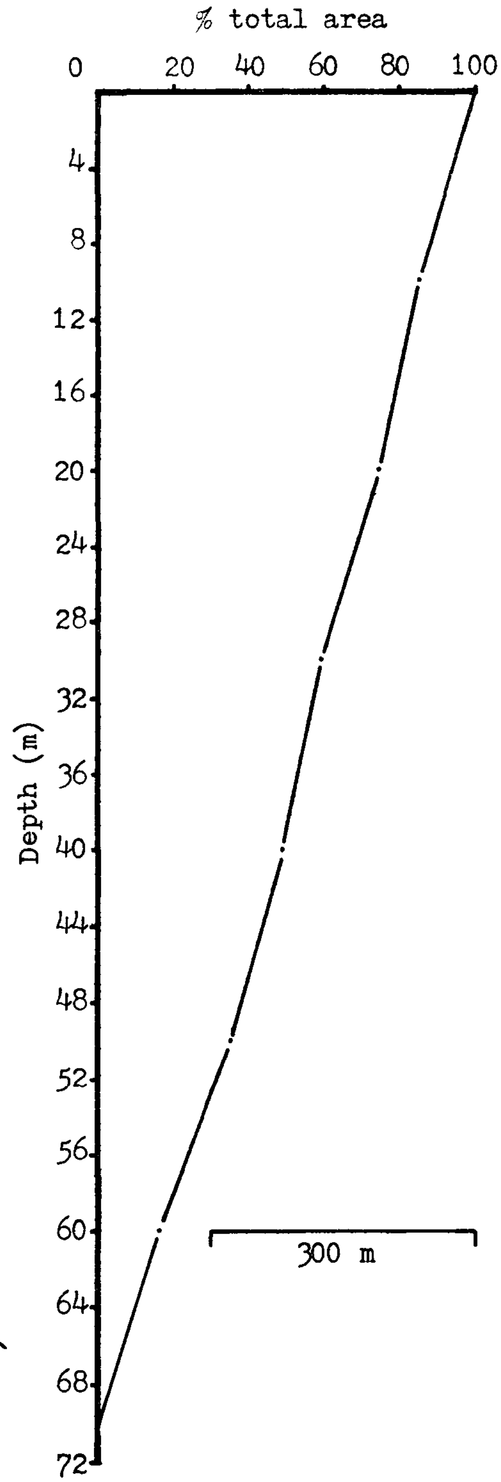


Figure 2.75. Bathymetric map and hypsographic curve of Lake Louise. Depths are in metres.
b - bottom fauna collection
s - shoreline collection
⊢ ⊣ - gillnet set between points

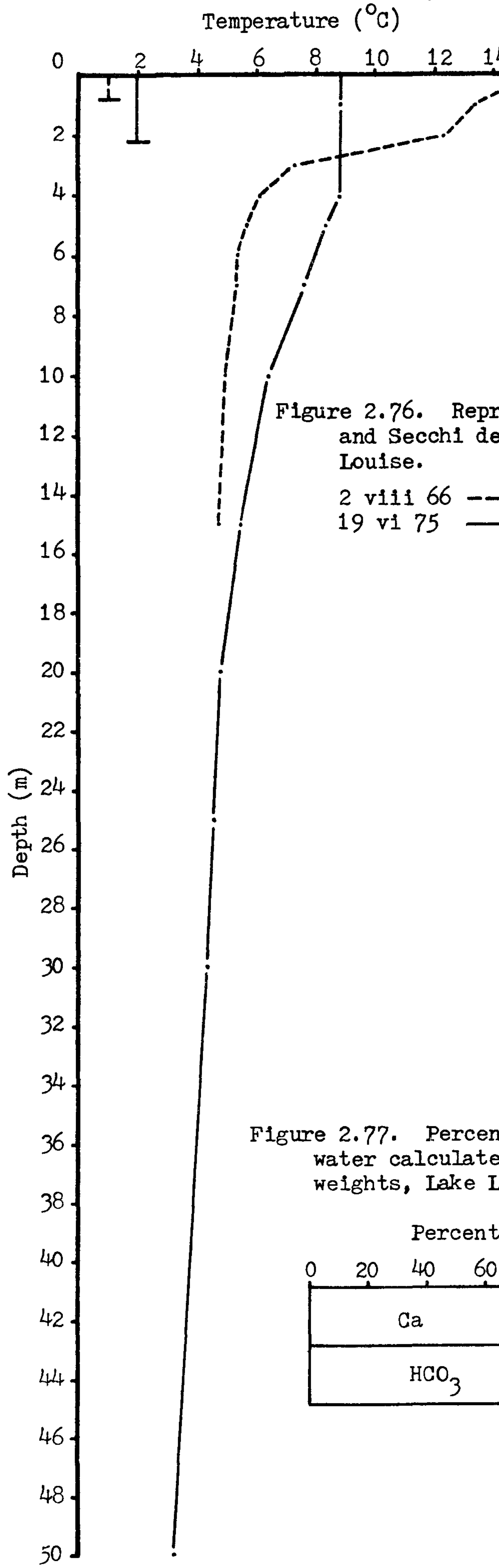
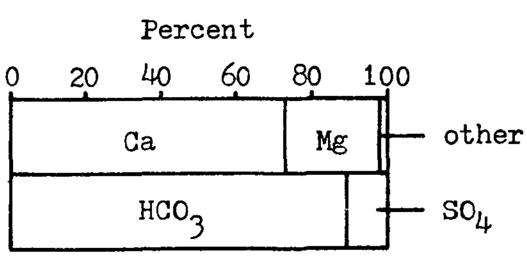


Figure 2.76. Representative temperature profiles and Secchi depth readings (⊥), Lake Louise.

2 viii 66 ----
19 vi 75 ——

Figure 2.77. Percent ionic composition of surface water calculated on the basis of equivalent weights, Lake Louise, 15 viii 73.



McNAIR POND

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 587952, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Transport corridor

Access: Highway 1-A forms part of the shoreline

Elevation: 1539 m

Altitudinal zone: lower subalpine

Basin type: artificial basin created by damming a small valley with the 1-A Highway

Length: 238 m

Mean width: 71 m

Area: 1.7 ha

Maximum depth: 3.5 m

Mean depth: 1.2 m

Volume: $2.0 \times 10^4 m^3$

Shoreline length: 584 m

Shoreline development: 1.26

Volume development: 1.01

Mean depth/max. depth: 0.34

Area/mean depth: 1.42

Water level fluctuation: less than 30 cm drop in level through the summer (1975)

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 1	1.22	59.8
1 - 2	0.69	33.7
2 - 3.5	0.13	6.5

Water renewal time: 2.5 days (23 v 75), 249 days (16 ix 75)

Open-water period: mid May to late October (approximately 160 ice-free days)

Catchment area: unknown

Bedrock composition of catchment area: 100% Miette Group

Catchment area coverage: 100% forest

Human activities in catchment area: ski area parking lot, day lodge and runs, access road, abandoned and sunken road-bed, 1-A Highway, angling. Includes Kingfisher catchment area.

Bottom composition: brown silt in northern, shallow portion of basin; sandy sediments in deepest portion having an organic content of 21.1%.

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 16 vii 73 Depth: surface
Conductivity: 214.5 µmho/cm @ 25C pH: 8.0 units

Date: 23 v 75 Depth: 0 - 3 m composite
Conductivity: 247.5 µmho/cm @ 25C pH: 8.6 units
Total alkalinity as $CaCO_3$: 95.6

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 9 xi 71 Depth: surface (hole in ice)
Turbidity: 1.3 JTU Colour: 5 HU
pH: 8.0 units Sum of constituents: 117.65
Conductivity: 223 µmho/cm @ 25C Sum const./cond: 0.53
Total alkalinity as $CaCO_3$: 87.1
Phenolphthalein alkalinity as $CaCO_3$: 0
Total hardness as $CaCO_3$: 105
Total inorganic carbon: 21 Total organic carbon: < 2

Major constituents
Calcium: 25.8 Magnesium: 9.9 Sodium: 2.1 Potassium: 0.3
Bicarbonate: 106.2 Carbonate: 0 Sulphate: 18.7 Chloride: 0.4

Minor constituents
Copper: < 0.001 Iron: 0.02 Lead: < 0.006 Manganese: < 0.016
Zinc: 0.004
Fluoride: 0.05 Nitrogen (nitrate + nitrite): 0.01 Phosphate: <0.010 (both ortho- and inorganic)

Silica: 8.1

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 23 v 75 Depth: 0 - 3 m composite

Chlorophyta
Chlamydomonas sp. 20
Cosmarium bioculatum 3

Cyanophyta
Lyngbya limnetica 50
Oscillatoria sp. 34

Chrysophyta
Chrysophyceae
Chromulina sp. 20
Conradocystis? 6
Mallomonas acaroides 3

Chrysophyta (continued)
Diatomaceae
Achnanthes linearis var. curta 3
A. microcephala 3
Achnanthes spp. 34
Cymbella sp. 3
Diatoma tenue var. elongatum 6
Fragilaria sp. 11
Gomphonema parvulum 3
Hannea arcus 3

Diatomaceae (continued)		Diatomaceae (continued)	
Meridion circulare	14	Synedra rumpens	6
Navicula sp.	11	Synedra sp.	28
Nitzschia acicularis	6	Rhizosolenia eriensis	11
Nitzschia dissipata var. media	3	Cryptophyta	
Nitzschia sp.	20	Cryptomonas ovata	3

b. Zooplankton[1] (collections: 9 xi 71, 25 vi 73, 16 vii 73, 23 v 75) Units are maximum numbers per litre.

Rotifera		Cladocera (continued)	
Ascomorpha?	< 0.1	Chydorus sphaericus	< 0.1
Asplanchna priodonta	< 0.1	Daphnia rosea	< 0.1
Brachionus	< 0.1	Copepoda	
Conichiloides?	trace	Diacyclops bicuspidatus thomasi	< 0.1
Kellicottia longispina	< 0.1	Eucyclops agilis	0.074
Keratella cochlearis	0.1 - 1	Macrocyclops albidus	0.016
Keratella quadrata	0.1 - 1	Orthocyclops modestus	0.07
Polyarthra vulgaris	< 0.1	Insecta	
Synchaeta	< 0.1	Chironomidae	0.139
Cladocera			
Bosmina longirostris	0.52		

2. Bottom and Shoreline Organisms

a. Macrophytes

Beds of emergent Carex occur around most of the shoreline. The bottom of the north basin is covered almost completely by dense beds of Potamogeton (filiformis or pectinatus) and Chara.

b. Shoreline fauna
Units are numbers collected.

collections:	16 vii 73 30 min	19 vi 75 30 min
Annelida		
Oligochaeta		6
Crustacea		
Cladocera		
Simocephalus vetulus	4	
Insecta		
Ephemeroptera		
unidentified nymphs (no gills)	1	
Centroptilum	4	11
Paraleptophlebia	2	
Siphlonurus	1	3
Odonata		
Zygoptera		
Coenagrionidae	1	
Anisoptera		
Aeshnidae (unidentified)	2	1
Aeshna	1	3
Aeshna palmata	2	

1. maximum crustacean standing crop: 10.0 animals/l

b. Shoreline fauna (continued)

collections:	16 vii 73 30 min	19 vi 75 30 min
Hemiptera		
Gerris incognitus		2
Trichoptera		
Limnephilidae	3	11
Diptera		
Chironomidae		
Orthocladiinae	19	
Paracladopelma		1
unidentified pupae		
Arachnida		
Hydracarina		
Limnesia	18	
Mollusca		
Pelecypoda		
Pisidium		4
unidentified Sphaeriidae		1

c. Bottom fauna (collection: 16 vii 73, n = 2)
Units are mean numbers/m^2.

Annelida	
Oligochaeta	581
Crustacea	
Ostracoda	22
Insecta	
Diptera	
Chironomidae	
Ablabesmyia	22
Procladius s. str.	775
Tanypus	65
Tanypodinae pupae	22
Paratrichocladius	22
Orthocladiinae? pupae	22
Diamesinae? pupae	65
Psectrocladius	22
Chironomidae (continued)	
Chironomus	344
Cryptochironomus	65
Cryptotendipes	2153
Dicrotendipes	22
Paracladopelma	43
Stictochironomus	4865
Tanytarsus	22
Arachnida	
Hydracarina	
Hygrobates	129
Lebertia	108
Mollusca	
Pelecypoda	
Pisidium	43

Standing crop (mean preserved wet weight/m^2):

Chironomidae	28.774 gm
Oligochaeta	3.955 gm
Sphaeriidae	0.347 gm
Hydracarina	0.153 gm

3. Fish

Collection date: 17-18 ix 75 Set duration: 21 h 30 min

Gear: 10 m each of 3/4, 1½, 2, 3, 4-inch mesh green multifilament nylon gillnet set on float but reaching to the bottom.

Catch: 11 brook trout (<u>Salvelinus fontinalis</u>); 5 males, 5 females, 1 unsexed
1 rainbow trout (<u>Salmo gairdneri</u>); male

a. Brook trout

Age:	3	5	6
Number:	2	3	2
Mean fork l. (mm):	110.0	199.3	235.0
Mean weight (gm):	16.0	129.0	211.0

Four brook trout could not be aged because annuli on the otoliths were too obscure.

Maturity: Six brook trout were judged to be very near spawning condition, with very large ovaries or testes. Two others, both females of 143 mm and 156 mm, respectively, were deemed to be maturing virgins and would not spawn in the autumn of 1975. The remaining 3 fish were immature. These included the two age 3 fish and one 178 mm age 6 fish.

Food: 11 stomachs examined, 0 empty

Food item	% of fish with item	mean % total stomach contents by volume
Tipulidae	54	36.8
unident. insect parts	54	33.6
<u>Gyraulus</u>	9	5.4
<u>Eurycercus</u>	36	5.4
Hydracarina	18	5.4
Chironomidae larvae	27	2.3
Trichoptera larvae	18	2.3
Cladocera ephippia	9	0.45
<u>Palpomyia</u>, <u>Bezzia</u> or <u>Johannsenomyia</u>	18	0.45
Ephemeroptera	9	0.45
<u>Pisidium</u>	9	~0

b. Rainbow trout

fork length 205 mm, weight 119 gm, testes very large (near gravid size), unknown age; stomach contents Aeshnidae nymph 70%, flying ants 20%, Trichoptera larvae 10% of the total stomach content volume

D. Discussion

The water strider <u>Gerris incognitus</u> found in this pond may be a new but not unexpected record for Alberta. See discussion of Little Herbert Lake.

Damm (personal communication) has observed sudden siltation in McNair Pond on occasion, which may disappear overnight. He has suggested (Damm 1975) that this may be related to summer work on the ski area through which the inlet to the pond runs.

Conroy's (1968) site number 53 appears to be McNair Pond. He found the following water mites there: Lebertia porosa, Limnesia maculata, Hygrobates neooctoporus and Neoaxonopsis unguitarsa.

The last recorded stocking of brook trout in McNair Pond was in 1968 (National Parks stocking records). Since some brook trout in our collection were definitely less than 7 years old, it appears that there is at least some natural recruitment of brook trout. The small inlet may provide a suitable, though small, spawning site.

Only rainbow trout have been stocked since 1971, according to the stocking records. The present policy is to stock limited numbers of trout in the pond.

Angling in McNair Pond in 1975 was apparently poor. Damm (1975) interviewed 14 anglers who had caught a total of 5 fish, averaging 3.0 angler-hours per fish. He estimated that the total 1975 harvest was 175 fish.

Captions for figures on page 152

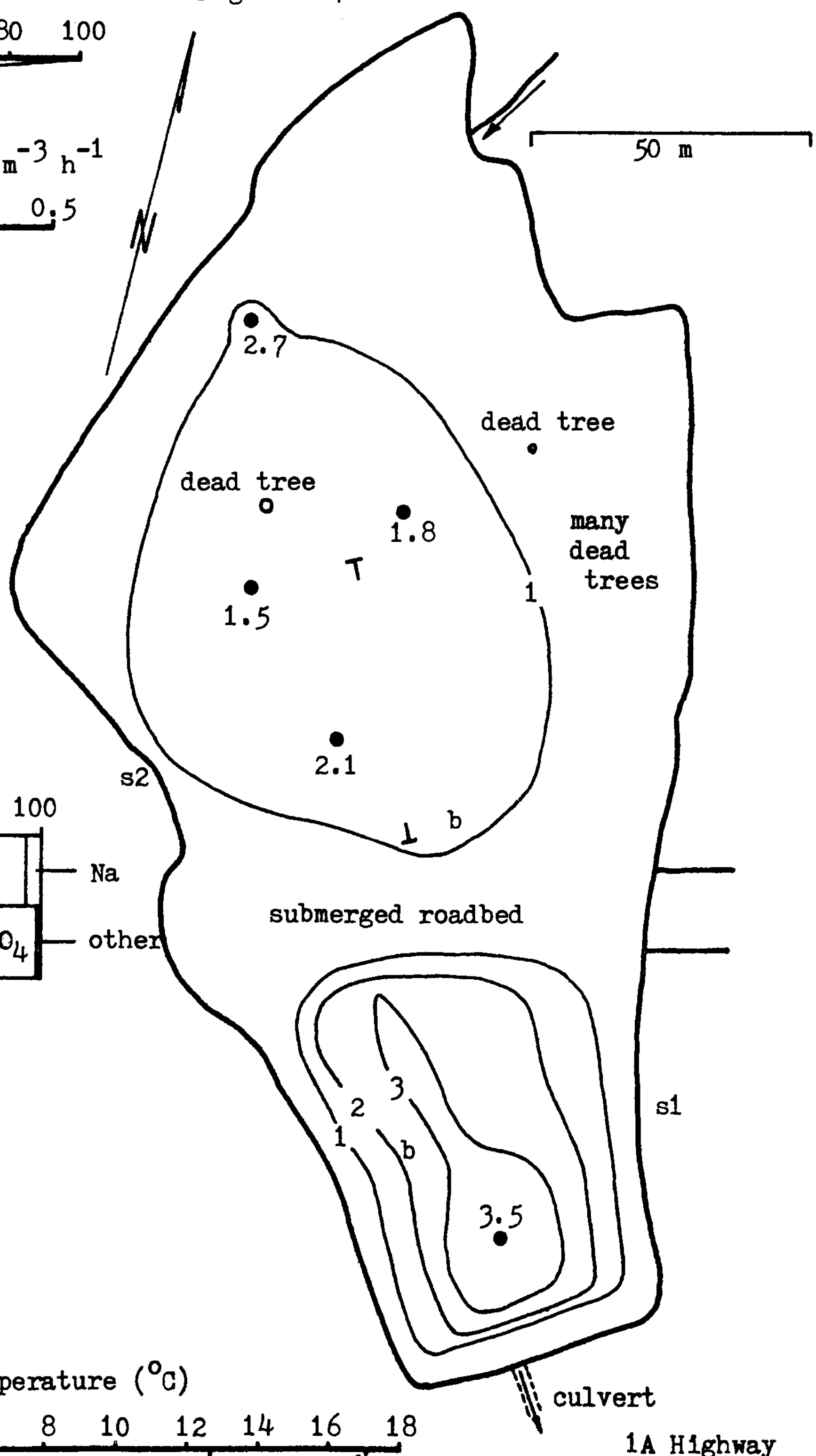
Figure 2.78. Bathymetric map and hypsographic curve of McNair Pond. Depths are in metres.
b - bottom fauna collection
s - shoreline collection
⊢ ⊣ - gillnet set between points

Figure 2.79. Profile of primary productivity, McNair Pond, 23 v 75. Points are net figures (light minus dark). Samples were collected with a hose. Incubation 0915 - 1240 h MST.

Figure 2.80. Percent ionic composition of surface water calculated on the basis of equivalent weights, McNair Pond, 9 xi 71.

Figure 2.81. Temperature profiles and Secchi depth readings (⊥), McNair Pond. ---- 25 vi 73, —— 16 vii 73, —•— 23 v 75.

Figure 2.78



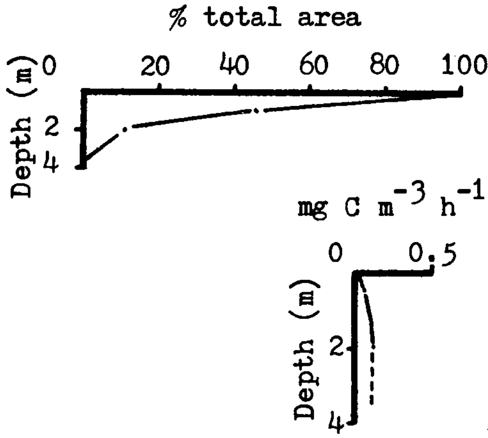


Figure 2.79

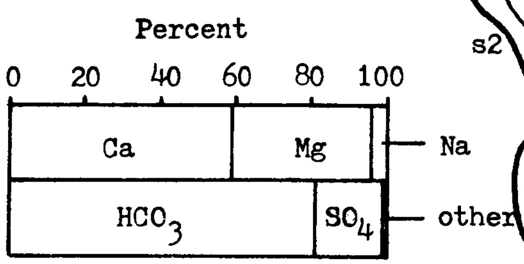
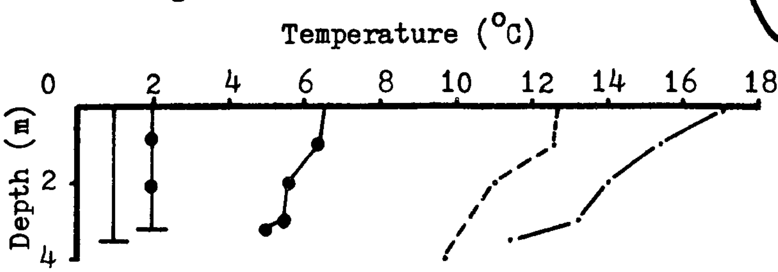


Figure 2.80

Figure 2.81



MIRROR LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 529961, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Chateau Lake Louise 2.6 km (1.6 mi)

Elevation: 2027 m

Altitudinal zone: upper subalpine

Basin type: dammed behind lateral moraine of the Lake Louise Valley

Length: 106 m

Mean width: 47 m

Area: 0.5 ha

Maximum depth: 4.5 m

Mean depth: 1.4 m

Volume: $0.7 \times 10^4 m^3$

Shoreline length: 273 m

Shoreline development: 1.09

Volume development: 0.93

Mean depth/max. depth: 0.31

Area/mean depth: 0.36

Waterlevel fluctuation: extreme - water level varies by at least 2 m through the summer

Water renewal time: 1 day (22 vii 75), based on ½ Agnes Lake outflow (lost to Chateau Lake Louise - estimated), and maximum volume of Mirror Lake

Open-water period: mid June to mid October (1975) (approximately 120 ice-free days)

Catchment area: 194 ha

Bedrock composition of catchment area: 63% quartzite, 37% Cambrian carbonate rocks

Catchment area coverage: 10% forest, 90% exposed rock and low plants

(Catchment area - lake area)/lake area: 387

Human activities in catchment area: includes Agnes catchment area. Chateau Lake Louise water supply drawn from Mirror Lake inlet just below Agnes Lake, horseback riding, hiking, unauthorized camping.

Bottom composition: medium gray silt having an organic content of 18.7%

Secchi depth: $\simeq$ 3 m (22 viii 75)

Surface temperature: 13.9°C near shore (8 vii 75), 11°C (22 viii 75)

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 8 vii 75 Depth: surface

pH: 8.0 units

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 8 vii 75 Depth: surface

Turbidity: 4.8 JTU Colour: < 5 HU

pH: 7.9 units Sum of constituents: 55.2

Conductivity: 110 µmho/cm @ 25C Sum const./cond: 0.50

Total alkalinity as $CaCO_3$: 52.0

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 56.9

Total inorganic carbon: 12 Total organic carbon: 2

Major constituents
Calcium: 13.2 Magnesium: 5.8 Sodium: 0.1 Potassium: 0.1
Bicarbonate: 63.4 Carbonate: 0 Sulphate: 4.4 Chloride: 0.2

Minor constituents
Nitrogen (nitrate + nitrite): 0.03 Nitrogen (Kjeldahl): < 0.1
Phosphorus (total): 0.003

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 22 viii 75 Depth: surface

Chlorophyta	
Chlamydomonas sp.	11
Oocystis parva	3
Chrysophyta	
Chrysophyceae	
Bitrichia chodatii	39
Dinobryon sociale	3
Mallomonas sp.	45
Spiniferomonas bourrelli	6
Diatomaceae	
Achnanthes linearis var. *curta*	3
A. microcephala	6
Achnanthes spp.	50
Diatomaceae (continued)	
Cyclotella sp.	605
Cymbella sp.	3
Fragilaria sp.	28
Gyrosigma sp.	3
Nitzschia dissipata var. *genuina*	3
Nitzschia sp.	6
Pinnularia sp.	3
Synedra sp.	1423
Cryptophyta	
Rhodomonas minuta	11

b. Zooplankton (collection: 22 viii 75)

Units are maximum numbers per litre.

Insecta	
Chironomidae	0.01

maximum crustacean standing crop: 0 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

no macrophytes in lake

b. Shoreline fauna (collection: 22 viii 75, 15 min)
Units are numbers collected.

Insecta	
Ephemeroptera	
Ameletus (_velox_-type gill)	1
" exuviae	2
Trichoptera	
Limnephilidae	2
Insecta (continued)	
Coleoptera	
Hydroporus occidentalis	14

c. Bottom fauna (collection: 22 viii 75, n = 1)
Units are mean numbers/m^2.

Annelida	
Oligochaeta (2 spp.)	732
Insecta	
Trichoptera	
Limnephilidae	43
Diptera	
Chironomidae	
Procladius s. str.	1550
Stictochironomus	43
Mollusca	
Pelecypoda	
Pisidium	86

Standing crop (mean preserved wet weight/m^2):

Oligochaeta	13.308 gm	Trichoptera	0.744 gm
Sphaeriidae	0.896 gm	Chironomidae mainly	3.694 gm

3. Fish

no collection

D. Discussion

The water level of Mirror Lake fluctuates widely through the summer. We have never seen the lake at its maximum level, probably because of the withdrawal of water for Chateau Lake Louise from the inlet.

The lake has apparently never been stocked with fish (National Parks stocking records). We have seen no sign of fish in several visits to the lake.

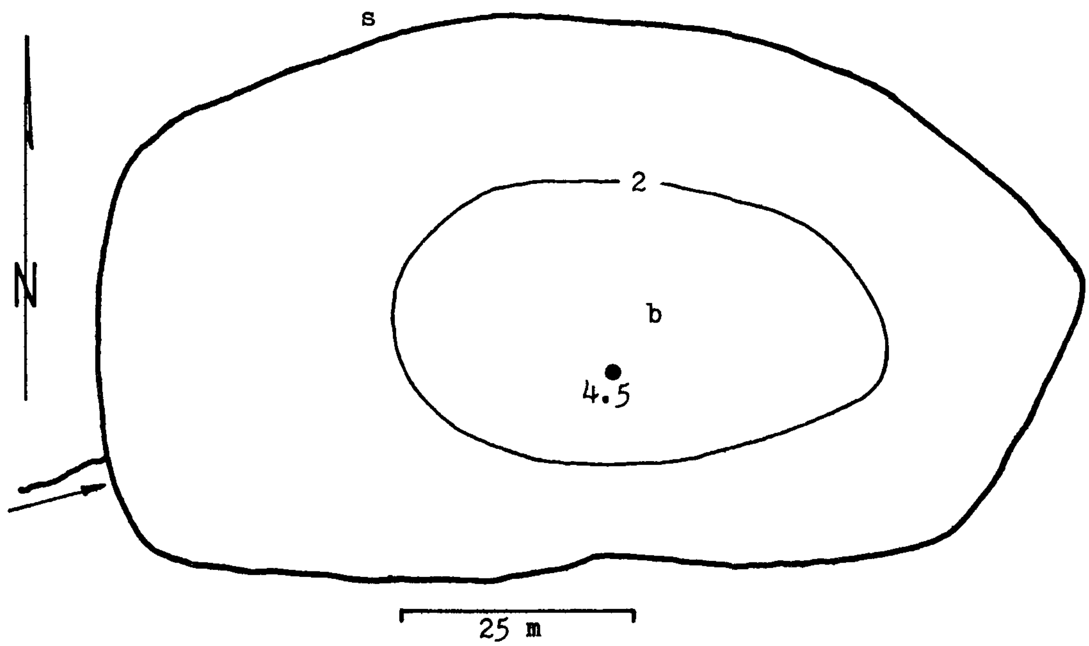
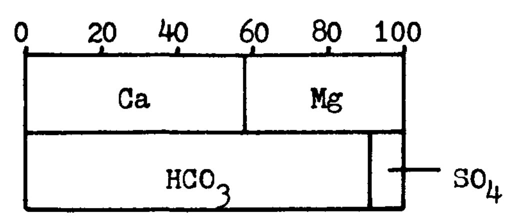


Figure 2.82. Bathymetric map of Mirror Lake. Depths are in metres.

b - bottom fauna collection
s - shoreline collection

Figure 2.83. Percent ionic composition of surface water calculated on the basis of equivalent weights, Mirror Lake, 8 vii 75.



MORAINE LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 579358, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Transport corridor; most of lake Class II (Wilderness)

Access: by road from Lake Louise townsite

Elevation: 1887 m

Altitudinal zone: lower subalpine

Basin type: deepest portion a valley rock basin formed by glacial corrasion; enlarged as a result of a rockslide dam (Kucera 1974)

Length: 1505 m

Mean width: 274 m

Area: 41.3 ha

Maximum depth: 22.9 m

Mean depth: 9.6 m

Volume: $397.1 \times 10^4 m^3$

Shoreline length: 3596 m

Shoreline development: 1.58

Volume development: 1.26

Mean depth/max. depth: 0.42

Area/mean depth: 4.30

Water level fluctuation: extreme - level just before spring break-up is about 6 m or more below high-water mark. After filling in spring, there is a decline of 2 m or more through the summer.

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 3	113.88	28.7
3 - 6	92.87	23.4
6 - 9	69.43	17.5
9 - 12	47.29	11.9
12 - 15	30.67	7.7
15 - 18	22.34	5.6
18 - 21	17.51	4.4
21 - 22.9	3.09	0.8

Water renewal time: less than 14 days (n=3, 1974), or approximately 10 times per year

Open-water period: early or mid June to probably late October (approximately 130 - 150 ice-free days; no direct observations of freeze-up dates)

Catchment area: 2630 ha

Bedrock composition of catchment area: 74% quartzite, 26% Cambrian carbonate rocks

Catchment area coverage: 13% forest, 19% glaciers, 68% exposed rock and low plants

(Catchment area - lake area)/lake area: 63

Human activities in catchment area: includes Eiffel, Sentinel, Larch Valley East and West catchment areas. Small lodge and motel, non-motorized boating, angling, hiking, mountaineering hut, unauthorized camping.

Bottom composition: The northern portion of the lake bottom is covered by coarse sand, gravel and talus, and the bottom along the west side is covered by rock fragments. The bottom in the central and southern parts of the basin is covered by sometimes cohesive, but more frequently granular, clay having an organic content of 7.0%.

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) surface, summer

Conductivity: 124.9 µmho/cm @ 25C (n=2) pH: 8.2 units (n = 4)

Total alkalinity as $CaCO_3$: 62

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 72.5 (n = 2)

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 20 ix 67 Depth: 0.5 m

Turbidity: 0.3 JTU Colour: 5 HU

pH: 7.9 units Sum of constituents: 65.0

Conductivity: 124 µmho/cm @ 25C Sum const./cond: 0.52

Total alkalinity as $CaCO_3$: 54.9

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 63.4

Major constituents
Calcium: 15.7 Magnesium: 5.9 Sodium: 0.4 Potassium: 0.2
Bicarbonate: 66.9 Carbonate: 0 Sulphate: 7.6 Chloride: < 0.1

Minor constituents
Iron: 0.03 (total), 0.01 (dissolved) Manganese: < 0.005
Copper: < 0.005 Zinc: < 0.005
Fluoride: 0.02 Phosphate: < 0.01 (total and dissolved)
Nitrate: 0.1

Silica: 2.1

Ammonia: < 0.1

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 17 vii 73 — Depth: 0.5 m

Chrysophyta	
Chrysophyceae	
Kephyrion sp.	21
Diatomaceae	
Achnanthes spp.	10
Cyclotella nr. *kuetzingianum*	14
Diatomaceae (continued)	
Cyclotella sp.	51
Hannea arcus var. *amphioxys*	2
Navicula sp.	3
Cryptophyta	
Rhodomonas minuta	2

b. Zooplankton[1] (collections: 23 vi 66, 2 viii 66, 20 ix 67, 17 vii 73, 26 vi 74, 13 viii 74, 17 ix 74)

Units are maximum numbers per litre.

Rotifera	
Kellicottia longispina	$<$ 0.1
Cladocera	
Chydorus sphaericus	0.03
Daphnia middendorffiana	0.003
Copepoda	
Diaptomus arcticus	3.113
Acanthocyclops vernalis	0.01
Insecta	
Chironomidae	0.024

2. Bottom and Shoreline Organisms

a. Macrophytes

no macrophytes seen

b. Shoreline fauna

Units are numbers collected.

collections:	17 vii 73 30 min	17 ix 74 30 min
Platyhelminthes		
Turbellaria	48	5
Annelida		
Oligochaeta	16	22
Crustacea		
Copepoda		
Diaptomus arcticus		10
Insecta		
Ephemeroptera		
Ameletus (nr. *celer* and *celeroides*)	24	
Cinygmula	1	
Siphlonurus	12	
Plecoptera (very young)	1	
Trichoptera		
Limnephilidae	4	
Diptera		
Simuliidae	1	
Chironomidae		
Orthocladiinae	1	1
Pseudodiamesa?	7?	
Chironominae	6	

1. maximum crustacean standing crop: 4.9 animals/l

c. Bottom fauna (collection: 26 vi 74, n = 4)
Units are mean numbers/m^2.

Nematoda	161
Annelida	
Oligochaeta	764
Crustacea	
Ostracoda	43
Insecta	
Plecoptera	11
Trichoptera	
Limnephilidae	11
Diptera	
Chironomidae	
Protanypus	11
Paracladius	1141
Chironomidae (continued)	
Parakiefferiella?	334
~~*Limnophyes?*~~ *Zalutschia*	151
Orthocladiinae pupae	118
Chironomus	54
Stictochironomus	75
Micropsectra	366
" pupae	11
Arachnida	
Hydracarina	
Lebertia	86
Mollusca	
Pelecypoda	
Pisidium	850

Standing crop (mean preserved wet weight/m^2):

Chironomidae mainly	2.559 gm	Trichoptera	0.744 gm
Sphaeriidae	1.524 gm	Oligochaeta mainly	0.311 gm

3. Fish

Collection dates: 24-25 vi 74, 12-13 viii 74, 16-17 ix 74

Set durations: 15 h, 13 h, 14 h, respectively

Gear: 20 m each of 3/4, 1½, 2, 3, 4-inch mesh green multifilament nylon gillnet set on bottom, 1 gang each date

Catch: 24-25 vi 74 - 6 splake (*Salvelinus namaycush* X S. *fontinalis*); 2 males, 4 females
2 rainbow trout (*Salmo gairdneri*); 2 males

12-13 viii 74 - 3 splake; 2 males, 1 female
3 brook trout (*Salvelinus fontinalis*); 2 females
1 unsexed
1 lake trout (*Salvelinus namaycush*); male

16-17 ix 74 - 6 splake; 4 males, 2 females
4 brook trout; 2 males, 2 females

a. Rainbow trout

specimen 1: fork length 249 mm, 178 gm, mature male, stomach contents 50% terrestrial Arachnida (by volume), also Plecoptera and unidentifiable insect parts (20% each), Ephemeroptera (10%), and traces of dytiscid larvae, chironomid larvae and pupae

specimen 2: fork length 168 mm, 59.5 gm, male, stomach contents Plecoptera 50%, Tanypodinae 40%, and Ephemeroptera 10%.

Neither specimen could be accurately aged, but the first appeared to be at least age 8.

b. Brook trout

mean fork length 267.4 mm (range 242 - 296 mm), mean weight 269.3 gm (range 177 - 358 gm) None of the specimens could be accurately aged because checks were obscure or non-existent. Stomach contents of the one specimen examined were Ephemeroptera nymphs 90%, Trichoptera 10%.

c. Splake trout

mean fork length 345.3 mm (range 234 - 430 mm), mean weight 516.3 gm (range 142 - 901 gm) None of the specimens could be accurately aged, but of those fish with some clear annuli, none had fewer than 8 and some had 12 or 13 (both otoliths and opercula were examined for some specimens).

Food: 7 stomachs examined, 1 (14.3%) were empty

Food item	% of fish with item	mean % total stomach contents by volume
Plecoptera	83.3	55.0
Trichoptera	66.7	23.3
Dytiscidae adults	33.3	13.3
Ephemeroptera	83.3	8.3
Chironomidae	16.7	~0
Simuliidae	16.7	~0

d. Lake trout

fork length 438 mm, weight 944 gm, mature male, stomach contents not examined, not aged

D. Discussion

Moraine Lake is very cold even in mid-summer, particularly at the head of the lake. Kucera (1974) noted that the August surface temperature at the inlet end is only about 3.3 °C, though it may be 6.7 °C near the outlet. The major inlet of the lake, Wenkchemna Creek, does not exceed 3 °C in summer (Part 3). Since the residence time of the water in the lake is short, the low temperatures are not surprising. The high water renewal rate and the low temperature of the inlet water also account for the lack of thermal and dissolved oxygen stratification noted (Rawson 1939; this study).

The occurrence of the stream forms *Cinygmula* and Simuliidae in the shoreline collections reflects the proximity of the collecting site to a small creek.

The following additional species have been found in Moraine Lake.

Asterionella formosa	R	*Ceratium hirundinella*	R
Bulbochaete sp.	R	*Cosmarium speciosum*	T
Campylodiscus hibernicus	R	*Diatoma hiemale* var. *mesodon*	T
Campylodiscus noricus var. *hibernica*	T	*Gonatozygon monotaenium*	T
		Melosira granulata	R

Meridion circulare	R,T	Bosmina sp.	R
Merismopedia glauca	T	Daphnia longispina[2]	R
Navicula ovalis	R	D. pulex[2]	R
Surirella ovalis	R	Diaptomus sp.[3]	R
S. spiralis	R	Diaptomus arcticus[3]	Re
Tetracladium maxilliformis	T	Diacyclops bicuspidatus thomasi (as Cyclops bicuspidatus)	R
Filinia (as Triarthra)[1]	R	Agabus tristis	R
Polyarthra trigla	R	Lebertia wolcotti	R

R: Rawson (1939)
T: Thomasson (1962)
Re: Reed (1959), in Rawson's samples

1. species no longer recognized (Edmondson 1959)
2. Both Brooks (1957) and Reed (1959) identified only D. middendorffiana in Rawson's samples from Moraine Lake.
3. Reed (1959) identified only D. arcticus from Rawson's samples. Specimens of D. eiseni recorded by Rawson (1939) from Moraine Lake are undoubtedly D. arcticus.

Rawson (1939) collected a total of 8 Ekman grab samples on two dates. The mean standing crop was 3.62 gm wet weight m^{-2} or 2220 animals m^{-2}. These figures are much lower than ours. The meaning of the difference is unclear, because we sampled in different places at different times of the summer and may have used a different seive mesh size than did Rawson.

Rawson (1939) caught only 9 Dolly Varden (Salvelinus malma) and 5 cutthroat trout (Salmo clarki) in three gillnet sets. Both species had eaten mainly mayfly nymphs, crustacean zooplankton, and stonefly nymphs. The Dolly Varden were infected with the tapeworm Eubothrium salvelini, and the cutthroats were infected with nematodes.

Two rainbow trout and a lake trout were among the species collected in the present survey. The last recorded stocking of rainbows was 1945 (National Parks stocking records). If the stocking records are correct, there has been some natural recruitment of rainbow trout in Moraine Lake. There is no record of lake trout being stocked in the lake.

It is unclear whether there has been natural recruitment of splake or brook trout. Splake were last stocked in the lake in 1969; brook trout in 1971 (National Parks stocking records). The smallest splake and brook trout caught appeared to be too large to have hatched since the last recorded introductions of these species, and the very limited age data tends to support this conclusion for splake. On the other hand, the sample size, particularly of brook trout, was small.

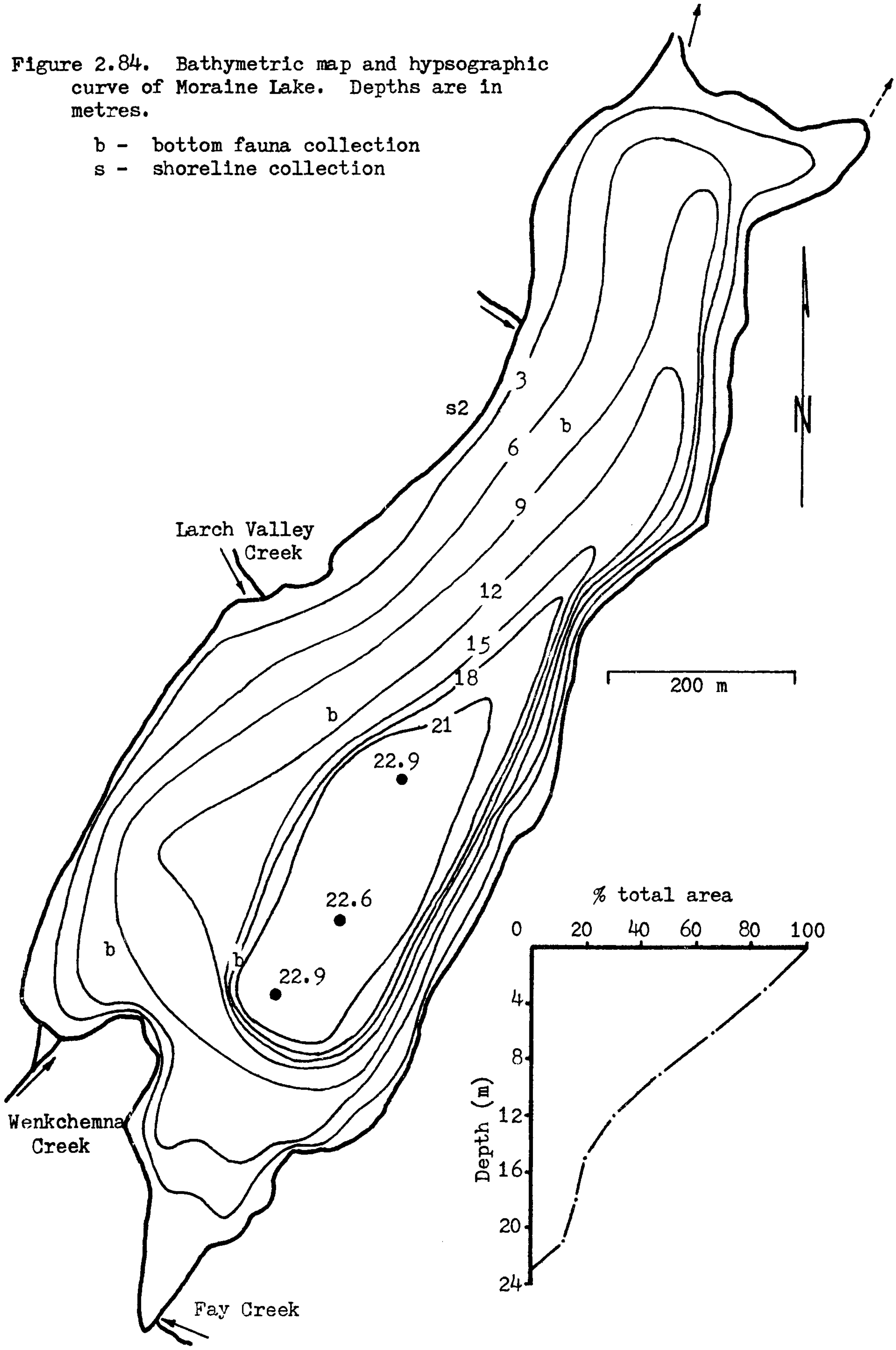
Cutthroat trout did not appear in the collections in this survey, but were apparently caught by anglers in the spring of 1975 (Damm 1975). Some fish of this species were stocked in August of the previous year, and may have been the fish the anglers caught. The size of the fish when stocked was not given in the records. The last stocking of cutthroat prior to 1974 was in 1955 (National Parks stocking records).

Vick (1913, in Paetz and Nelson 1970) reported mountain whitefish (Prosopium williamsoni) to occur in this lake. We are unaware of any records of the species since that time.

Damm (1975) indicated that the fishing in Moraine Lake was good in spring for cutthroat and splake. He interviewed 11 anglers who had caught a total of 11 fish at an average of 2.02 angler-hours per fish. Overall fishing success is thus rather poor. Damm believed his estimate of total harvest, 368 fish in 1975, to be too high.

Figure 2.84. Bathymetric map and hypsographic curve of Moraine Lake. Depths are in metres.

b - bottom fauna collection
s - shoreline collection



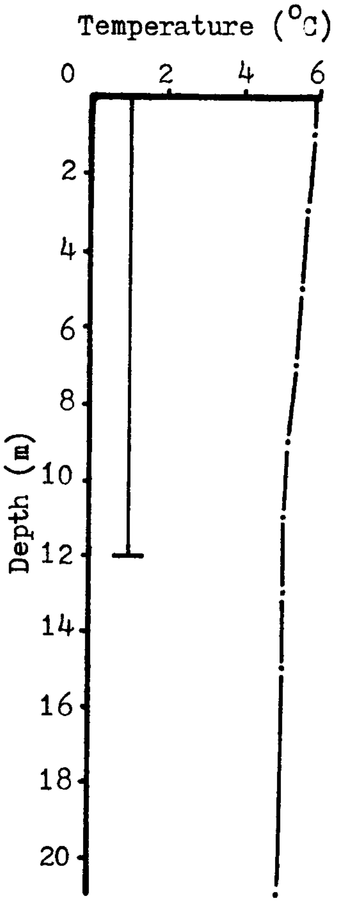


Figure 2.85. Representative summer temperature profile and Secchi depth reading (⊥), Moraine Lake, 13 viii 74.

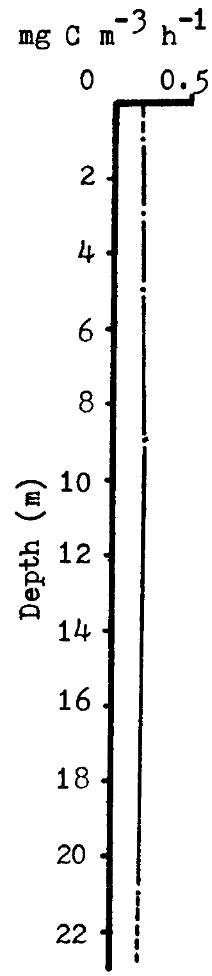
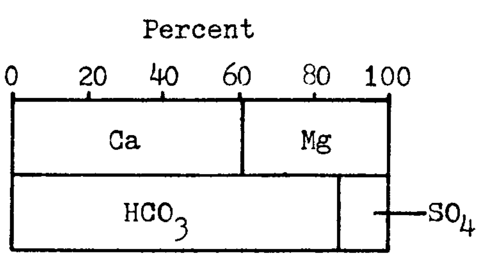


Figure 2.86. Representative summer profile of primary productivity, Moraine Lake, 13 viii 74. Points are net figures (light minus dark). Samples were collected with a hose. Incubations 0850 - 1205 h MST

Figure 2.87. Percent ionic composition of surface water calculated on the basis of equivalent weights, Moraine Lake, 20 ix 67.



MUD LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 573989, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class III (Natural Environment)

Access: by trail from Pipestone River service road, approximately 2.1 km (1.3 mi)

Elevation: 1600 m

Altitudinal zone: lower subalpine

Basin type: depression in fluted ground moraine

Length: 622 m

Mean width: 117 m

Area: 7.3 ha

Maximum depth: 7.2 m

Mean depth: 2.4 m

Volume: $17.6 \times 10^4 m^3$

Shoreline length: 1367 m

Shoreline development: 1.43

Volume development: 1.00

Mean depth/max. depth: 0.33

Area/mean depth: 3.04

Water level fluctuation: minimal - less than 30 cm drop in level through the summer.

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 1	5.75	32.6
1 - 2	4.01	22.7
2 - 3	3.28	18.6
3 - 4	2.48	14.1
4 - 5	1.44	8.2
5 - 6	0.55	3.1
6 - 7.2	0.11	0.7

Water renewal time: 78 days (n=3), or approximately twice per year

Open-water period: mid May to late October (approximately 160 ice-free days)

Catchment area: unknown

Bedrock composition of catchment area: 100% Miette Group

Catchment area coverage: 100% forest

Human activities in catchment area: angling, hiking, unauthorized camping

Bottom composition: The shallow 60% of the bottom (0-3m) is covered by light-coloured, flocculent sediments. The remaining deeper regions are covered by dark brown flocculent or jelly-like mud having an organic content of 70.0%.

Secchi depth: usually > maximum depth during open-water period

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 25 vi 70 Depth: surface

Conductivity: 253 µmho/cm @ 25C pH: 8.5 units

Total alkalinity as $CaCO_3$: 124

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 25 vi 70 Depth: 0.5 m

Turbidity: 0.84 JTU Colour: 0 HU

pH: 8.0 units Sum of constituents: 155

Conductivity: 272 µmho/cm @ 25C Sum const./cond: 0.57

Total alkalinity as $CaCO_3$: 125

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 146

Major constituents
Calcium: 34.0 Magnesium: 14.9 Sodium: 3.1 Potassium: 0.4
Bicarbonate: 152 Carbonate: 0 Sulphate: 21.8 Chloride: 0.2

Minor constituents
Iron: 0.94 Manganese: 0.001 Copper: < 0.001 Zinc: < 0.001
Lead: < 0.011
Fluoride: 0.05 Nitrate: < 0.01 Phosphate: < 0.01 (ortho- and inorganic)

Silica: 6.0

Ammonia: < 0.01

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 20 viii 74 Depth: 0 - 6 m composite

Chlorophyta	
Ankistrodesmus falcatus	11
Chlamydomonas spp.	43
Gloeocystis gigas	72
Oocystis borgei	4
O. parva	50
Scenedesmus bijuga	7
Tetraëdron minimum	4
Cyanophyta	
Chroococcus limneticus	29
Pyrrophyta	
Peridinium pusillum	14
Chrysophyta	
Chrysophyceae	
Dinobryon divergens	7

Chrysophyceae (continued)		Diatomaceae	
Dinobryon crenulatum	29	Achnanthes sp.	4
Kephyrion obliquum	4	Cyclotella comta	338
Kephyrion spp.	4	Cymbella sp.	4
Ochromonas sp.	4	Denticula sp.	4
Pseudokephyrion striatum	25	Nitzschia palea	4
Pseudokephyrion sp.	4	Cryptophyta	
		Cryptomonas sp.	14
		Rhodomonas minuta	126

b. Zooplankton[1] (collections: 25 vi 70, 15 ii 74, 6 vi 74, 18 vii 74, 20 viii 74, 20 ix 74)

Units are maximum numbers per litre.

Rotifera		Cladocera (continued)	
Asplanchna priodonta	10 - 100	Daphnia schødleri	23.310
Conichilus	0.1	Polyphemus pediculus	10
Kellicottia longispina	1 - 10	Copepoda	
Keratella cochlearis	1 - 10	Acanthodiaptomus denticornis	~20
Keratella quadrata	10 - 100	Acanthocyclops vernalis	3.552
Polyarthra vulgaris	10 - 100	Orthocyclops modestus	0.019
Cladocera		Insecta	
Bosmina longirostris	1 - 10	Chironomidae	0.009
Daphnia (pulex?)	0.028		

2. Bottom and Shoreline Organisms

a. Macrophytes

Emergent sedges (Carex) are sparsely-distributed around the shoreline. Dense clumps of Chara occur in several places, particularly at the south end of the lake. The species is also sparsely-distributed in the 0 - 2 m zone throughout the lake, as is Potamogeton (pectinatus or filiformis). P. natans was found at one point on the east shore. Coverage by macrophytes (mainly Chara) might be as high as 20% of the bottom area.

b. Shoreline fauna

Units are numbers collected.

collections:	18 vi 74 15 min	18 vii 74 20 min
Crustacea		
Cladocera		
Eurycercus lamellatus	17	
Polyphemus pediculus	1	
Scapholeberis kingi		1
Copepoda		
Macrocyclops albidus	2	
Amphipoda		
Hyalella azteca	40	1
Insecta		
Ephemeroptera		
Caenis		1

1. maximum crustacean standing crop: 70.0 animals/l

b. Shoreline fauna (continued)

collections:	18 vi 74 15 min	18 vii 74 20 min
Insecta (continued)		
Odonata		
Zygoptera		
Coenagrionidae	2	1
Anisoptera		
Aeshna	3	
Aeshna palmata		1
Libellulidae	1	
Somatochlora cingulata	1	
Trichoptera		
Limnephilidae	9	5
Diptera		
Chironomidae		
Thienemannimyia group	4	+
Endochironomus	1	
Paratanytarsus	+	
Ceratopogonidae		
Culicoides?	1	
Arachnida		
Hydracarina		
Hydrochoreutes ungulatus	2	
Mollusca		
Gastropoda		
Planorbidae	5	

c. Bottom fauna (collection: 20 viii 74, n = 8)
Units are mean numbers/m^2.

Nematoda	11
Annelida	
Oligochaeta	32
Hirudinoidea	
Helobdella stagnalis	5
Crustacea	
Amphipoda	
Hyalella azteca	86
Insecta	
Ephemeroptera	
Caenis	75
Trichoptera	
Oecetis	11
Phryganeidae	5
Diptera	
Chironomidae	
Guttipelopia	129
Procladius s. str.	91
Psectrocladius?	16
Parakiefferiella?	5
Chironomidae (continued)	
Chironomus?	5
Dicrotendipes	54
Endochironomus	5
Pagastiella	54
Polypedilum?	11
Tanytarsus	452
" pupae	5
Ceratopogonidae	
Alluaudomyia	113
Culicoides	732
Palpomyia, *Bezzia* or *Johannsenomyia*	22
Mollusca	
Pelecypoda	
Pisidium	151

c. Bottom fauna (continued)

Standing crop (mean preserved wet weight/m^2):

Hyalella	0.232 gm	Trichoptera	0.014 gm
Diptera	0.667 gm	Oligochaeta	0.134 gm
Caenis	0.115 gm		

3. Fish

Collection date: 18-19 vi 74   Set duration: 21 h

Gear: 20 m each of 3/4, 1½, 2, 3, 4-inch mesh green multifilament gillnet set on bottom

Catch: 18 brook trout (_Salvelinus fontinalis_); 3 males, 6 females, 9 unsexed
6 longnose dace (_Rhinichthyes cataractae_); all female

a. Brook trout

Age:	2	4	5	8
Number:	1	5	5	1
Mean fork l. (mm):	112	304.8	308.2	381
Mean weight (gm):	18	331.4	336.8	652

Six specimens could not be aged.

Maturity: The single age 2 trout was immature. All the other specimens were mature.

Food: 10 stomachs examined, 0 empty

Food item	% of fish with item	mean % total stomach contents by volume
Chironomidae	90	83.5
unident. insect parts	20	11.0
Anisoptera nymphs	20	4.5
Ceratopogonidae	30	0.5
Coleoptera (terrest.)	10	0.5
Hyalella	10	~0

Parasites: Three of the four trout examined for parasites were infected with _Crepidostomum farionis_ and _Diphyllobothrium_ sp. larvae, averaging 13.5 trematodes per fish for the former and 9.0 larvae per fish for the latter. The ranges were 0 - 25 and 0 - 31, respectively (Mudry and Anderson, in press).

b. Longnose dace

Five of the six dace could be aged, and all of these were age 3. The mean fork length was 85.7 mm and the mean weight, 7.0 gm. One specimen was partly spent, and the remainder were very near spawning condition. Stomach contents were not examined. All three of the dace examined for parasites were uninfected (Mudry and Anderson, in press).

D. Discussion

Rawson (1939) found no decline in dissolved oxygen with increasing depth in Mud Lake in late July 1938. Temperature stratification at that time was similar to that found in this survey in late August (Figure 2.89).

The following additional species have been recorded from Mud Lake.

Ceratium hirundinella	R	*Mougeotia* sp.	R
Closterium sp.	R	*Planorbis*	R
Coelosphaerium sp.	R	*Diaptomus sicilis*	Re
Epithemia sp.	R	*Daphnia rosea*	B,Re

R: Rawson (1939)
Re: Reed (1959), in Rawson's samples
B: Brooks (1957), in Rawson's samples

Although cutthroat (*Salmo clarki*), rainbow (*S. gairdneri*) and brook trout have been stocked in Mud Lake in the past (National Parks stocking records; Ward 1974), only the latter species now occurs there (this survey; unreported data). Since brook trout were last stocked in 1968, the age 2, 4 and 5 fish collected in 1974 must be the result of natural recruitment. We found many fingerling brook trout near the small inlet at the north end of the lake.

The minnow *Rhinichthyes cataractae*, also found in this survey, is native to the Bow drainage. Ward (1974) reported it only from the Cave and Basin hotspring outlet in Banff Park, but Paetz and Nelson (1970) show a site record for it from the Spray River also. We collected it nowhere else in this survey.

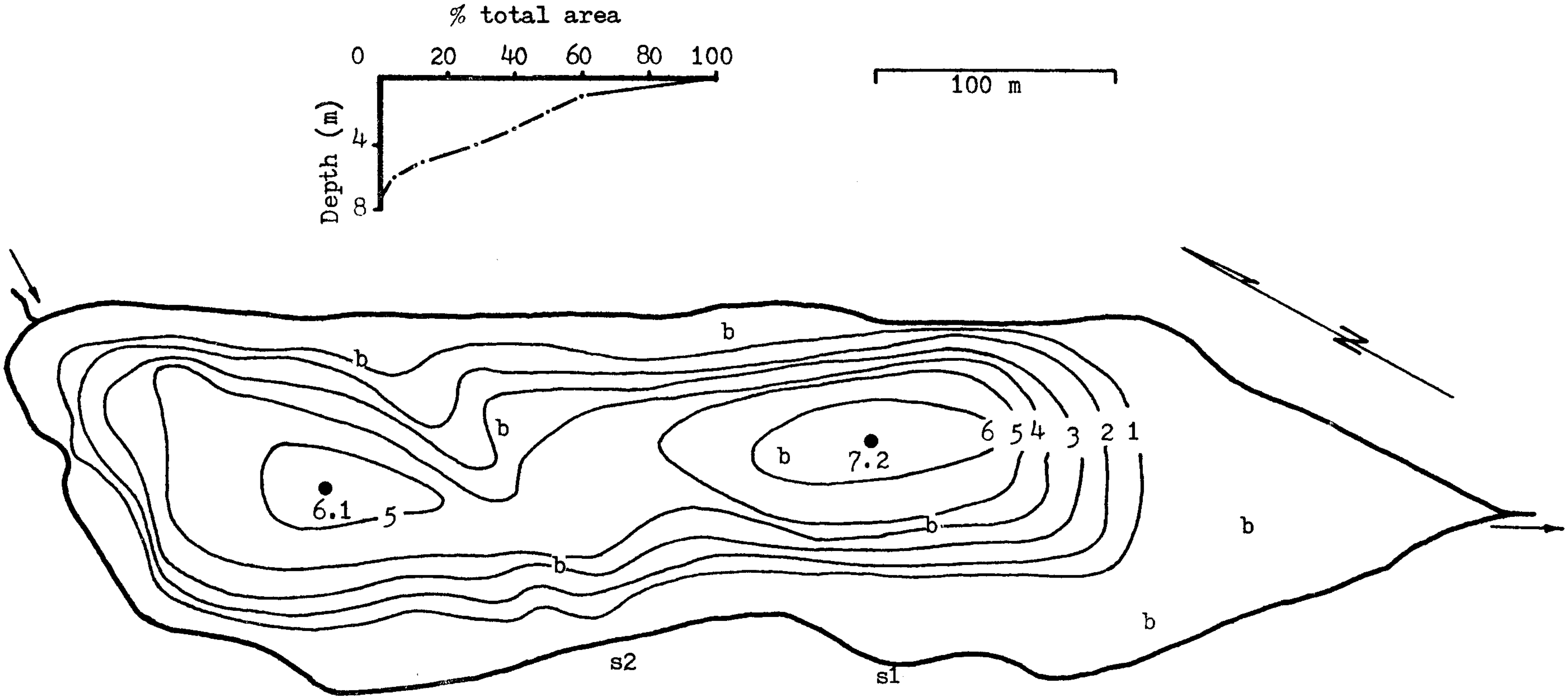


Figure 2.88. Bathymetric map and hypsographic curve of Mud Lake. Depths are in metres.

b - bottom fauna collection
s - shoreline collection

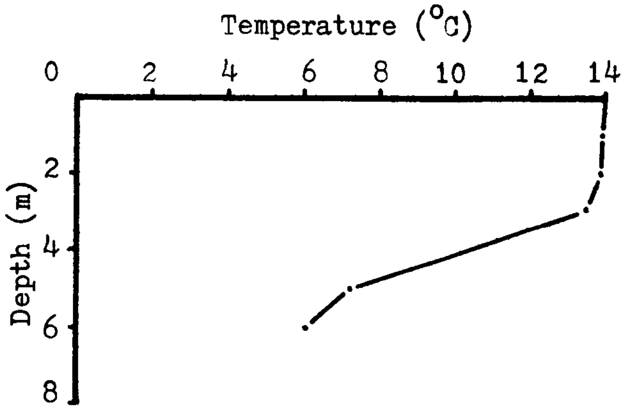


Figure 2.89. Representative temperature profile, Mud Lake, 20 viii 74.

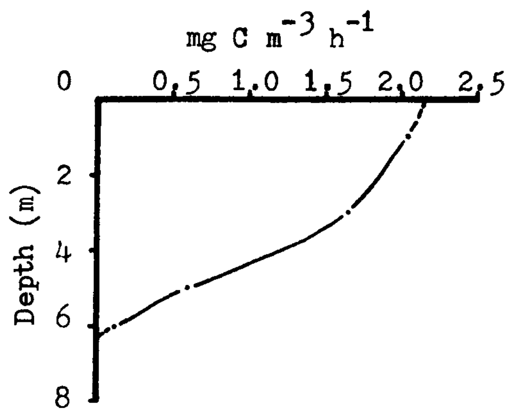
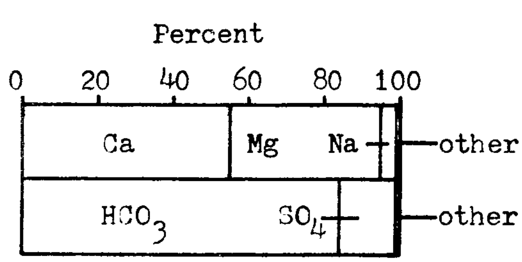


Figure 2.90. Representative profile of primary productivity, Mud Lake, 20 viii 74. Points are net figures (light minus dark). Samples were collected with a hose. Incubations 0845 - 1145 h MST

Figure 2.91. Percent ionic composition of surface water calculated on the basis of equivalent weights, Mud Lake, 25 vi 70.



O'BRIEN LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 640819, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class III (Natural Environment)

Access: by trail from Taylor Creek picnic site on Trans-Canada Highway 8.3 km (5.1 mi)

Elevation: 2118 m

Altitudinal zone: upper subalpine

Basin type: cirque, dammed by drift

Length: 334 m

Mean width 138 m

Area: 4.6 ha

Maximum depth: 20.7 m

Mean depth: 7.4 m

Volume: $33.9 \times 10^4 m^3$

Shoreline length: 915 m

Shoreline development: 1.20

Volume development: 1.07

Mean depth/max. depth: 0.36

Area/mean depth: 0.62

Water level fluctuation: less than 30 cm drop in water level through the summer

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 4	14.34	42.3
4 - 8	8.85	26.1
8 - 12	5.72	16.8
12 - 16	3.50	10.3
16 - 20	1.50	4.4
20 - 20.7	0.03	0.1

Water renewal time: 39 days (14 viii 75)

Open-water period: unknown

Catchment area: 195 ha

Bedrock composition of catchment area: 7% Miette Group, 93% quartzite

Catchment area coverage: 5% forest, 95% exposed rock and low plants

(Catchment area - lake area)/lake area: 41

Human activities in catchment area: hiking, angling

Bottom composition: organic content of sediment 18.3%

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 25 vii 74

	composite 0 - 10 m	20 m
Conductivity:	60.5 μmho/cm @ 25C	231 μmho/cm @ 25c
pH:	7.1 units	6.8 units
Total alkalinity:	34.2	54.6

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 14 viii 75 Depth: surface

Turbidity: 0.5 JTU Colour: < 5 HU

pH: 7.7 units Sum of constituents: 17.78

Conductivity: 35.3 μmho/cm @ 25C Sum const./cond: 0.50

Total alkalinity as $CaCO_3$: 12.4

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 18.1

Total inorganic carbon: 3 Total organic carbon: 2

Major constituents
Calcium: 3.3 Magnesium: 2.4 Sodium: 0.2 Potassium: 0.1
Bicarbonate: 15.1 Carbonate: 0 Sulphate: 4.1 Chloride: 0.1

Minor constituents
Nitrogen (nitrate + nitrite): 0.03 Nitrogen (Kjeldahl): 0.1
Phosphorus (total): 0.006

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date:	19 vii 73	25 vii 74	25 vii 74
Depth:	0.5 m	0 - 10 m composite	20 m
Chlorophyta			
Chlamydomonas spp.	1		
Chrysophyta			
Chrysophyceae			
Kephyrion sp.		15	
Mallomonas akrokomos			8
Pseudokephyrion sp.		2	
Diatomaceae			
Achnanthes sp.	14	2	
Asterionella formosa			3
Cyclotella sp.	24	2	
Diatoma hiemale var. *mesodon*	1		

a. Phytoplankton (continued)

Date:	19 vii 73	25 vii 74	25 vii 74
Depth:	0.5 m	0 - 10 m composite	20 m
Diatomaceae (continued)			
Gomphonema olivaceum	4		
Hannea arcus	3		
Cymbella ventricosa	1		
Navicula elginensis			2
Navicula spp.	2		
Pinnularia nodosa			2
Synedra amphicephala	12		3
S. ulna		2	
Cryptophyta			
Cryptomonas sp.			11
Rhodomonas minuta	4	375	341

b. Zooplankton (collections: 19 vii 73, 25 vii 74)
Units are maximum numbers per litre.

Rotifera	
Keratella quadrata	0.1 - 1
Copepoda	
Diaptomus arcticus	5.856
Diacyclops bicuspidatus thomasi	0.122

maximum crustacean standing crop: 10.8 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

no macrophytes in lake, but filamentous green algae cover the surface of the sediments in many places, even below 10 m

b. Shoreline fauna
Units are numbers collected.

collections:	19 vii 73	25 vii 74 30 min
Annelida		
Oligochaeta		10
Crustacea		
Copepoda		
Macrocyclops albidus	8	
Insecta		
Ephemeroptera		
Ameletus (nr. *celer* and *celeroides*)	1	1
Trichoptera		
Limnephilidae	13	17
" pupae	3	
Coleoptera		
Agabus sp. adults		1
Agabus (*tristis*?) adults		4

b. Shoreline fauna (continued)

collections:	19 vii 73	25 vii 74 30 min
Coleoptera (continued)		
Hydroporus sp. adults		2
Hydroporus (*compertus*?) adults		1
Hydroporus or *Hygrotus* larvae		4
Diptera		
Chironomidae		
Procladius s. str.		4
Zavrelimyia		3
Corynoneura	3	16
Cricotopus or *Orthocladius*		+
Paracladius		+
Psectrocladius		1
Paratanytarsus	+	1
Mollusca		
Pelecypoda		
Sphaeriidae		29

c. Bottom fauna (collection: 25 vii 74, n = 4)
Units are mean numbers/m^2.

Crustacea	
Copepoda	
Diaptomus copepodids	54
Amphipoda	
Gammarus lacustris	11
Insecta	
Trichoptera	
Limnephilidae (v. small)	11
Diptera	
Chironomidae	
Procladius s. str.	1173
Thienemannimyia group	32
Chironomidae (continued)	
Eukiefferiella	22
Corynoneura	334
Cricotopus or *Orthocladius*	388
" " " pupae	11
Chironomus	11
Paratanytarsus	1281
Tanytarsus	1701
" pupae	43
Mollusca	
Pelecypoda	
Pisidium	1281

Standing crop (mean preserved wet weight/m^2):

Chironomidae	6.192 gm
Gammarus	0.090 gm
Sphaeriidae	1.528 gm

3. Fish

Collection date: 24-25 vii 74 Set duration: 16 h

Gear: 20 m each of 3/4, 1½, 2, 3, 4-inch mesh green multifilament nylon gillnet set on bottom

Catch: 21 cutthroat trout (*Salmo clarki*); 3 males, 17 females, 1 unsexed

Age:	3	4	5	6	7	8	9	10
Number:	1	1	9	5	1	1	1	1
Mean fork l. (mm):	94	250	205.8	285.0	350	301	277	390
Mean weight (gm):	8.5	136	90.3	210.8	482	289	213	595

One specimen could not be aged.

Maturity: All of the females and all but one of the males had just finished spawning or were partly spent. Milt ran freely from the remaining male. The age 3 specimen was immature.

Food: 21 stomachs examined, 2 (9.5%) were empty

Food item	% of fish with item	mean % total stomach contents by volume
Chironomidae	89	47.6
unident. winged insects	42	12.6
Trichoptera	58	12.1
unident. insect parts	16	8.9
unident. material	10	6.3
small mammal (shrew?)	5	4.2
Coleoptera (terrest.)	32	2.9
Gammarus lacustris	5	2.4
Arachnida (terrest.)	5	0.3
Coleoptera (aquatic)	16	~0

D. Discussion

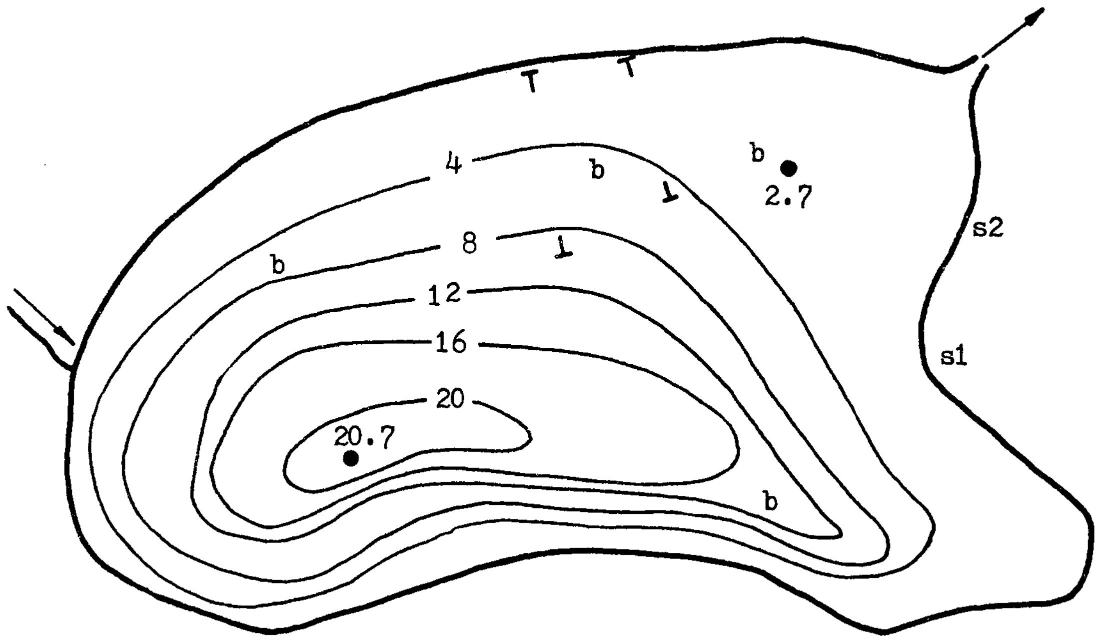
Although Rawson (1939) did not examine O'Brien (Larch) Lake, he was told the lake was always clear. The water clarity has evidently not changed in the intervening years (Figure 2.93).

The large midwater maximum in the primary productivity curve (Figure 2.94) is significant. *Rhodomonas minuta* was essentially the only phytoplankter, particularly in the upper 10 m. It was collected at all depths from 0 to 10 m, but incubated only at 1, 3, 7 and 10 m. Temperatures in the upper 10 m were nearly uniform (Figure 2.93), thus the most significant difference in environmental factors was in light. *R. minuta* evidently had a light intensity optimum at 7 m under the conditions of this experiment.

Cutthroat trout were last stocked in O'Brien Lake in 1968. All of the fish caught in this survey were therefore the result of natural recruitment. The outlet and a short section of the main inlet stream might serve as suitable spawning sites. During our 1974 visit, we observed several places in the gravel of the outlet that had been disturbed, possibly by the trout during redd-building.

No line was calculated for the length - weight plot (Figure 2.97) because the points include both gravid and spent fish.

The water chemistry data revealed substantial chemical stratification that was not reflected in the thermal profile (Figure 2.93). This stratification probably explains the discrepancy between the field and laboratory results.



(outline map from NTS map 82 N/8 east)

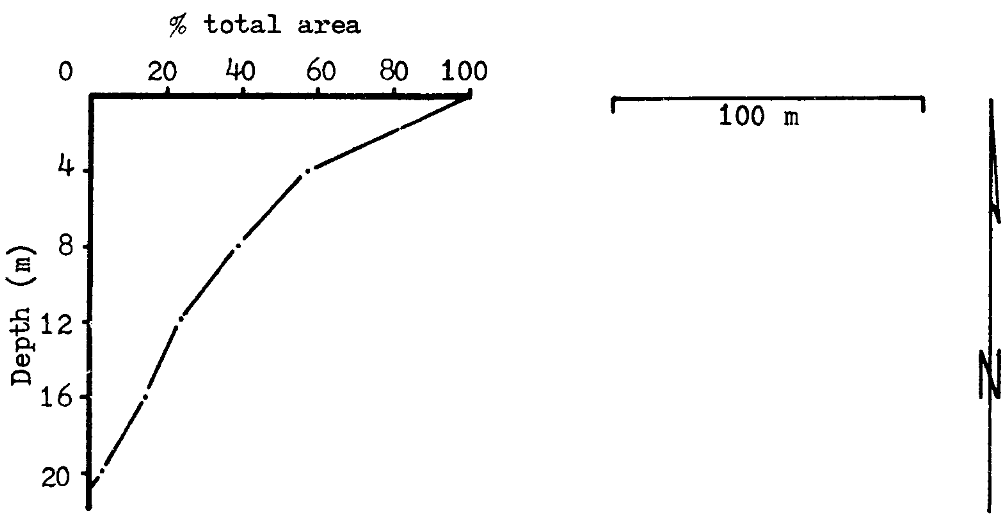
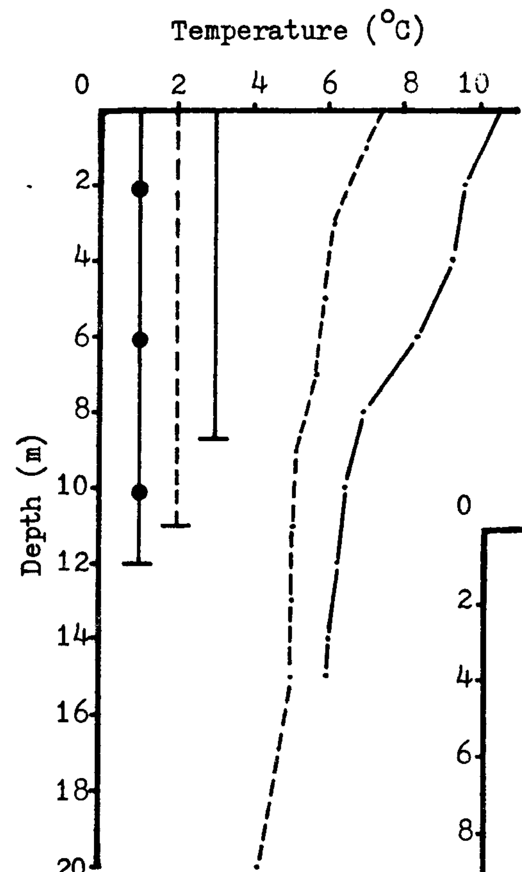


Figure 2.92. Bathymetric map and hypsographic curve of O'Brien Lake. Depths are in metres.

- b - bottom fauna collection
- s - shoreline collection
- ⊢ ⊣ - gillnet set between points

Figure 2.93. Temperature profiles and Secchi depth readings (⊥), O'Brien Lake.

19 vii 73 —●—
25 vii 74 - - - -
14 viii 75 ———



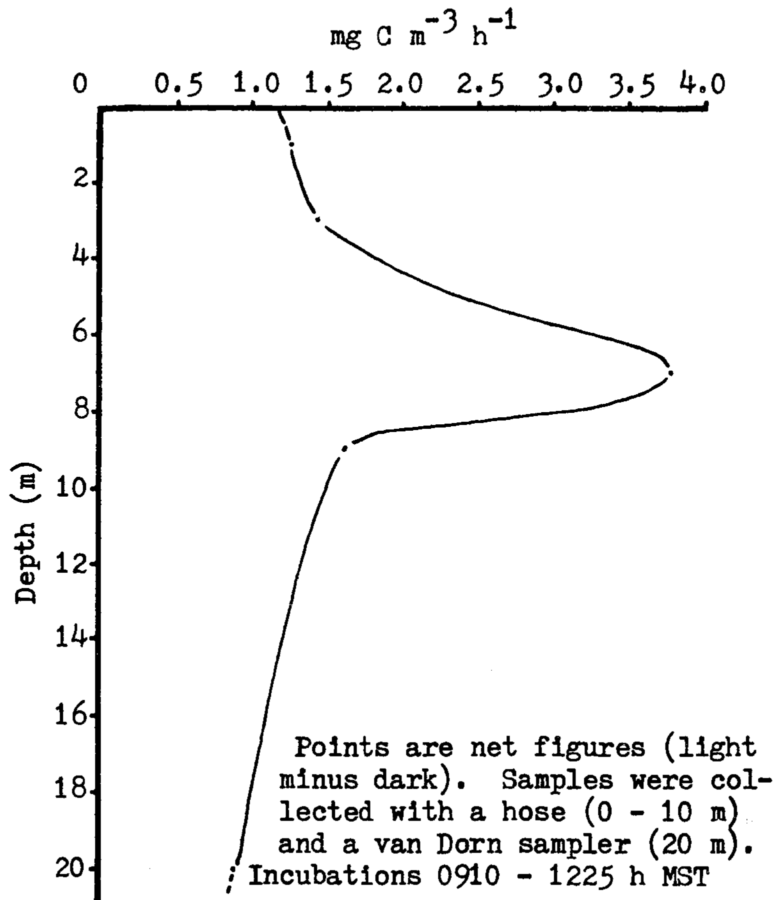


Figure 2.94. Profile of primary productivity, O'Brien Lake, 25 vii 74.

Figure 2.95. Percent ionic composition of surface water calculated on the basis of equivalent weights, O'Brien Lake, 14 viii 75.

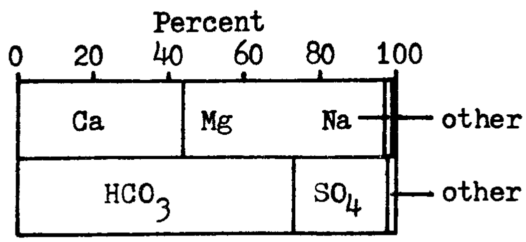


Figure 2.96. Growth diagram of cutthroat trout, O'Brien Lake, 24-25 vii 74.

Figure 2.97. Length - weight relationship of cutthroat trout, O'Brien Lake, 24-25 vii 74.

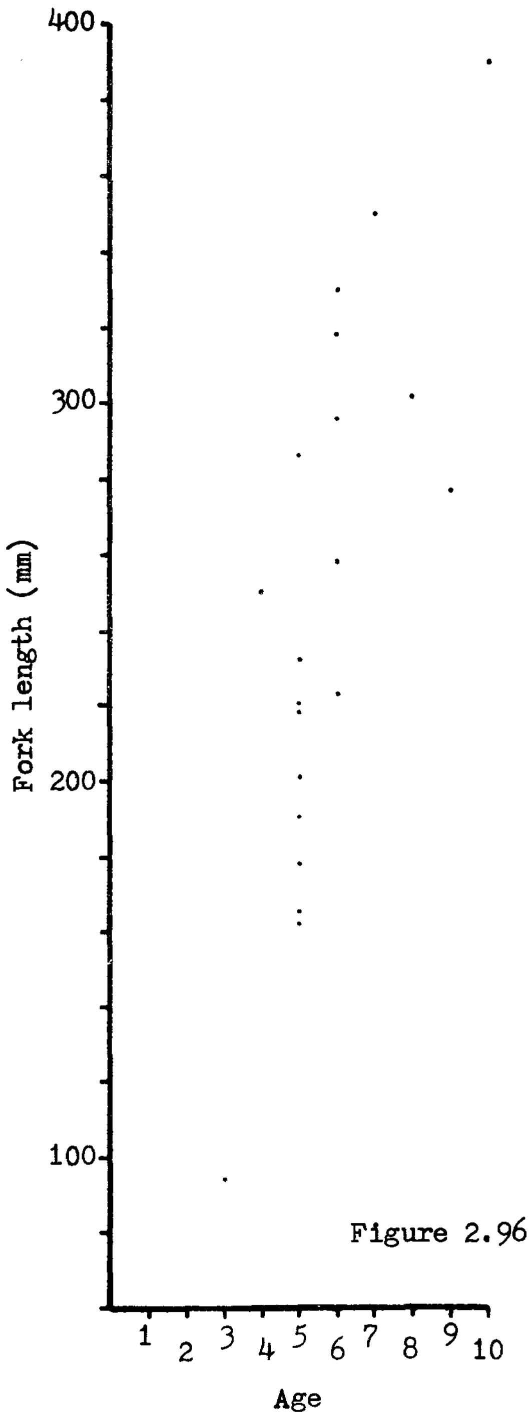


Figure 2.96

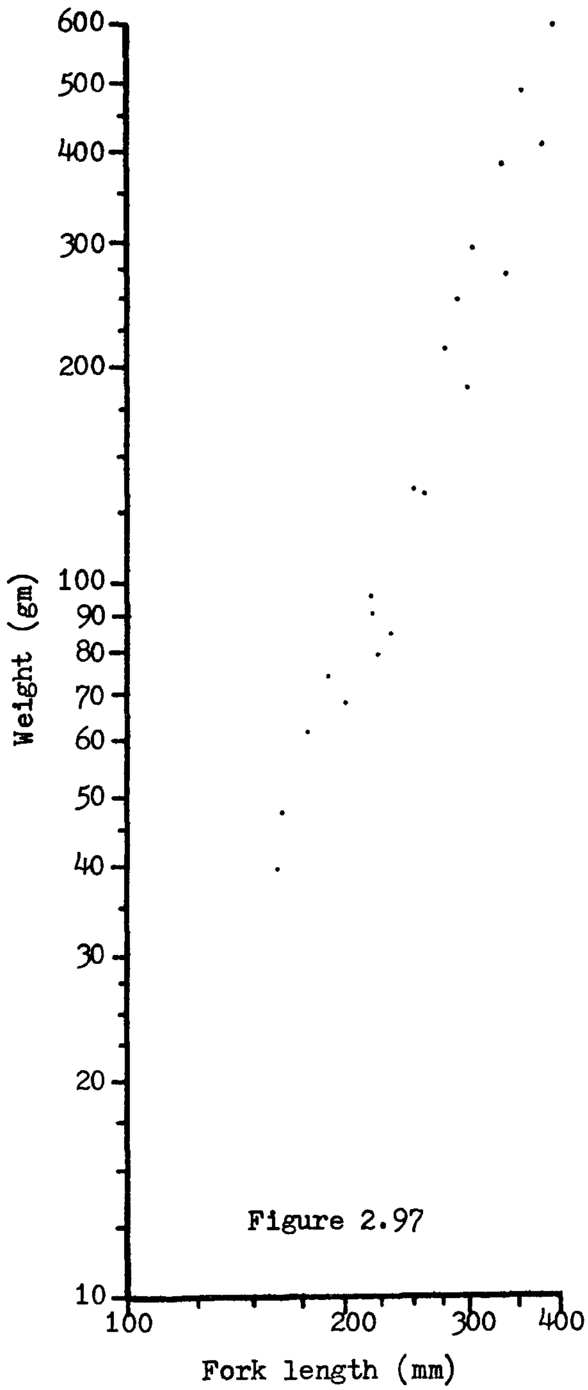


Figure 2.97

PTARMIGAN LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NH 643039, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: restricted road to Temple Lodge, then by trail 4.7 km (2.9 mi)

Elevation: 2332 m

Altitudinal zone: alpine

Length: 1152 m

Mean width: 242 m

Area: 27.9 ha

Maximum depth: 21.3 m

Mean depth: 7.0 m

Volume: $195.0 \times 10^4 m^3$

Shoreline length: 2764 m

Shoreline development: 1.48

Volume development: 0.98

Mean depth/max. depth: 0.33

Area/mean depth: 3.99

Water level fluctuation: approximately 30 cm drop in level through the summer (1975)

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 3	66.42	34.1
3 - 6	43.11	22.1
6 - 9	34.20	17.5
9 - 12	24.03	12.3
12 - 15	15.14	7.8
15 - 18	8.84	4.5
18 - 21	3.24	1.7
21 - 21.3	0.04	~0

Water renewal time: 68 days (n=2), or approximately 2 times per year (1974)

Open-water period: mid July to late October (approximately 110 ice-free days)

Catchment area: 195 ha

Bedrock composition of catchment area: 85% quartzite, 15% Cambrian carbonate rocks

Catchment area coverage: 100% exposed rock and low plants

(Catchment area - lake area)/lake area: 6

Human activities in catchment area: horseback riding, hiking, angling, unauthorized camping

Bottom composition: The bottom of the shallow eastern end of the lake is covered by light-coloured sediments. The bottom of the near shore areas elsewhere is covered mainly by rock fragments and sandy deposits. The deep sediments are mainly black, gritty and have an organic content of 13.1% (n=2).

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise) summer, surface

Conductivity: 71.5 µmho/cm @ 25C pH: 7.3 units (n = 2)

Total alkalinity as $CaCO_3$: 34.1

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 34.2 Total acidity: 2.96

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 22 vii 66 Depth: 0.5 m

Turbidity: 0.4 JTU Colour: 7 HU

pH: 7.4 units Sum of constituents: 26.6

Conductivity: 53.3 µmho/cm @ 25C Sum const./cond: 0.50

Total alkalinity as $CaCO_3$: 22.1

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 26.3

Major constituents
Calcium: 6.2 Magnesium: 2.6 Sodium: 0.3 Potassium: 0.3
Bicarbonate: 26.9 Carbonate: 0 Sulphate: 3.2 Chloride: 0.05

Minor constituents
Iron: 0.02 (total), < 0.01 (dissolved) Aluminum: 0.00
Manganese: 0.010 (total and dissolved) Copper: 0.000 Zinc: < 0.005
Fluoride: < 0.02 Phosphate: < 0.05 (total) Nitrate: < 0.05

Silica: 0.7

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 1 viii 74

Depth:	0 - 10 m composite	16 m
Chlorophyta		
Chlamydomonas botrys	3	
Chlamydomonas spp.	9	
Dictyosphaerium ehrenbergianum	315	202

a. Phytoplankton (continued)

Depth:	0 - 10 m composite	16 m
Pyrrophyta		
Glenodinium pulviscus	2	
Chrysophyta		
Chrysophyceae		
Bitrichia chodatii		2
Chrysococcus sp.	2	15
Chrysoikos skujae	14	42
Chrysolykos planctonicus	3	
Chromulina sp.	4	
Dinobryon cylindricum	50	14
Kephyrion sp.	4	
Pseudokephyrion hiemale	4	2
Diatomaceae		
Asterionella formosa	6	
Amphora ovalis		2
Cyclotella glomerata?	58	202
Cymbella sp.	2	
Nitzschia sp.	2	
Synedra nr. *radians*	12	33
Cryptophyta		
Cryptomonas sp.	2	4
Rhodomonas minuta	18	170

b. Zooplankton (collections: 22 vii 66, 20 viii 66, 31 vii 74, 30 viii 74)

Units are maximum numbers per litre.

Rotifera	
Filinia longiseta	0.1 - 1
Gastropus	10 - 100
Kellicottia longispina	10 - 100
Keratella quadrata	10 - 100
Polyarthra vulgaris	1 - 10
Synchaeta (*oblonga?*)	1 - 10
Cladocera	
Chydorus sphaericus	1
Daphnia middendorffiana	3.25
Copepoda	
Diaptomus arcticus	1
Diaptomus tyrrelli	5.615
Acanthocyclops vernalis	1
Insecta	
Chironomidae	0.010

maximum crustacean standing crop: 7.5 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

Horsetails (*Equisetum* sp.) are very sparsely-distributed at the shoreline. Clumps of an unidentified species of Characeae occur in the shallow eastern end of the lake.

b. Shoreline fauna
Units are numbers collected.

collections:	31 vii 74 30 min	30 viii 74 30 min
Platyhelminthes		
Turbellaria		20
Annelida		
Oligochaeta	2	70
Crustacea		
Gammarus lacustris		1
Insecta		
Trichoptera		
Limnephilidae	1	3
Diptera		
Chironomidae		
Corynoneura	1	
Cricotopus or *Orthocladius*		4
Paracladius		1
Psectrocladius		1
Orthocladiinae pupae		1
Phaenopsectra s. str.		10
Arachnida		
Hydracarina		
Hygrobates		11
Lebertia	3	1
Mollusca		
Pelecypoda		
Sphaeriidae		2

c. Bottom fauna (collection: 31 vii 74, n = 7)
Units are mean numbers/m^2.

Nematoda	18
Annelida	
Oligochaeta	62
Insecta	
Diptera	
Chironomidae	
Procladius s. str.	43
Tanypodinae pupae	12
Protanypus	6
Parakiefferiella?	43
Orthocladiinae pupae	12
Corynoneura	246
" pupae	68
Cricotopus	18
Heterotrissocladius	49
Psectrocladius	178
Chironomus	314
" pupae	12
Chironomidae (continued)	
Phaenopsectra s. str.	1931
Stictochironomus	55
Paratanytarsus?	800
" ? pupae	31
Tanytarsus	554
" pupae	6
Arachnida	
Hydracarina	
Lebertia	12
Mollusca	
Pelecypoda	
Pisidium	332

c. Bottom fauna (continued)

Standing crop (mean preserved wet weight/m^2).

Chironomidae	8.494 gm	Oligochaeta	0.919 gm
Sphaeriidae	0.547 gm	Nematoda	0.030 gm

3. Fish (B. D. Smiley data)

Collection date: 17-18 vii 73 Set duration: 20 h approx.

Gear: 7.6 m each of 3/4, 1, 1½, 2, 3, 4-inch mesh green monofilament nylon gillnet; 5 gangs set

Catch: 93 brook trout (Salvelinus fontinalis); 33 male, 59 females, 1 unsexed
1 lake trout (S. namaycush); male

a. Brook trout

Age:	1	3	5	6	7	8
Number:	1	1	12	22	26	15
Mean fork l. (mm):	105	171	240.3	251.2	252.4	265.6
Mean weight (gm):	12	55	151.8	169.5	173.8	196.1

Age:	9
Number:	2
Mean fork l. (mm):	254.5
Mean weight (gm):	181.0

Maturity: no reliable data

Food: 25 stomachs examined, none empty

Food item	% of fish with item	no. of times item rated as rare	common	abundant
Chironomidae	92.0		9	14
Diptera (unident.)	88.0	1	10	11
Hydracarina	60.0	5	9	1
Coleoptera (aquatic)	24.0	3	3	
Trichoptera	20.0	3	2	
Coleoptera (terrest.)	16.0	4		
Plant material	16.0	4		
Sphaeriidae	4.0		1	
Hymenoptera	8.0	2		
Amphipoda	4.0	1		

b. Lake trout

fork length 397 mm, weight 751 gm, age 6, male, stomach contents not examined

D. Discussion

At least some of the spot depths marked on Rawson's sketch map of Ptarmigan Lake (Rawson 1939) are apparently in feet rather than in the stated metres. The eastern basin is definitely not 12 to 19 m deep, but only 3 to 4 m; and the point indicated as 22 m is certainly no more than 12 m deep. Contrary to Rawson's belief, only about 20% of the lake area is greater than 12 m deep (Figure 2.98). There is no evidence on the shoreline of a change in water level since Rawson's time.

The following additional species have been recorded from Ptarmigan Lake by Rawson (1939).

Ceratium sp.	Conichilus sp.
Fragilaria sp.	Keratella cochlearis
Gomphosphaerium sp.	Daphnia pulex [1]
Tabellaria flocculosa	

1. probably D. middendorffiana according to present taxonomy (Brooks 1957)

Smiley (1976) reported on the fish population of Ptarmigan Lake. We re-examined his data for the present survey and make the following points.

1. Smiley (1976, pp. 15 and 27) concluded that brook trout males and females matured at age 7 and 5, respectively, but expressed doubt about the maturity data elsewhere (pp. 15 - 16). We believe that this conclusion is unreliable because his raw data show that 13 of 17 (76.5%) age 8 and 9 fish were of doubtful maturity or were immature.

2. Substitution into Smiley's length - weight equation shows that it is incorrect (cf. Figure 2.103); therefore his conclusions on fish condition based on the "condition index" (slope value) of his equation are invalid.

3. We agree with Smiley that natural recruitment appears to be rather limited in Ptarmigan Lake. We did observe some fingerling fish in one small inlet brook near the west end of the lake, however.

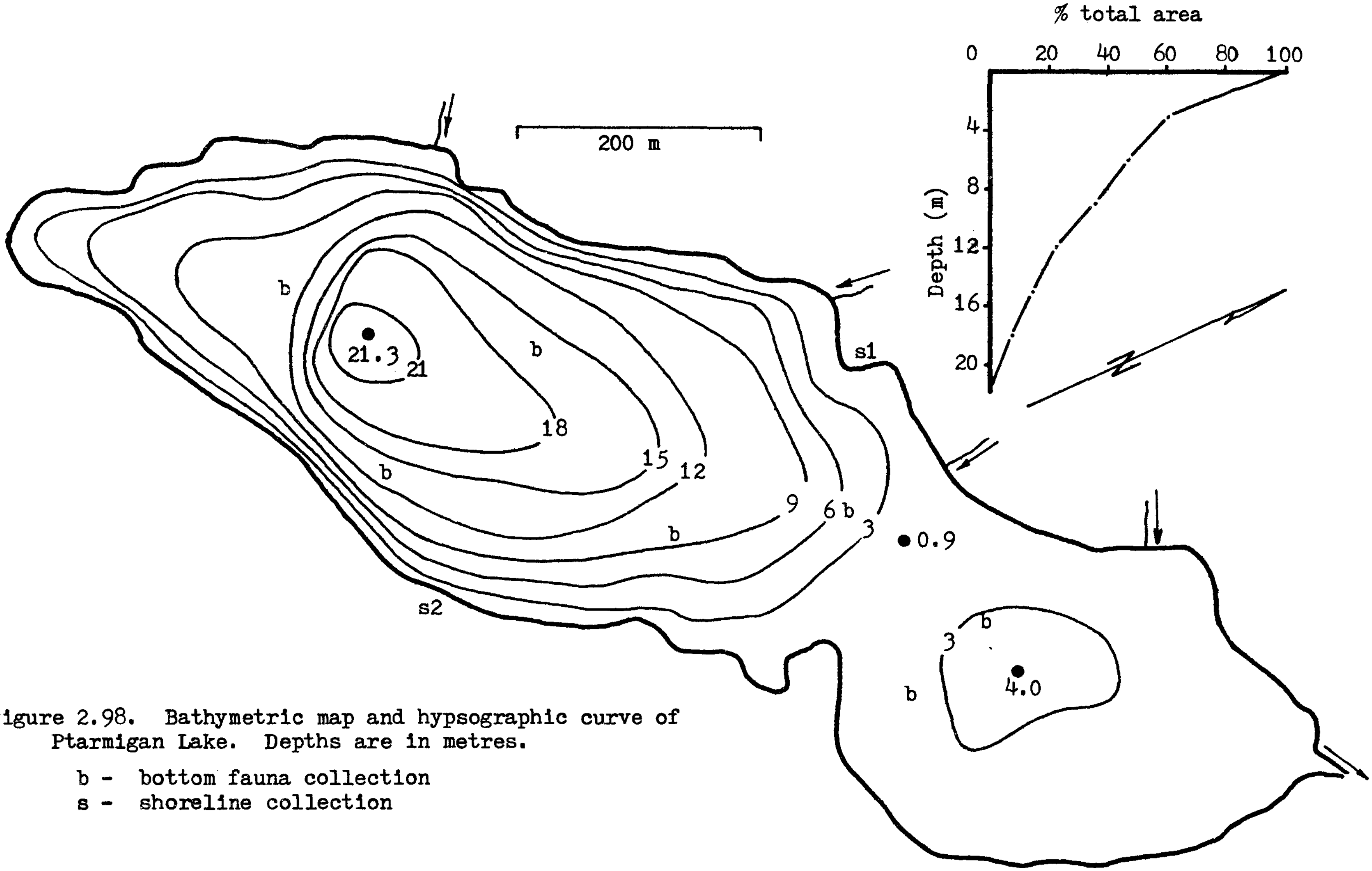


Figure 2.98. Bathymetric map and hypsographic curve of Ptarmigan Lake. Depths are in metres.

b - bottom fauna collection
s - shoreline collection

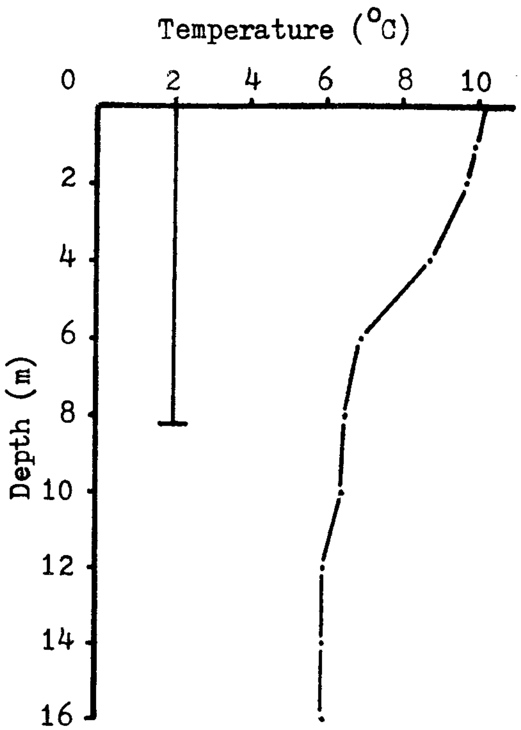


Figure 2.99. Representative mid-summer temperature profile and Secchi depth reading (⊥), Ptarmigan Lake, 1 viii 74.

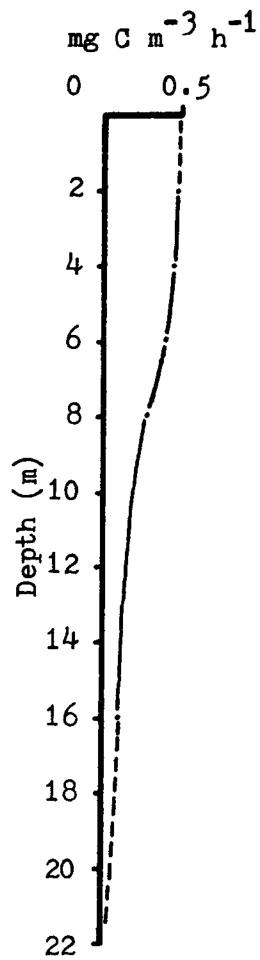


Figure 2.100. Representative mid-summer profile of primary productivity, Ptarmigan Lake, 1 viii 74. Points are net figures (light minus dark). Samples were collected with a hose (0 - 10 m) and a van Dorn sampler (16 m). Incubation 0815 - 1125 h MST

Figure 2.101. Percent ionic composition of surface water calculated on the basis of equivalent weights, Ptarmigan Lake, 22 vii 66.

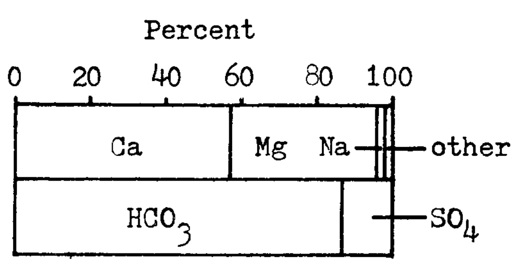
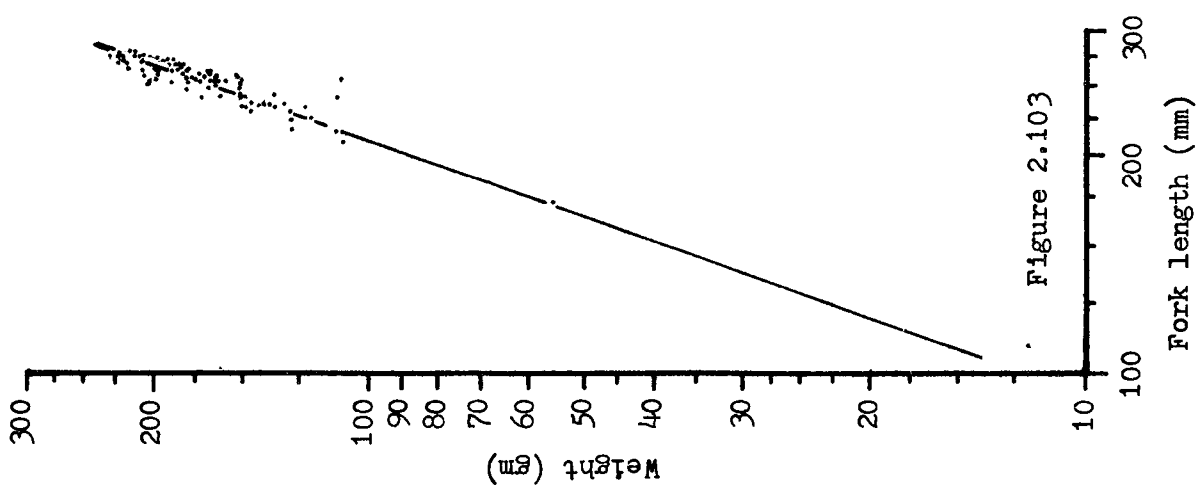
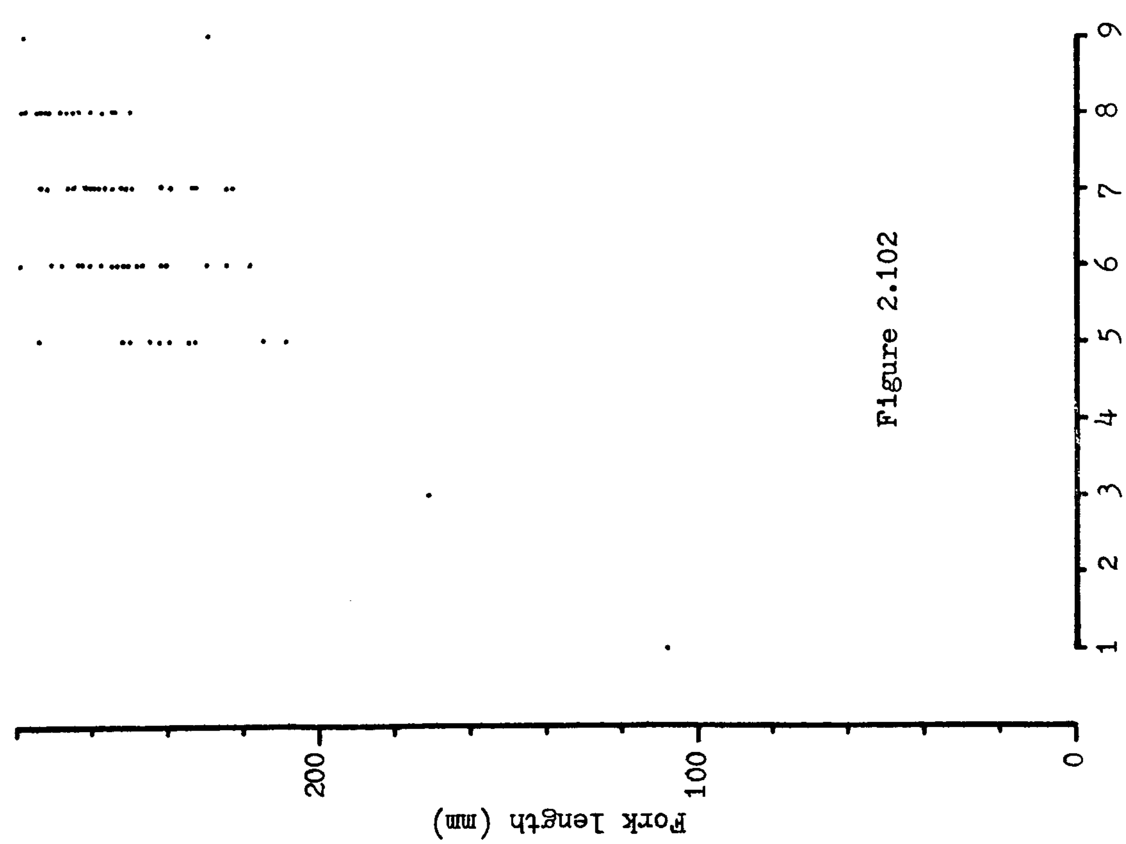


Figure 2.102. Growth diagram of brook trout, Ptarmigan Lake, 17-18 vii 73.

Figure 2.103. Length - weight relationship of brook trout, Ptarmigan Lake, 17-18 vii 73. The line was fitted by the method of least squares.

$$\log_{10} W = 2.87 \log_{10} L - 4.66$$





REDOUBT LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NH 645025, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: restricted road to Temple Lodge, then by trail 5.8 km (3.6 mi)

Elevation: 2393 m

Altitudinal zone: alpine

Basin type: depression at the junction of a tilted rock stratum and the base of Redoubt Mountain

Length: 1157 m

Mean width: 165 m

Area: 19.1 ha

Maximum depth: 11.0 m

Mean depth: 4.5 m

Volume: $85.4 \times 10^4 m^3$

Shoreline length: 2481 m

Shoreline development: 1.60

Volume development: 1.22

Mean depth/max. depth: 0.41

Area/mean depth: 4.24

Water level fluctuation: much less than 30 cm drop in level through the summer

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 2	33.22	38.9
2 - 4	24.00	28.1
4 - 6	15.63	18.3
6 - 8	9.02	10.6
8 - 10	3.31	3.9
10 - 11	0.18	0.2

Water renewal time: less than 45 days (29 viii 74), or about 2.5 times per year

Open-water period: probably early July to late October (approximately 110 ice-free days; no direct observations of break-up or freeze-up dates)

Catchment area: 99 ha

Bedrock composition of catchment area: 80% quartzite, 20% Cambrian carbonate rocks

Catchment area coverage: 100% exposed rock and low plants

(Catchment area - lake area)/lake area: 4

Human activities in catchment area: hiking, angling, primitive campsite

Bottom composition: Most of the bottom near the eastern shoreline is bare quartzite bedrock, and near the western shore, talus. The bottom of the shallow northern bay is covered by light-coloured mud. The deep sediments are dark brown and have an organic content of 17.0%.

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

	20 viii 66 surface	29 viii 74 composite 0 - 8 m
Conductivity (µmho/cm @ 25C):		126.5
pH (units):	7.9	8.0
Total alkalinity as $CaCO_3$:	61.5	54.6
Total hardness as $CaCO_3$:	68.4	
Total acidity:	2.28	

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 20 viii 66 Depth: 0.5 m

Turbidity: 0 JTU Colour: 0 HU

pH: 7.8 units Sum of constituents: 50.9

Conductivity: 99.0 µmho/cm @ 25C Sum const./cond: 0.51

Total alkalinity as $CaCO_3$: 48.1

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 50.6

Major constituents
Calcium: 15.2 Magnesium: 3.1 Sodium: 0.1 Potassium: 0.2
Bicarbonate: 58.6 Carbonate: 0 Sulphate: 1.6 Chloride: 0.2

Minor constituents
Iron: 0.03 (total), $<$ 0.01 (dissolved) Aluminum: $<$ 0.01
Manganese: 0.015 (total), 0.000 (dissolved) Copper: 0.005
Zinc: 0.005
Fluoride: $<$ 0.01 Phosphate: 0.01 (total) Nitrate: $<$ 0.05

Silica: 1.6

Ammonia: 0

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 29 viii 74

Depth: 0 - 8 m composite

a. Phytoplankton (continued)

Chlorophyta	
Chlamydomonas sp.	74
Dictyosphaerium ehrenbergianum	98
Chrysophyta	
Chrysophyceae	
Chrysoikos skujae	11
Chrysococcus sp.	12
Dinobryon sertularia	102
Kephyriopsis sp.	12
Pseudokephyrion hyalinum	20
Chrysophyta (continued)	
Diatomaceae	
Cyclotella sp.	69
Cymbella ventricosa	2
Navicula sp.	6
Synedra sp.	2
Cryptophyta	
Cryptomonas sp.	21
Rhodomonas minuta	9
unknown cell	39

b. Zooplankton (collections: 20 viii 66, 29 viii 74)

Units are maximum numbers per litre.

Copepoda	
Diaptomus arcticus	0.118
D. tyrrelli	7.826
Eucyclops speratus	0.007

maximum crustacean standing crop: 10.0 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

The only macrophyte seen was an unidentified species of moss which covered part of the bottom of the shallow north bay.

b. Shoreline fauna (collection: 29 viii 74)
Units are numbers collected.

Platyhelminthes	
Turbellaria	4
Annelida	
Oligochaeta	73
Crustacea	
Copepoda	
Diaptomus copepodids	2
Insecta	
Trichoptera	
Limnephilidae	1
Coleoptera	
Agabus tristis	3
Insecta (continued)	
Diptera	
Chironomidae	
unidentified pupae	1
Procladius s. str.	9
Cricotopus or *Orthocladius*, *Paracladius*, *Psectrocladius*	12
Phaenopsectra s. str., *Stictochironomus*	7
Mollusca	
Pelecypoda	
Sphaeriidae	13

c. Bottom fauna (collection: 29 viii 74, n = 6)
Units are mean numbers/m^2.

Nematoda	7
Annelida	
Oligochaeta	65
Crustacea	
Copepoda	
Diaptomus	7
Eucyclops speratus	7
Insecta	
Diptera	
Chironomidae	
Procladius s. str.	3114
Corynoneura	7
Paracladius	7
Phaenopsectra s. str.	179
Stictochironomus	187

c. Bottom fauna (continued)

Chironomidae (continued)		Mollusca	
Paratanytarsus?	22	Pelecypoda	
Tanytarsus	1902	Pisidium	1105
" pupae	22		

Standing crop (mean preserved wet weight/m^2):

Oligochaeta	1.665 gm	Sphaeriidae	5.092 gm
Chironomidae	13.274 gm		

3. Fish (B. D. Smiley data)

Collection date: 21-22 viii 73 Set duration: approx. 20 h

Gear: 7.6 m each of 3/4, 1, 1½, 2, 3, 4-inch mesh green monofilament nylon gillnet; 4 gangs set

Catch: 191 brook trout (Salvelinus fontinalis); 101 males, 90 females

Age:	2	3	4	5	6
Number:	6	24	7	2	2
Mean fork l. (mm):	218.0	232.4	244.0	295.5	243.5
Mean weight (gm):	127.3	156.5	199.0	400.5	208.0

Otoliths were not taken from most fish.

Maturity: The state of maturity of most fish was not recorded. The only class having enough observations to allow conclusions to be drawn was the age 3 male group. Of these, 9 of 13 whose state of maturity was recorded (69.2%) were mature.

Food: 42 stomachs examined, 2 (4.8%) empty

Food item	% of fish with item	no. of times item rated as rare	common	abundant
Diaptomidae	87.5	2	1	32
Chironomidae	82.5	3	10	20
Trichoptera	62.5	6	10	9
Diptera (unident.)	22.5	6	1	(2 unknown)
Hydracarina	12.5	4	1	
plant material	15.0	6		
Hymenoptera	10.0	3	1	
Hemiptera	12.5	5		
Sphaeriidae	7.5	3		
Cladocera	2.5	1		
Coleoptera (terrest.)	2.5	1		
" (aquatic)	2.5	1		
Lepidoptera	2.5	1		

D. Discussion

The following additional species have been recorded from Redoubt Lake by Rawson (1939).

Fragilaria sp.
Tabellaria flocculosa
Zygnema sp.
Kellicottia longispina (as *Notholca longispina*)
Keratella quadrata

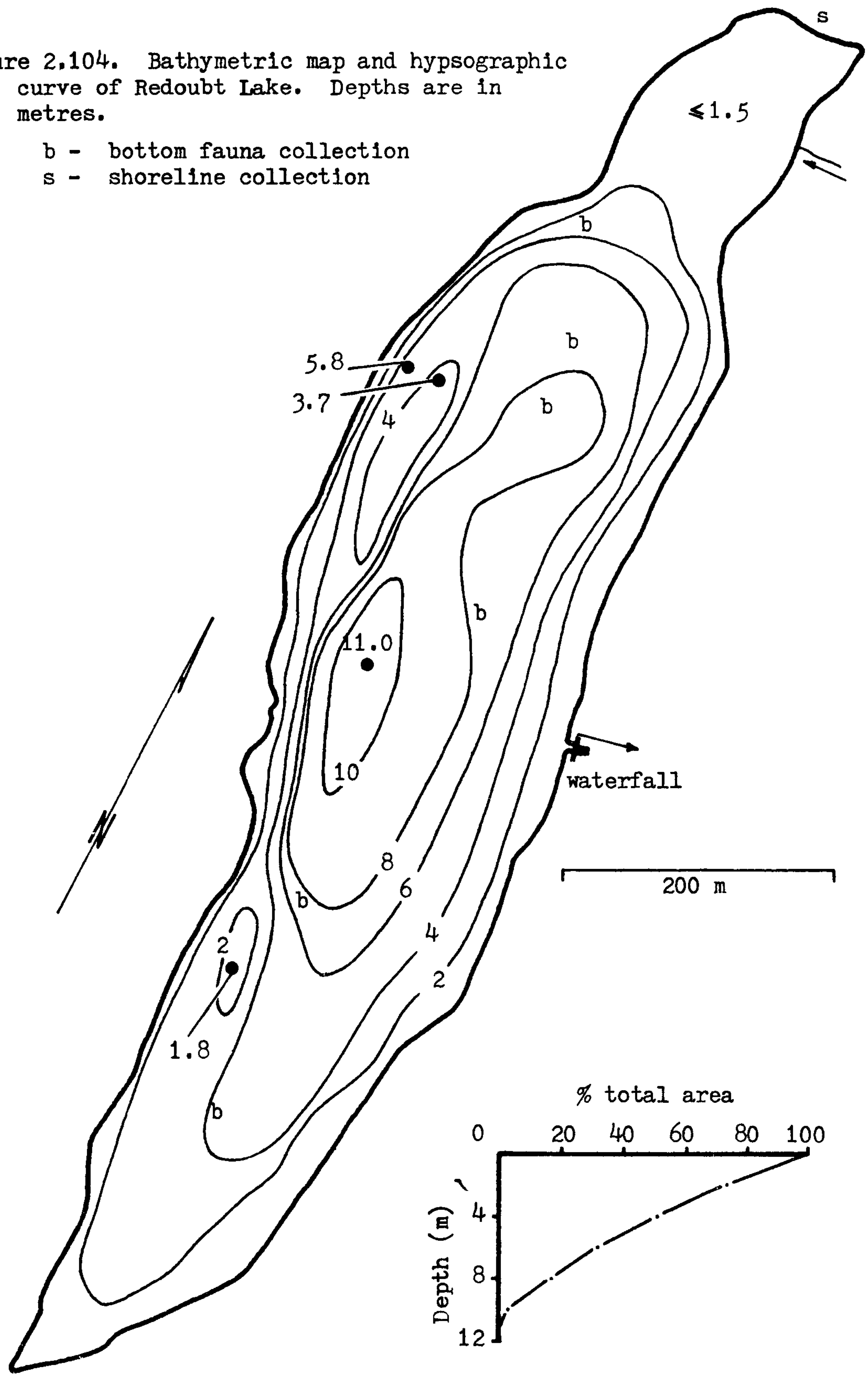
Cutthroat trout (*Salmo clarki*) were stocked in Redoubt Lake several times from 1932 to 1957. Thereafter only brook trout were stocked -- the last time in 1971 (National Parks stocking records). There appear to be no suitable spawning areas, and Smiley's (1976) netting data indicate cutthroats have been unable to maintain a population since stocking of them ceased. It is unclear whether there is any natural recruitment of brook trout, because the youngest fish caught in 1973 (age 2 fish) could be part of the 1971 stocked group depending on when they formed a recognizable growth check. Additional sampling would be required to determine if natural recruitment of brook trout occurs in Redoubt Lake.

Smiley's length - weight equation is incorrect (cf. Figure 2.109). His comments on the condition of the brook trout based on the slope factor of his equation are therefore invalid.

Data provided by Damm (1975) suggest that angling in Redoubt Lake is not particularly good, although his sample size is too small to draw any conclusions with confidence. He interviewed 6 anglers who had caught a total of 11 brook trout, spending an average of 1.73 hours to catch each fish. He estimated the total harvest for 1975 to be about 163 fish.

Figure 2.104. Bathymetric map and hypsographic curve of Redoubt Lake. Depths are in metres.

b - bottom fauna collection
s - shoreline collection



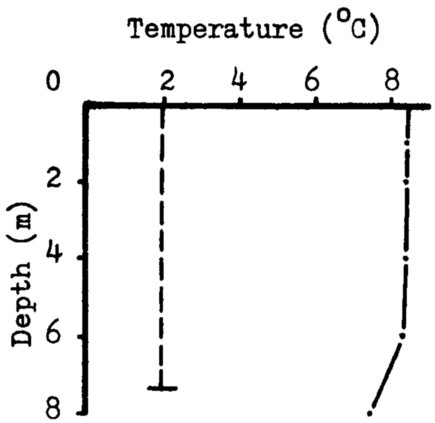


Figure 2.105. Temperature profile and Secchi depth reading (⊥), Redoubt Lake.

20 viii 66 ----
29 viii 74 ——

Figure 2.106. Profile of primary productivity, Redoubt Lake, 29 viii 74. Points are net figures (light minus dark). Samples were collected with a hose. Incubations 0825 - 1130 h MST

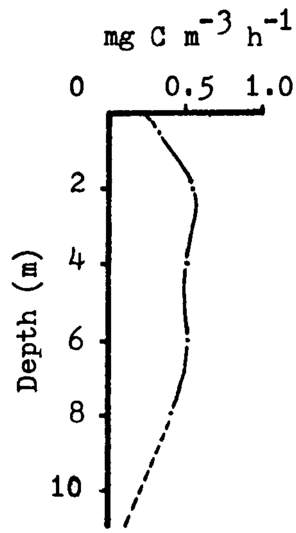


Figure 2.107. Percent ionic composition of surface water calculated on the basis of equivalent weights, Redoubt Lake, 20 viii 66.

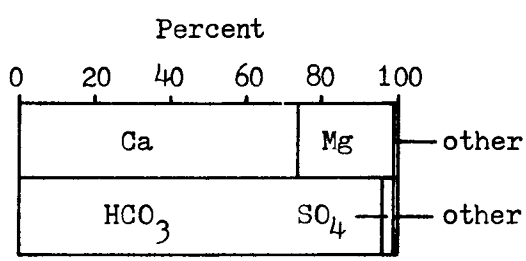
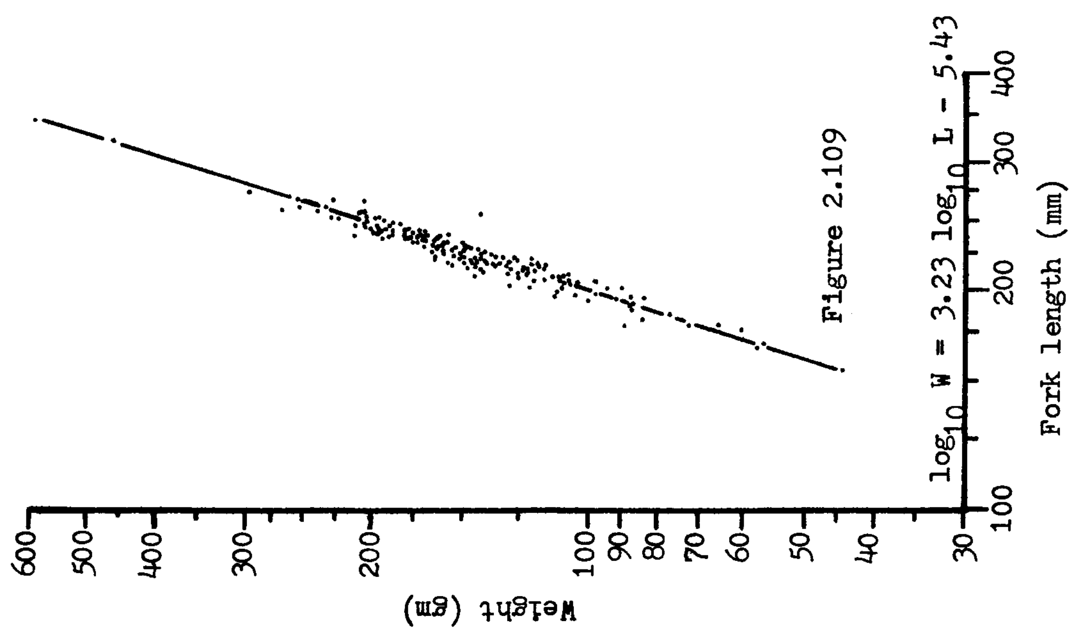
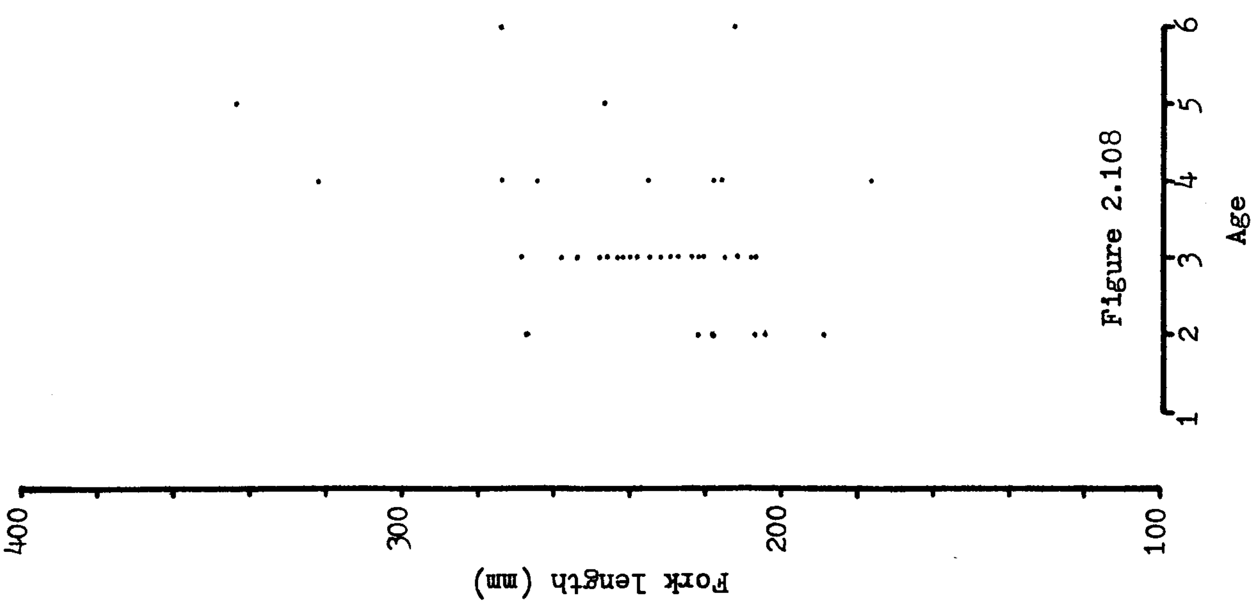


Figure 2.108. Growth diagram of brook trout, Redoubt Lake, 21-22 viii 73.

Figure 2.109. Length - weight relationship of brook trout, Redoubt Lake, 21-22 viii 73. The line was drawn by eye.





SENTINEL LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 543871, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Moraine Lake parking lot 4.7 km (2.9 mi)

Elevation: 2423 m

Altitudinal zone: alpine

Basin type: depression at the junction between the base of Pinnacle Mtn. and drift mounds

Length: 267 m

Mean width: 105 m

Area: 2.8 ha

Maximum depth: 6.7 m

Mean depth: 2.4 m

Volume: $6.7 \times 10^4 m^3$

Shoreline length: 718 m

Shoreline development: 1.21

Volume development: 1.07

Mean depth/max. depth: 0.36

Area/mean depth: 1.17

Water level fluctuation: 30 cm or less drop in water level through the summer (1975)

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 1	2.50	37.1
1 - 2	1.83	27.1
2 - 3	1.20	17.8
3 - 4	0.72	10.7
4 - 5	0.34	5.1
5 - 6	0.12	1.8
6 - 6.7	0.02	0.4

Water renewal time: more than 18 days (31 vii 75), based on maximum flow in the outlet on this date

Open-water period: unknown - Ice-free days certainly less than 100

Catchment area: 74 ha

Bedrock composition of catchment area: 41% quartzite, 59% Cambrian carbonate rocks

Catchment area coverage: 100% exposed rock and low plants

(Catchment area - lake area)/lake area: 25

Human activities in catchment area: hiking, unauthorized camping

Bottom composition: light greenish-coloured flocculent sediments in the shallow areas. Dark mud in the deep central zone of the pond has an organic content of 18.3%.

Secchi depth: greater than maximum depth throughout open-water period

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date:	7 viii 66	12 ix 67	31 vii 75
Depth:	surface	surface	0 - 4.5 m
Conductivity (µmho/cm @ 25C):		110	132
pH (units):	8.0	8.75	8.4
Total alkalinity as $CaCO_3$:	75.1	58	75.1
Total hardness as $CaCO_3$:	68.4	68	
Total acidity:	4.56	2.5	

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 7 viii 66 Depth: 0.5 m

Turbidity: 0.2 JTU Colour: 1 HU

pH: 8.2 units Sum of constituents: 62.9

Conductivity: 118 µmho/cm @ 25C Sum const./cond: 0.53

Total alkalinity as $CaCO_3$: 59.9

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 61.3

Major constituents
Calcium: 17.6 Magnesium: 4.2 Sodium: 0.2 Potassium: 0.1
Bicarbonate: 73.0 Carbonate: 0 Sulphate: 2.9 Chloride: 0.1

Minor constituents
Iron 0.02 (total), 0.00 (dissolved) Aluminum: 0.01
Manganese: 0.005 (total), 0.000 (dissolved) Copper: 0.000
Zinc: 0.000
Fluoride: 0.01 Phosphate: $<$ 0.05 (total) Nitrate: 0.1

Silica: 1.7

Ammonia: 0

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 31 vii 75 Depth: 0 - 4 m composite

Chlorophyta
Chlamydomonas sp. 7

Chrysophyta
Chrysophyceae
Chrysococcus rufescens 14

a. Phytoplankton (continued)

Chrysophyceae (continued)		Diatomaceae (continued)	
Pseudokephyrion sp.	28	*Navicula* spp.	28
Diatomaceae		*Pinnularia* sp.	14
Achnanthes lanceolata var. *elliptica*	7	*Nitzschia acicularis*	152
Achnanthes spp.	41	*Nitzschia* sp.	7
Cymbella microcephala	7	*Surirella* sp.	7
Cyclotella sp.	524	*Synedra radians*	110
Fragilaria construens	7	Cryptophyta	
F. pinnata	55	*Rhodomonas minuta*	55
Fragilaria spp.	97		
Gomphonema angustatum var. *productum*	7		
Navicula pupula var. *rectangularis*	7		

b. Zooplankton[1] (collections: 7 viii 66, 12 ix 67, 31 vii 75)
Units are maximum numbers per litre.

Cladocera		Copepoda	
Daphnia middendorffiana	0.69	*Diaptomus arcticus*	8.34

2. Bottom and Shoreline Organisms

a. Macrophytes

no macrophytes in lake

b. Shoreline fauna (collection: 31 vii 75, approx. 15 min)
Units are numbers collected.

Platyhelminthes		Insecta (continued)	
Turbellaria	1	Diptera	
Insecta		Chironomidae	
Trichoptera		*Psectrocladius*	6
Limnephilidae	2		
" pupae	7		

c. Bottom fauna (collection: 31 vii 75, n = 2)
Units are mean numbers/m^2.

Crustacea		Insecta (continued)	
Cladocera		Diptera	
Daphnia middendorffiana	22	Chironomidae	
Insecta		*Procladius* s. str.	6265
Trichoptera		*Tanytarsus*	1421
Limnephilidae	22	" pupae	840

Standing crop (mean preserved wet weight/m^2):

Trichoptera	3.363 gm	Chironomidae	15.087 gm

3. Fish

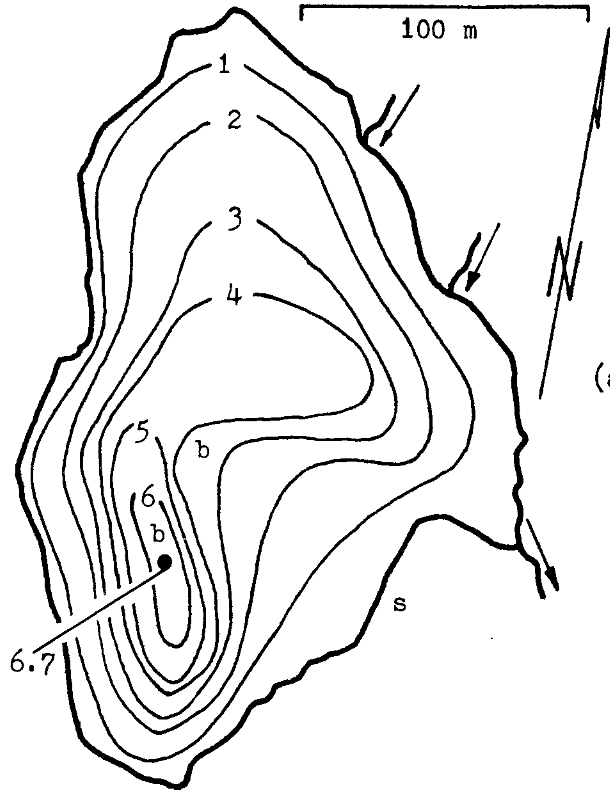
no collections

---

1. maximum crustacean standing crop: 8.5 animals/l

D. Discussion

This lake has apparently never been stocked with fish (Ward 1974; National Parks stocking records). We saw no fish in our visits to the lake. It is incapable of supporting a sport fishery of any size.



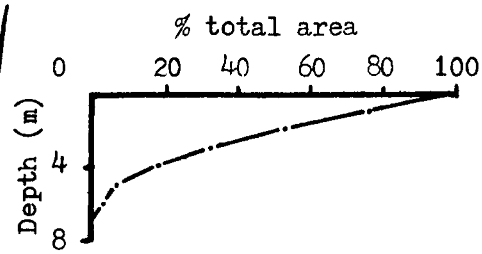


Figure 2.110

(after Anderson 1969a)

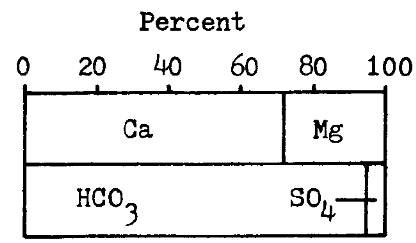


Figure 2.111

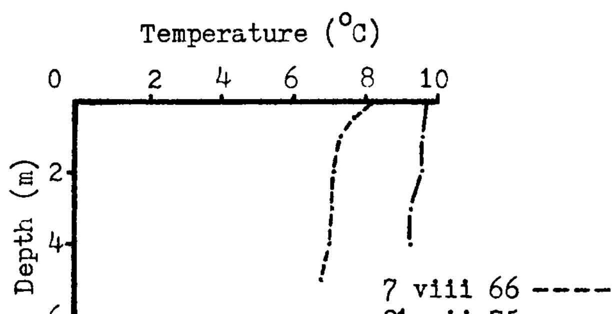


Figure 2.112

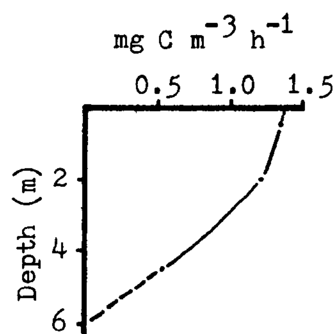


Figure 2.113.

Figure 2.110. Bathymetric map and hypsographic curve of Sentinel Lake. Depths are in metres.

b - bottom fauna collection
s - shoreline collection

Figure 2.111. Percent ionic composition of surface water calculated on the basis of equivalent weights, Sentinel Lake, 7 viii 66.

Figure 2.112. Temperature profiles, Sentinel Lake.

Figure 2.113. Profile of primary productivity, Sentinel Lake, 31 vii 75. Points are net figures (light minus dark). Samples were collected with a hose. Incubation 1135 - 1440 h MST

TAYLOR LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 630828, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: by trail from Taylor Creek picnic site on Trans-Canada Highway 6.3 km (3.9 mi)

Elevation: 2057 m

Altitudinal zone: upper subalpine

Basin type: cirque, dammed by drift

Length: 1192 m

Mean width: 226 m

Area: 27.0 ha

Maximum depth: 43.9 m

Mean depth: 14.7 m

Volume: 396.4 x $10^4 m^3$

Shoreline length: 2746 m

Shoreline development: 1.49

Volume development: 1.00

Mean depth/max. depth: 0.34

Area/mean depth: 1.84

Water level fluctuation: 30 cm drop or less in water level through the summer

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 5	116.49	29.4
5 - 10	81.51	20.6
10 - 15	58.92	14.9
15 - 20	45.20	11.4
20 - 25	34.38	8.7
25 - 30	25.48	6.4
30 - 35	18.79	4.7
35 - 40	12.93	3.3
40 - 43.9	2.70	0.6

Water renewal time: 116 days (23 vii 74), 245 days (13 viii 75), or approximately once per year

Open-water period: early July to probably late November (approximately 130 ice-free days; no direct observations of freeze-up dates)

Catchment area: 305 ha

Bedrock composition of catchment area: 31% Miette Group, 69% quartzite

Catchment area coverage: 12% forest, 8% glaciers, 80% exposed rock and low plants

(Catchment area - lake area)/lake area: 10

Human activities in catchment area: hiking, angling, primitive campsite

Bottom composition: organic content of sediments 6.0%

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 24 vii 74

Depth:	0 - 10 m composite	25 m
Conductivity (µmho/cm @ 25C):	82.5	88
pH (units):	7.2	7.2
Total alkalinity as $CaCO_3$:	34.2	27.3

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 14 viii 75 — Depth: surface

Turbidity: 1.5 JTU — Colour: 5 HU

pH: 7.7 units — Sum of constituents: 17.39

Conductivity: 35.9 µmho/cm @ 25C — Sum const./cond: 0.48

Total alkalinity as $CaCO_3$: 12.0

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 17

Total inorganic carbon: 3 — Total organic carbon: 2

Major constituents
Calcium: 2.7 Magnesium: 2.5 Sodium: 0.2 Potassium: 0.1
Bicarbonate: 14.6 Carbonate: 0 Sulphate: 4.4 Chloride: 0.2

Minor constituents
Nitrogen (nitrate + nitrite): 0.02 Nitrogen (Kjeldahl): 0.2
Phosphorus (total): 0.004

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date:	19 vii 73	23 vii 74	23 vii 74
Depth:	0.5 m	0 - 10 m composite	25 m
Chlorophyta			
Ankistrodesmus falcatus var. *acicularis*			2

a. Phytoplankton (continued)

Date:	19 vii 73	23 vii 74	23 vii 74
Depth:	0.5 m	0 - 10 m composite	25 m
Chlorophyta (continued)			
Ankistrodesmus falcatus		5	
Chlamydomonas spp.		9	
Crucigenia quadrata	24	6	
Dictyosphaerium ehrenbergianum	147	9	16
Gloeocystis gigas			2
Oocystis pusilla	12		6
Oocystis sp.			2
Quadrigula chodatii			6
Sphaerocystis schroeteri	6		13
Chrysophyta			
Chrysophyceae			
Chromulina sp.		2	6
Chrysococcus sp.		3	3
Kephyrion sp.	119	2	2
Ochromonas sp.			2
Diatomaceae			
Cyclotella ocellata	3		
Cyclotella spp.	275	51	14
Fragilaria crotonensis	2		
Navicula rhynchocephala		2	
Cryptophyta			
Rhodomonas minuta		192	26

b. Zooplankton[1] (collections: 19 vii 73, 24 viii 74)
Units are maximum numbers per litre.

Rotifera		Copepoda	
Conichilus unicornis	1 - 10	*Diaptomus* (*arcticus*?)	2.981
Kellicottia longispina	0.1 - 1	unident. cyclopoid (nauplii only)	0.004

2. Bottom and Shoreline Organisms

a. Macrophytes

no macrophytes seen

b. Shoreline fauna (collection: 23 vii 74, 30 min)
Units are numbers collected.

Platyhelminthes		Insecta	
Turbellaria	5	Plecoptera	
		Isoperla (nr. *ebria*)	1
Annelida		Trichoptera	
Oligochaeta	40	Limnephilidae	18
Crustacea		" pupae	2
Cladocera		Diptera	
Eurycercus lamellatus	4	Tipulidae	
		Dicranota	1

1. maximum crustacean standing crop: 2.6 animals/l

Diptera (continued)		Arachnida	
Chironomidae		Hydracarina	
Zavrelimyia	1	*Lebertia*	1
Cricotopus	2	Mollusca	
Cricotopus or *Orthocladius*	6	Pelecypoda	
Phaenopsectra s. str.	3	Sphaeriidae	3
unidentified larvae	1		

c. Bottom fauna (collection: 23 vii 74, n = 4)
Units are mean numbers/m^2.

Nematoda	11	Chironomidae (continued)	
Annelida		Orthocladiinae pupae	11
Oligochaeta (2 spp.)	269	*Chironomus*?	22
Crustacea		*Phaenopsectra* s. str.	495
Copepoda		*Stictochironomus*	1044
Diaptomus	172	Chironomini pupae	22
Macrocyclops albidus	11	*Constempellina*	11
Ostracoda	32	*Micropsectra*	161
Insecta		Mollusca	
Diptera		Pelecypoda	
Chironomidae		*Pisidium*	1141
Procladius s. str.	183		
Thienemannimyia group	11		
Heterotrissocladius	97		

Standing crop (mean preserved wet weight/m^2):

Oligochaeta	0.814 gm	Sphaeriidae	2.855 gm
Chironomidae	4.373 gm		

3. Fish

Collection date: 23-24 vii 74 Set duration: 14 h

Gear: 20 m each of 3/4, 1½, 2, 3, 4-inch mesh green nylon multi-filament gillnet set on bottom

Catch: 11 cutthroat trout (*Salmo clarki*); 6 males, 5 females

Age:	4	5	6	7
Number:	4	3	3	1
Mean fork l. (mm):	210.0	325.7	328.3	385
Mean weight (gm):	90.2	363.7	358.7	595

All specimens could be aged.

Maturity: Six fish were either spawning or spent. Three small age 4 males were immature.

Food: 11 stomachs examined, 2 (18.2%) empty

Food item	% of fish with item	mean % total stomach contents by volume
Chironomidae	77.8	37.2
Gammarus	33.3	21.1

Food item	% of fish with item	mean % total stomach contents by volume
Trichoptera	44.4	18.9
flying insects (unident.)	44.4	17.2
Plecoptera adults	11.1	4.4
insect parts (unident.)	11.1	1.1

D. Discussion

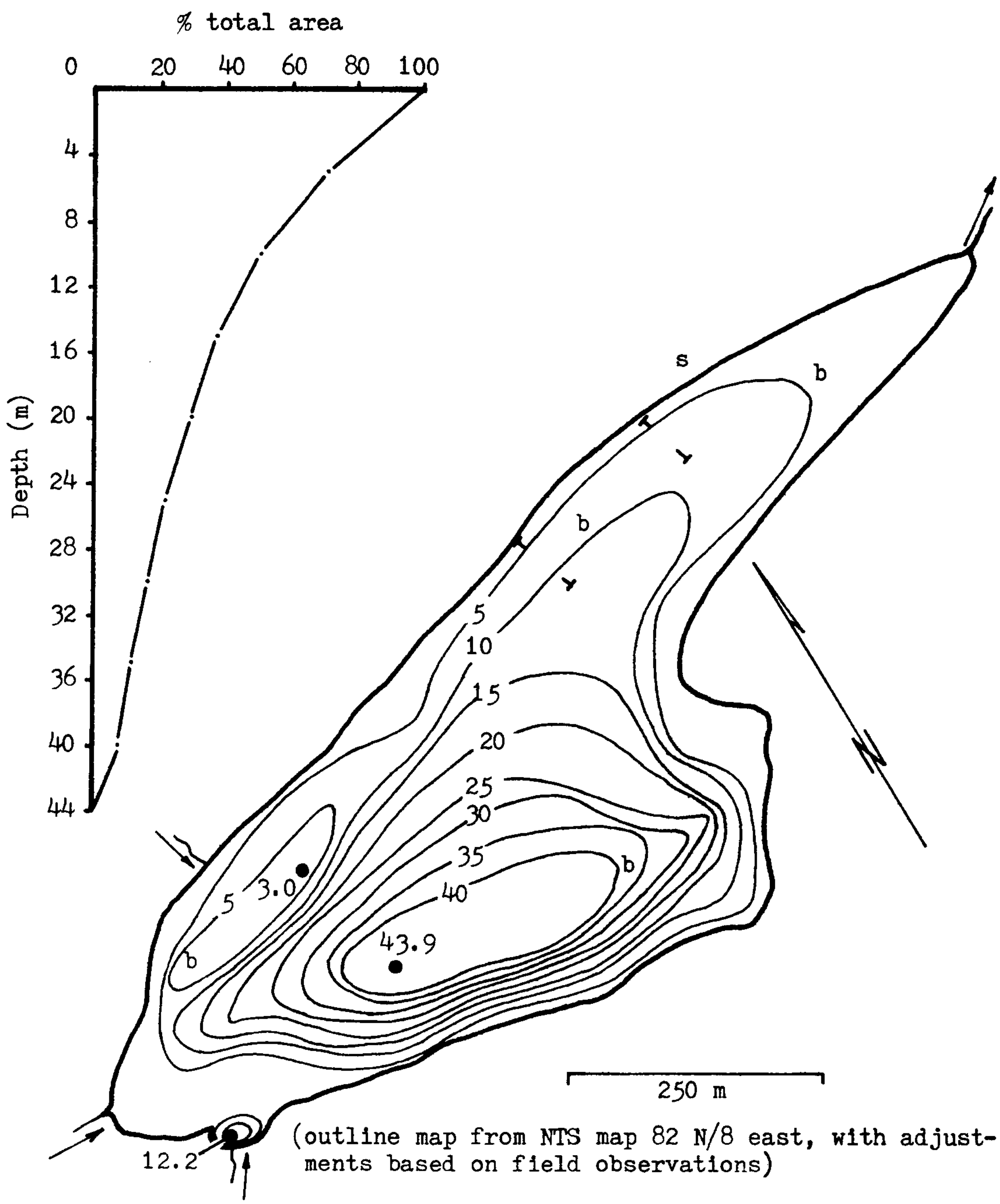
The maximum depth of Taylor Lake may be somewhat deeper than the 43.9 m shown in Figure 2.114. No soundings were made in the centre of the deepest portion.

Rawson (1939) did not visit Taylor Lake, but was told that it was heavily silted. Our recent Secchi data (Figure 2.115) indicate that siltation still occurs, but may be absent at times.

Taylor Lake has been stocked only with cutthroat trout, the last time in 1953 (Ward 1974; National Parks stocking records). The population is therefore being maintained by natural recruitment. The outlet appears to be a good spawning area, and the main inlet stream may be a suitable spawning site as well.

Figure 2.114. Bathymetric map and hypsographic curve of Taylor Lake. Depths are in metres.

b - bottom fauna collection
s - shoreline collection
⊢ ⊣ - gillnet set between points



(outline map from NTS map 82 N/8 east, with adjustments based on field observations)

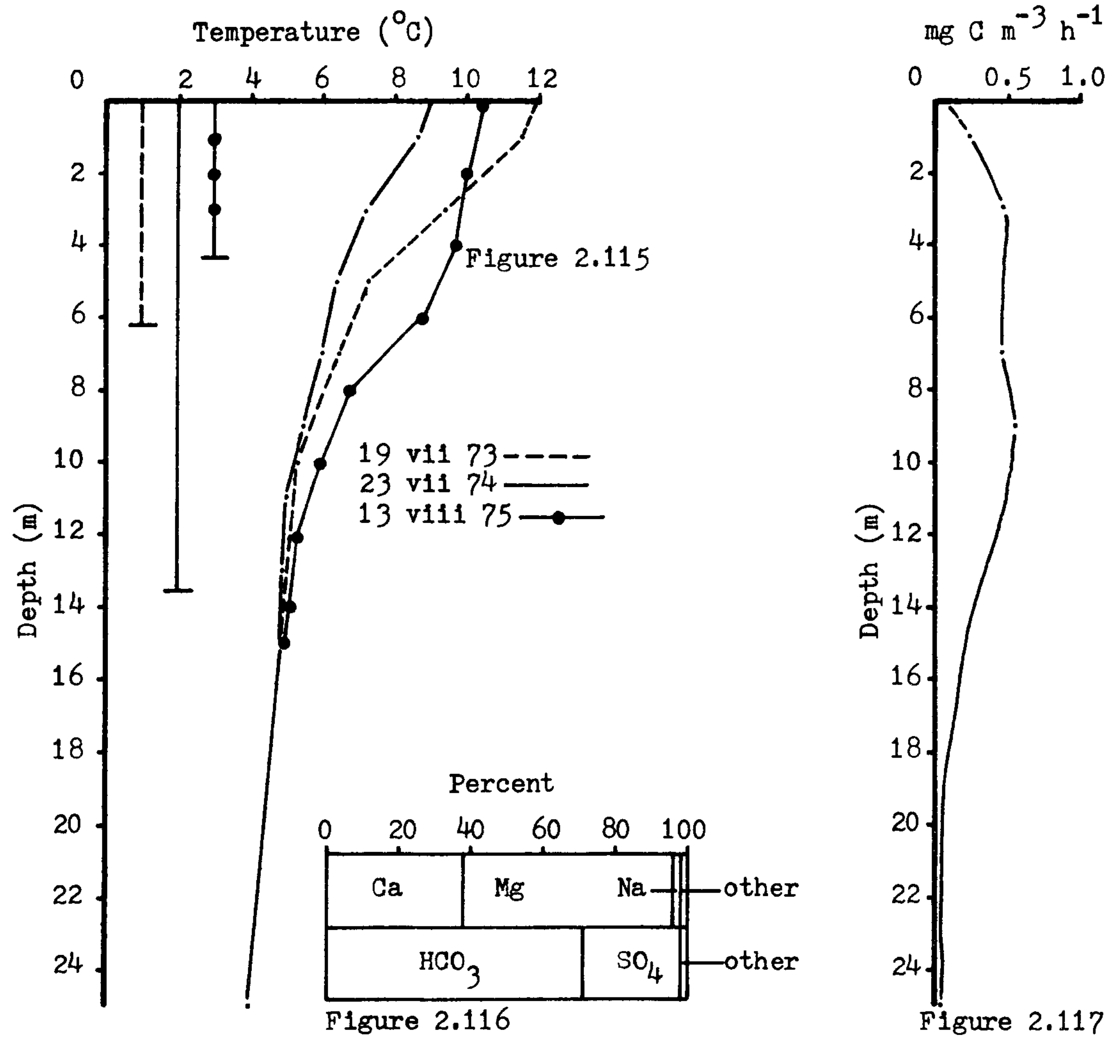


Figure 2.115. Temperature profiles and Secchi depth readings (⊥), Taylor Lake.

Figure 2.116. Percent ionic composition of surface water calculated on the basis of equivalent weights, Taylor Lake, 14 viii 75.

Figure 2.117. Profile of primary productivity, Taylor Lake, 24 vii 74. Points are net figures (light minus dark). Samples were collected with a hose (0 - 10 m) and a van Dorn sampler (25 m). Incubation 0920 - 1230 h MST

TEMPLE LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NG 571905, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class III (Natural Environment)

Access: by game trail from Moraine Lake road 1.9 km (1.2 mi)

Elevation: 2179 m

Altitudinal zone: treeline

Basin type: cirque

Length: 378 m

Mean width: 82 m

Area: 3.1 ha

Maximum depth: 14.0 m

Mean depth: 5.0 m

Volume: $15.4 \times 10^4 m^3$

Shoreline length: 862 m

Shoreline development: 1.38

Volume development: 1.06

Mean depth/max. depth: 0.36

Area/mean depth: 0.62

Water level fluctuation: no evidence of any drop in water level through summer of 1975

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 2	5.18	33.5
2 - 4	3.62	23.4
4 - 6	2.58	16.7
6 - 8	1.83	11.9
8 - 10	1.23	8.0
10 - 12	0.73	4.7
12 - 14	0.28	1.8

Water renewal time: 16 days (30 vii 75), or approximately 7 times per year

Open-water period: probably late June to late October (approximately 120 ice-free days; no direct observations of break-up or freeze-up dates)

Catchment area: 73 ha

Bedrock composition of catchment area: 14% Miette Group, 86% quartzite

Catchment area coverage: 100% exposed rock and low plants

(Catchment area - lake area)/lake area: 22

Human activities in catchment area: hiking, angling (both rare), angling probably only locally known

Bottom composition: organic content of sediment 15.9%.

Colour (½ secchi): murky-white

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date: 30 vii 75

Depth:	surface	10 m
Conductivity (µmho/cm @ 25C):	62.7	77
pH (units):	7.9	7.6
Total alkalinity as $CaCO_3$:	34.2	34.2

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 29 viii 75 — Depth: surface

Turbidity: 1.2 JTU — Colour: < 5 HU

pH: 8.7 units — Sum of constituents: 59.33

Conductivity: 95.3 µmho/cm @ 25C — Sum const./cond: 0.62

Total alkalinity as $CaCO_3$: 30.6

Phenolphthalein alkalinity as $CaCO_3$: 1.7

Total hardness as $CaCO_3$: 54.5

Total inorganic carbon: 7 — Total organic carbon: < 1

Major constituents
Calcium: 16.4 Magnesium: 3.3 Sodium: 0.2 Potassium: < 0.1
Bicarbonate: 33.2 Carbonate: 2 Sulphate: 14.4 Chloride: 7.4

Minor constituents
Nitrogen (nitrate + nitrite): < 0.01 Nitrogen (Kjeldahl): < 0.1
Phosphorus: 0.028 (total)

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 30 vii 75 — Depth: surface

Chlorophyta	
Chlamydomonas sp.	55
Dictyosphaerium elegans	7
Schroederia sp.	428
Chrysophyta	
Chrysophyceae	
Chrysococcus rufescens	7
Chrysophyceae (continued)	
Ochromonas sp.	55
Pseudokephyrion nr. *hyalinum*	138
Diatomaceae	
Achnanthes sp.	7
Cyclotella sp.	794
Synedra radians	1704

b. Zooplankton (collection: 30 vii 75)
Units are maximum numbers per litre.

Rotifera
Keratella cochlearis, *Keratella quadrata*, *Polyarthra vulgaris* — no counts

maximum crustacean standing crop: 0.2 animals/l

Copepoda
?*Orthocyclops modestus* (nauplius to C2) 0.18

2. Bottom and Shoreline Organisms

a. Macrophytes

no macrophytes seen

b. Shoreline fauna (collection: 29 viii 75, 10 min)

Units are numbers collected.

Insecta		Coleoptera	
Plecoptera		*Hydroporus compertus*	5
Capniinae	2		

c. Bottom fauna (collection: 30 vii 75, n = 2)
Units are mean numbers/m^2.

Insecta		Chironomidae (continued)	
Diptera		*Psectrocladius*	43
Chironomidae		*Chironomus*	2325
Cricotopus	86	*Paracladopelma*	22
Paracladius	22		

Standing crop (mean preserved wet weight/m^2):

Chironomidae 18.680 gm

3. Fish

Collection date: 29 viii 75 Set duration: 3 h

Gear: 20 m each of 3/4, $1\frac{1}{2}$, 2, 3, 4-inch mesh green monofilament nylon gillnet set on bottom

Catch: 19 brook trout (*Salvelinus fontinalis*); 6 males, 13 females

Age:	6	7	9	12
Number:	3	12	1	2
Mean fork l. (mm):	179.7	186.8	193	249.5
Mean weight (gm):	72.3	80.4	89	152.0

One fish could not be aged.

Maturity: All fish were mature. Four males and 3 females were gravid; the remaining fish were approaching spawning condition. The males in the latter group appeared to be further advanced in gonad development than were the females.

Food: 19 stomachs examined, 1 (5.3%) empty

Food item	% of fish with item	mean % total stomach contents by volume
Trichoptera	88.9	62.5
Chironomidae	61.1	18.6
insect parts (unident.)	27.8	11.1
Plecoptera	16.7	3.9
Corixidae	5.6	2.2
Lebertia	5.6	~0

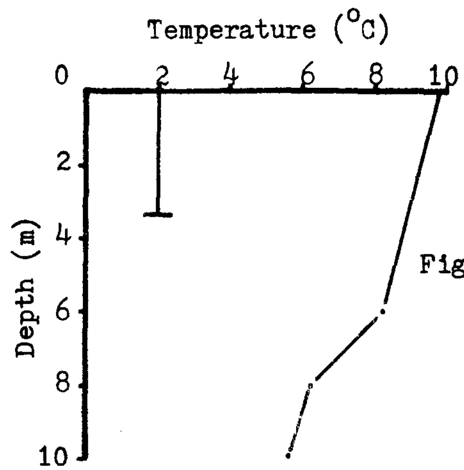
Parasites: Of 5 trout examined for parasites, one was infected with 5 _Crepidostomum farionis_ (Mudry and Anderson, in press).

D. Discussion

Brook trout were stocked in Temple Lake in 1964, 1965 and 1968; and rainbow trout (_Salmo gairdneri_) were planted in 1964 and 1967 (National Parks stocking records). Our netting results, though limited to only a three-hour gillnet set, suggest that rainbows no longer occur in the lake, and that there is a fairly large brook trout population.

Brook trout stocked in 1964, 1965 and 1968 should be age 11 or 12, 10 or 11, and 7 or 8, respectively, depending on whether the fish were able to add enough growth in the stocking year to be recognizable on the otoliths. (The fish were stocked in mid-summer in all years.) Our age data indicate that most of the fish were probably stocked. Perhaps 4 of the 19 caught (21%) were the result of natural recruitment. The absence of any fish younger than age 6 further suggests limited natural recruitment; however, one fingerling was seen near shore. Suitable spawning areas are not apparent, but points near the outlet might be adequate.

No line was calculated for the length - weight relationship because the few points suggest a curvilinear relationship.



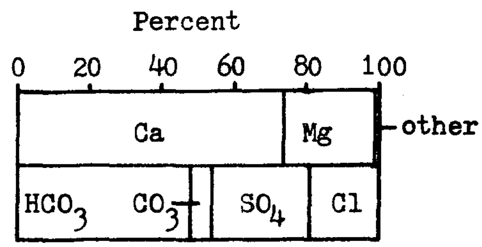


Figure 2.119. Percent ionic composition of surface water calculated on the basis of equivalent weights, Temple Lake, 29 viii 75.

Figure 2.118. Temperature profile and Secchi depth reading (⊥), Temple Lake, 30 vii 75.

Figure 2.120. Bathymetric map and hypsographic curve of Temple Lake. Depths are in metres.

b - bottom fauna collection
s - shoreline collection
⊢ ⊣ - gillnet set between points

(outline map from NTS map no. 82 N/8 east)

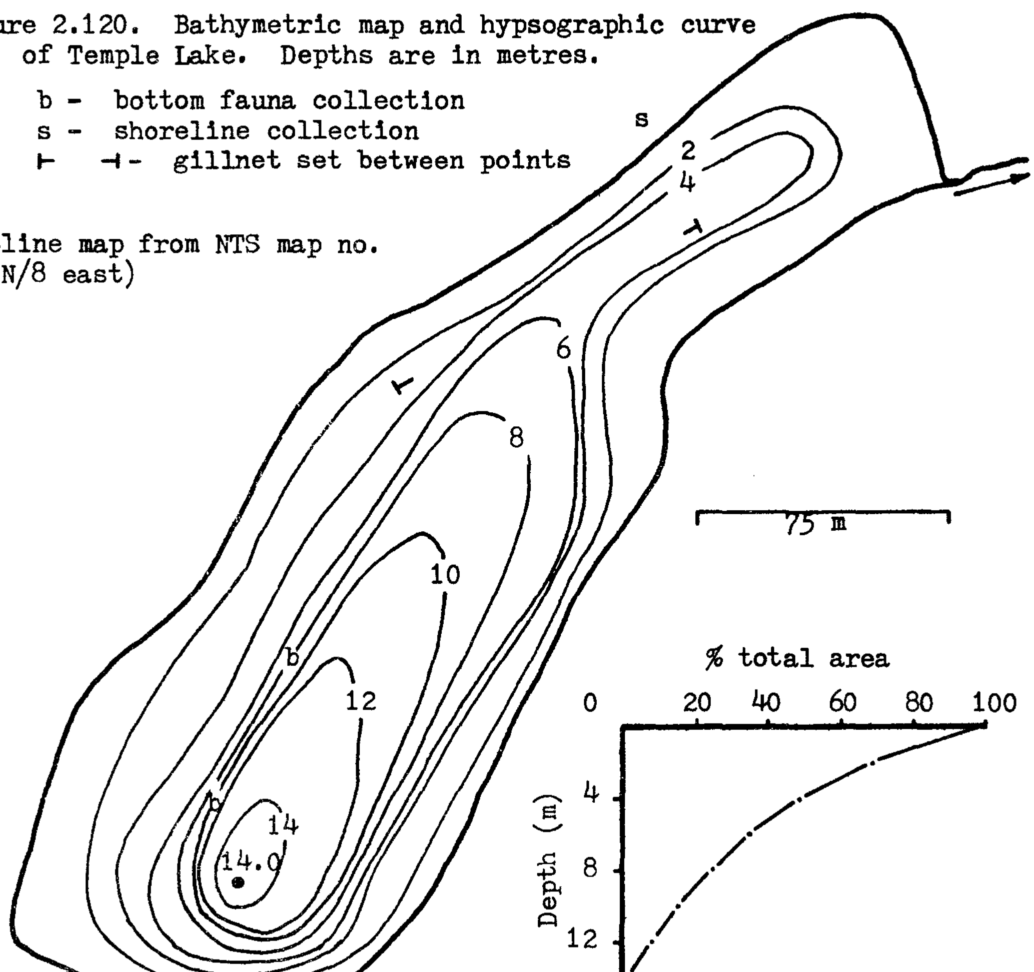


Figure 2.121. Growth diagram of brook trout, Temple Lake, 29 viii 75.

Figure 2.122. Length - weight relationship of brook trout, Temple Lake, 29 viii 75.

Figure 2.121

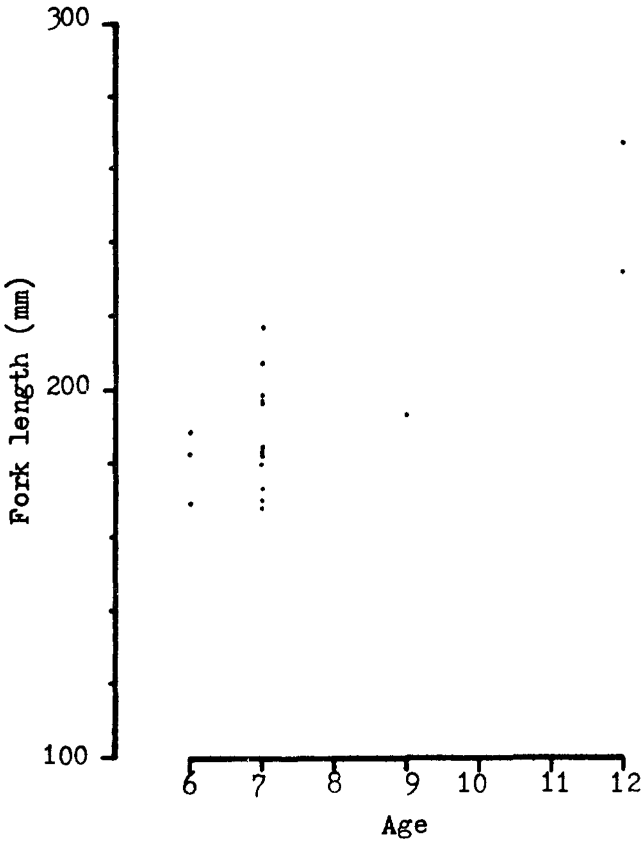
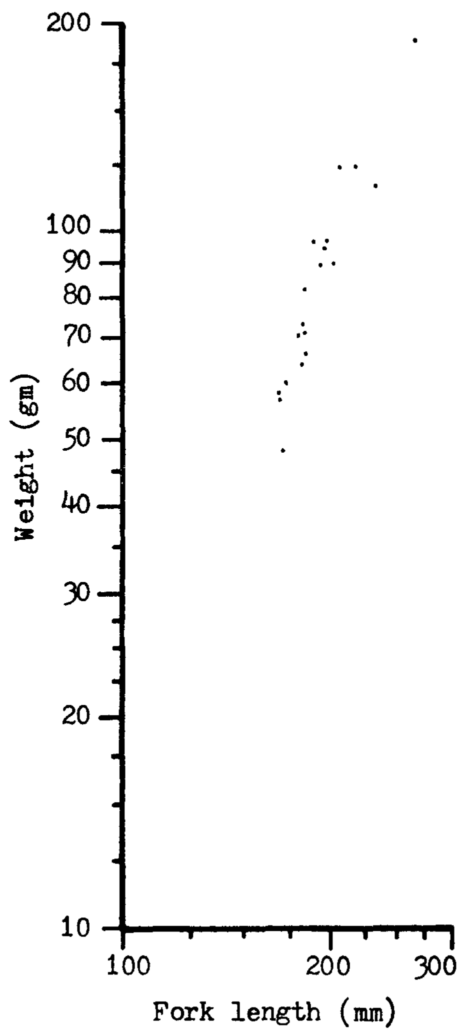


Figure 2.122



TILTED LAKE

A. General Attributes, Morphometry and Drainage Basin Features

Location: Grid reference 11U/NH 679058, NTS map No. 82 N/8 east (Lake Louise East map sheet)

Planning zone: Class II (Wilderness)

Access: restricted road to Temple Lodge, then by trail approximately 10.5 km (6.5 mi)

Elevation: 2210 m

Altitudinal zone: treeline

Basin type: depression in the upturned edges of rock strata

Length: 420 m

Mean width: 86 m

Area: 3.6 ha

Maximum depth: 12.2 m

Mean depth: 3.9 m

Volume: 13.8 x $10^4 m^3$

Shoreline length: 1077 m

Shoreline development: 1.60

Volume development: 0.94

Mean depth/max. depth: 0.32

Area/mean depth: 0.92

Water level fluctuation: less than 30 cm drop in level through summer (1975)

Stratum (m)	Volume ($10^4 m^3$)	% Total volume
0 - 2	5.37	38.8
2 - 4	3.37	24.4
4 - 6	2.48	18.0
6 - 8	1.58	11.4
8 - 10	0.80	5.8
10 - 12	0.22	1.6
12 - 12.2	0.001	~0

Water renewal time: unknown - water gain and loss must be mainly subsurface

Open-water period: no observations

Catchment area: 15 ha

Bedrock composition of catchment area: 100% Devonian carbonate rocks

Catchment area coverage: 25% widely-spaced trees, 75% low plants and exposed rock

(Catchment area - lake area)/lake area: 3

Human activities in catchment area: hiking, angling, unauthorized camping

Bottom composition: The bottom in shallow areas, particularly in the north bay, is covered by light-coloured, flocculent sediments. The dark brown mud in the deep portion of the lake has an organic content of 46.2%.

Secchi depth: extremely clear (19 viii 66)
>9 m (20 viii 75)

Colour ($\frac{1}{2}$ Secchi): light green (28 viii 75)

B. Water Chemistry

1. Field determinations (mg/l unless stated otherwise)

Date:	19 viii 66	28 viii 75	28 viii 75
Depth:	surface	surface	8 m
Conductivity (µmho/cm @ 25C):		187	182.5
pH (units):	8.0	8.3	8.3
Total alkalinity:	92.2	78.5	78.5
Total hardness:	85.5		
Total acidity:	4.56		

2. Laboratory analysis (mg/l unless stated otherwise)

Date: 21 viii 75 Depth: surface

Turbidity: 1 JTU Colour: < 5 HU

pH: 8.4 units Sum of constituents: 80.4

Conductivity: 143 µmho/cm @ 25C Sum const./cond: 0.56

Total alkalinity as $CaCO_3$: 72.3

Phenolphthalein alkalinity as $CaCO_3$: 0

Total hardness as $CaCO_3$: 78.9

Total inorganic carbon: 16 Total organic carbon: 3

Major constituents
Calcium: 25.0 Magnesium: 4.0 Sodium: 0.3 Potassium: 0.2
Bicarbonate: 88.1 Carbonate: 0 Sulphate: 2.2 Chloride: 0.2

Minor constituents
Nitrogen (nitrate + nitrite): < 0.01 Nitrogen (Kjeldahl): 1.6
Phosphorus (total): 0.004

C. Lake Biology

1. Plankton

a. Phytoplankton (cells/ml)

Date: 28 viii 75

a. Phytoplankton (continued)

Depth:	0.5 m	8.0 m
Chlorophyta		
Botryococcus braunii		84
Carteria sp.	3	3
Chlamydomonas sp.	22	6
Elaktothrix gelatinosa	62	53
Gloeocystis planktonica		11
Oocystis borgei	78	48
O. lacustris	73	31
O. parva	157	151
O. pusilla	112	112
O. submarina		14
Quadrigula lacustris	22	58
Sphaerocystis schroeteri	90	22
Chrysophyta		
Chrysophyceae		
Chromulina sp.	34	53
Chrysochromulina parva	45	213
Chrysosphaera sp. ?	1207	1450
Conradocystis sp. ?	8	
Dinobryon divergens	28	160
Kephyrion sp.	17	8
Ochromonas sp.	11	11
Diatomaceae		
Achnanthes sp.	3	3
Cyclotella ocellata	3	
Cyclotella sp.	12	17
Diatoma tenue var. *elongatum*	3	6
Navicula elginensis var. *rostrata*	3	
N. tuscula	3	
Navicula spp.		3
Nitzschia acicularis		14
Nitzschia sp.	3	
Synedra rumpens	25	
Cryptophyta		
Cryptomonas obovata		3
C. marsonii	3	11
Rhodomonas minuta	6	22

b. Zooplankton (collection: 19 viii 66, 28 viii 75)
Units are maximum numbers per litre.

Rotifera	
Filinia longiseta	10 - 100
Gastropus	1 - 10
Kellicottia longispina	1 - 10
Keratella quadrata	0.1 - 1
Polyarthra vulgaris	100 - 1000
Cladocera	
Bosmina longirostris	4.32
Cladocera (continued)	
Chydorus sphaericus	0.09
Daphnia (*galeata mendotae* - *rosea* type)	13.83
Daphnia (*middendorffiana*?)	trace
Copepoda	
Diaptomus tyrrelli	8.39
?*Eucyclops agilis*	trace

maximum crustacean standing crop: 27.0 animals/l

2. Bottom and Shoreline Organisms

a. Macrophytes

small patches of emergent sedges (Carex) at various points around the shoreline (coverage possibly 1% of total lake area)

b. Shoreline fauna (collection: 20 viii 75, 15 min)
Units are numbers collected.

Crustacea	
Amphipoda	
Gammarus lacustris	5
Insecta	
Trichoptera	
Limnephilidae	2
Coleoptera	
Agabus tristis	1
Hydroporus (compertus?)	2
Rhantus or *Colymbetes* larvae	1
Diptera	
Chironomidae	
Procladius s.str.	3
Tanytarsus	1
Mollusca	
Pelecypoda	
Sphaeriidae	1

c. Bottom fauna (collection: 20 viii 75, n = 2)

Crustacea	
Amphipoda	
Gammarus lacustris	65
Insecta	
Diptera	
Chironomidae	
Procladius s. str.	172
Tanytarsus	172

Standing crop (mean preserved wet weight/m^2):

Gammarus 0.702 gm Chironomidae 0.332 gm

3. Fish (B. D. Smiley data)

Collection date: 12-13 viii 73 Set duration: approx. 20 h

Gear: 7.6 m each of 3/4, 1, 1½, 2, 3, 4-inch mesh green monofilament nylon gillnet; 4 gangs set

Catch: 54 brook trout (*Salvelinus fontinalis*); 27 males, 25 females 2 unsexed

Age:	1	2	3	4	5	6	7
Number:	1	5	16	3	8	10	1
Mean fork l. (mm):	196	219.0	255.7	342.7	380.1	400.6	451
Mean weight (gm):	80	127.6	200.3	538.0	684.8	760.2	998

Maturity: no reliable data

Food: 43 stomachs examined, 3 (7.0%) empty

Food item	% of fish with item	no. of times item rated as rare	common	abundant
Diptera (unident.)	87.5	2	14	19
Chironomidae	90.0	8	10	18
Amphipoda	32.5	2	9	2
plant material	27.5	5	6	
Hydracarina	20.0	5	3	
Trichoptera	15.0	4	2	

Food item	% of fish with item	no. of times item rated as rare	common	abundant
Coleoptera (aquatic)	12.5	2	3	
Hirudinoidea	5.0	2		
Sphaeriidae	2.5	1		

D. Discussion

Cutthroat trout (Salmo clarki) were stocked in Tilted Lake in 1939, 1949 and 1950, and brook trout in 1964, 1965 and 1967. Only brook trout now occur in the lake.

Smiley (1976) stated that brook trout first mature at age 3 and that most are mature by age 4. His raw data, however, indicate that all but four of the catch were mature; two of the remaining fish being immature and two being of unknown maturity. All but one of the age 2 fish were judged to be mature according to his data sheets.

Smiley's (1976) length - weight equation is incorrect (cf. Figure 2.128). His conclusions of fish condition based on the slope constant of his equation are therefore invalid.

Natural recruitment in Tilted Lake is evidently adequate to support the brook trout population even though there appear to be no suitable spawning areas in the lake.

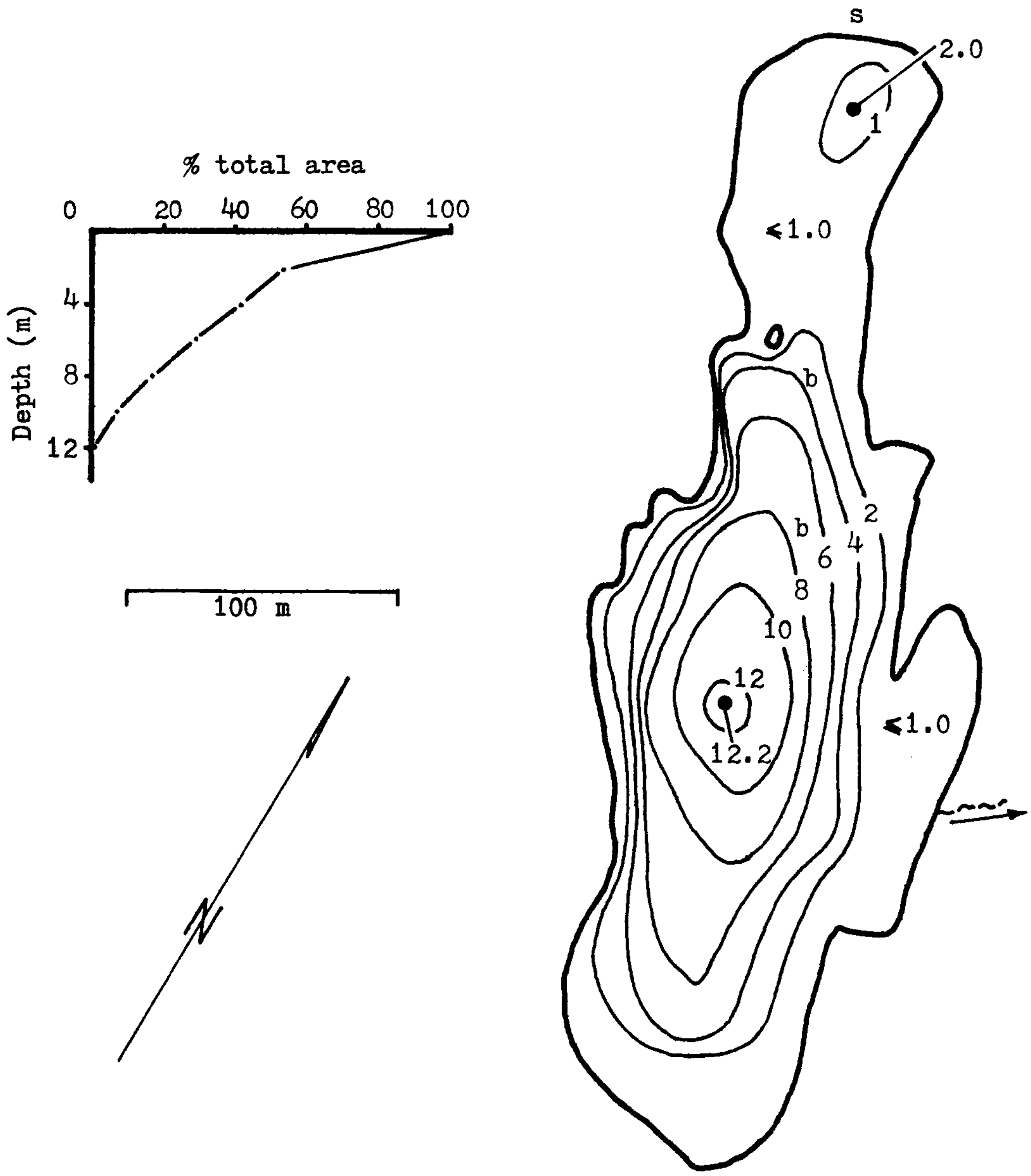


Figure 2.123. Bathymetric map and hypsographic curve of Tilted Lake. Depths are in metres.

b - bottom fauna collection
s - shoreline collection

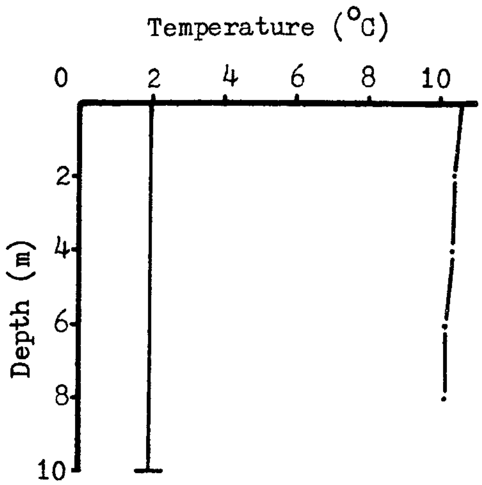


Figure 2.124. Temperature profile and Secchi depth reading (⊥), Tilted Lake, 28 viii 75.

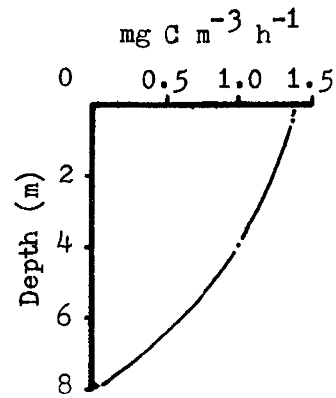


Figure 2.125. Profile of primary productivity, Tilted Lake, 28 viii 75. Points are net figures (light minus dark). Samples were collected with a student sampler. Incubation 0945 - 1300 h MST

Figure 2.126. Percent ionic composition of surface water calculated on the basis of equivalent weights, Tilted Lake, 21 viii 75.

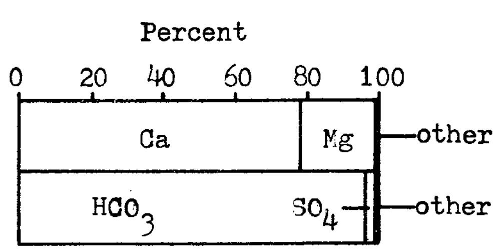
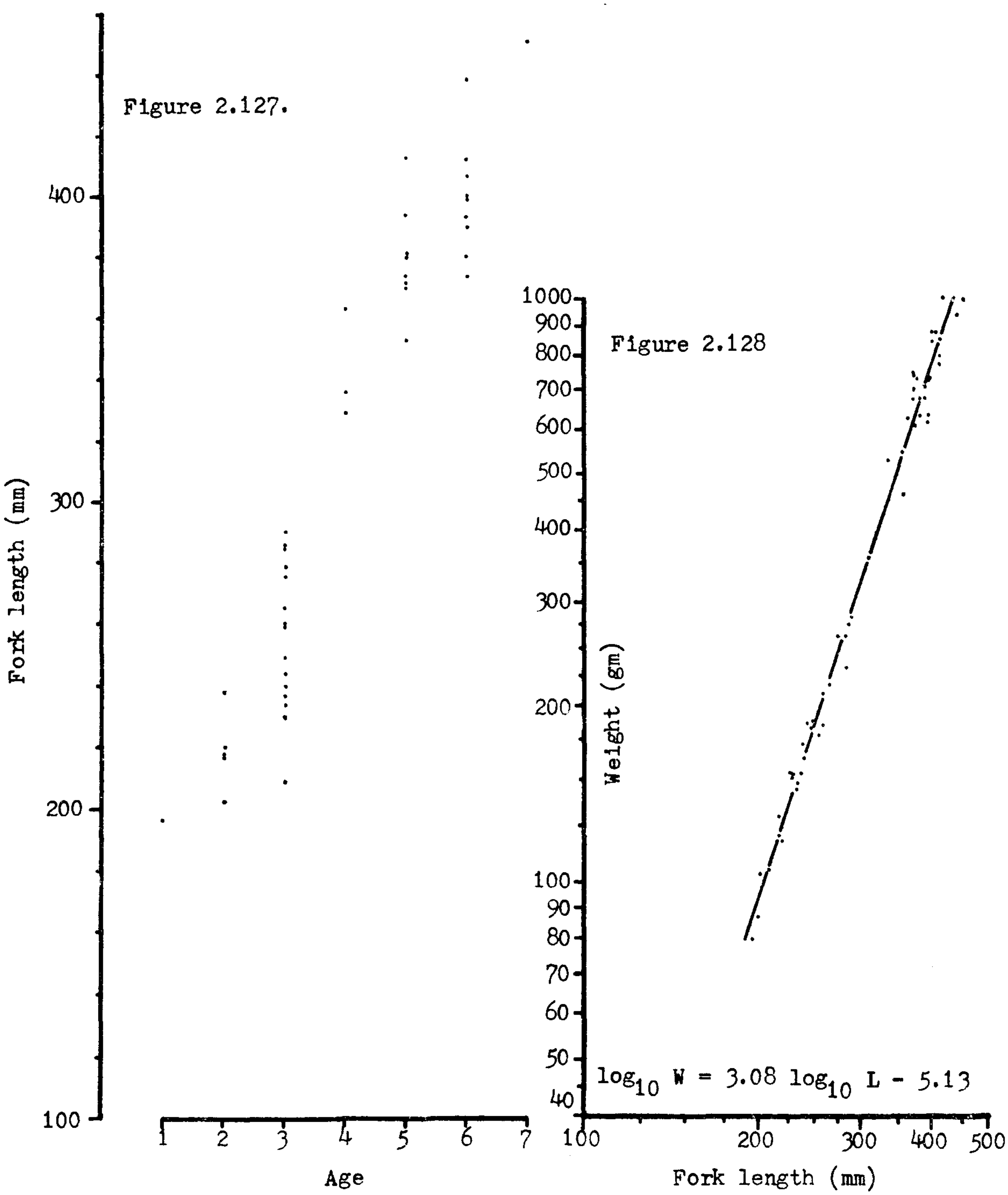


Figure 2.127. Growth diagram of brook trout, Tilted Lake, 12-13 viii 73.

Figure 2.128. Length - weight relationship of brook trout, Tilted Lake, 12-13 viii 73. Line drawn by eye.



THE LIMNOLOGY OF THE LAKE LOUISE AREA: SUMMARY AND DISCUSSION

The purpose of this section is to characterize the limnology of the study area as a whole based on the findings of the individual lakes, and to place the limnology of the area in a regional context. The treatment is somewhat superficial because work on this aspect is still in progress. Separate reports and publications are available, in preparation, or are comtemplated on various aspects of the lake surveys (e.g., Anderson 1974b; Mudry and Anderson, in press; Mayhood, in preparation). Such papers should be consulted for a more comprehensive analysis of the data summarized here.

A. General Attributes, Morphometry, and Drainage Basin Features

Two distinct groups of lakes can be readily discerned in the study area: those on the floor of the Bow Valley, which we call here the "low lakes"[1], and the lakes in the cirques and hanging valleys above the Bow Valley, hereinafter referred to as the "high lakes".

The low lakes are typically small and shallow. They all occupy basins primarily in drift over Miette Group bedrock, are fed mainly by groundwater, have little or no surface outflow, and have completely forested drainage basins. Their water levels fluctuate little, and they probably have long water renewal times when the entire year is considered. The ice-free period is about 160 days per year, from around mid-May to mid or late October. Most are thermally stratified in summer, are sheltered from the wind by surrounding forest, and all have warm surface waters. Light penetrates to the bottom at the deepest part of most of the lakes, but Secchi depths may be less

1. Herbert, Little Herbert, Herbert Pond, Island, Kingfisher, Kingfisher Pond, Lost, McNair, Mud

than 4m at times in some of them. The sediments of the low lakes are usually very flocculent or jelly-like, and are light-coloured in shallow water. Rocky areas are either rare or absent.

McNair Pond, one of the low lakes, is man-made. In consequence, it differs from the others in several important respects. The pond was formed when the 1-A Highway was built so as to dam a small brook. McNair Pond thus has a surface inlet and outlet, short water renewal time and a shallow depth artificially dictated by the placement of the outlet culvert. The relatively low organic content of the sediments (21.1%) may be owing to the short water renewal time, newness of the basin, and inclusion in the sediments of roadfill.

The high lakes, in contrast to the low lakes, are a more heterogenous assemblage. They occur in all four altitudinal zones in the study area, but most of them are near, at or above the treeline (about 2200 m). Most of the lakes are in a combination of rock and drift basins, often in long glacial valleys. Several are in cirques. One lake (Moraine) has been deepened by a rockslide and another (Eiffel) occupies a depression on top of a slide (Kucera 1974).

All but three of the high lakes have drainage basins in which quartzite makes up a high proportion of the bedrock. In most of these drainage basins Cambrian carbonates are also an important bedrock component, but in three of them Cambrian carbonates are missing and Miette Group rocks are present. The three high lakes not in basins having quartzite bedrock are Little Baker, Tilted and Brachiopod. With Baker Lake, they lie east of the Castle Mountain Thrust in a region of fossiliferous Devonian carbonates.

Unlike the drainage basins of the low lakes, those of the high lakes have very little forest cover. Many haven't any. Forest covers less than one-quarter of the high drainage basins at most, the remainder being covered by bare rock, low plants or glaciers.

Nearly all the high lakes have surface inlets and outlets; Eiffel, Mirror, Brachiopod and Moraine being exceptional in this regard[1]. These four lakes have subsurface outlets, and are the only lakes that fluctuate widely in water level. They fill up during periods of high runoff. When the amount of water entering the lake fails to exceed the capacity of the subsurface outlets, the water level drops. The amount of the drop may exceed several metres, and depends upon the position of the "holes" in the lake bottoms. For instance, Moraine Lake in spring can be 6m or more below its high water mark.

Water renewal times in the high lakes are usually short and are related to the area of the drainage basin relative to the volume of the lake. That is, lakes with small volumes relative to the area of their drainage basins have shorter water renewal times than do lakes with large volumes relative to their drainage basin area.

The ice-free period of the high lakes is variable depending on their volume, relative depth, elevation and exposure. There can be considerable year-to-year variation in the break-up and freeze-up dates of the individual lakes. The ice-free period of the lower subalpine high lakes approaches that of the low lakes, but the higher lakes are frozen much longer - particularly the treeline and alpine lakes. The shortest ice-free period of the latter lakes can be less than 3 months.

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1. At high water, Moraine also has a surface outlet.

Inspection of our results suggests that although large, deep lakes are open for about the same length of time as smaller lakes at the same elevation, both freeze-up and break-up dates are displaced to later in the year.

The high lakes vary widely in morphometry, but most are less than 20 ha in area or 20m in maximum depth. More than 80% could be classified as cold, 4 are moderately warm and not one is definitely warm. Only 8 lakes - 3 moderately warm and five cold - are thermally stratified in summer. Lake Louise is somewhat surprising in that the upper 2m may become quite warm in summer, although below 2 m it is decidedly cold.

The high lakes are typically cold as a result of their short open-water seasons, their high water renewal rates, the generally cool air temperatures at high elevation, and in some cases the contribution of glacial meltwater.

Water transparency is generally quite high in the high lakes, except in some fed by glaciers. Inlet water from some glaciers carries a heavy load of very fine silt, the result of glacial erosion. The silt remains in suspension for a long time in lakes receiving such water, in some cases rendering them nearly opaque. It is interesting to note that some lakes fed by active glaciers (eg; Boom and the Consolation Lakes) nevertheless remain clear all summer.

Sediments in the high lakes are usually quite firm and low in organic content. Rock is nearly always an important constituent of the bottom, in some cases covering nearly all of it (eg; Eiffel).

The attributes of both the high lakes and the low lakes are summarized and compared in Table 2.1.

Although there have been a number of studies of southern Canadian Rocky Mountain[1] lakes dating from the late 19th century (Wilcox 1899, Anderson 1974c), the complexity of the region has precluded any but the most superficial characterizations of its limnology (Northcote and Larkin 1963, Larkin 1974). These characterizations have emphasized the uniqueness of individual lakes, a feature attributed to widely variable lake elevation, orientation, drainage basin geology and climate.

Recently-acquired data on 321 Rocky Mountain lakes (Anderson 1974b, plus data on 6 lakes in the present survey) permit some initial generalizations on the limnology of the region to be made, thereby enabling us to assess how representative the study area lakes are with respect to a few limnological features. In gathering these data, an effort was made to include a wide variety of Rocky Mountain lakes from very large to very small, low to high elevation, and from the northern to the southern part of the region. Some areas are sparsely represented and others possibly over-represented, but the data are probably fairly representative of the region nevertheless.

Of the 321 Rocky Mountain lakes examined, 53% were between 1900 m and 2400 m in elevation. About 75% of the lakes were less than 15 ha in area, and 72% had maximum depths less than 15 m. Less than 6% of the lakes exceeded 35m in maximum depth. It appears, therefore, that most Rocky Mountain lakes are small, of moderate depth and of moderate to high elevation.

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1. that portion of the Rocky Mountains along the Continental Divide boundary between Alberta and British Columbia. In the remaining discussion, this region is referred to simply as the Rocky Mountain region.

Fifty-eight percent of the lakes included in the present survey were at elevations of 1900 to 2400 m, 77% were less than 15 ha in area and 71% were less than 15 m in maximum depth. The study area thus appears to be typical of the Rocky Mountain region with respect to the elevation, area and depth of its lakes.

Two of the survey lakes are somewhat unusual. Sentinel Lake at 2423 m is one of only six Rocky Mountain lakes examined that is more than 2400 m in elevation. Such lakes appear to be relatively rare. Lake Louise, with a maximum depth of 70.1 m is the fifth deepest Rocky Mountain lake of which we are aware.

The types of lake basins in the study area are characteristic of those in glaciated mountains. Cirque and glacial valley lakes are quite common near Lake Louise and throughout the Rocky Mountain region. Eiffel Lake, however, is exceptional. We know of no other lakes on landslides, though examples in other parts of the world are known (Hutchinson 1957, Wetzel 1975). We are unsure of how common certain other basin types are, because basin types usually have not been specifically identified in previous studies on Rocky Mountain lakes.

The bedrock geology of lake drainage basins has been considered only in passing in other limnological studies in the Rocky Mountain region, so we do not know how representative the Lake Louise area is in this respect. Judging from the geologic map of Alberta provided by Stelck (1967), drainage basin geology in the study area is likely to be more similar to that of basins to the north, rather than to the south of Lake Louise.

Table 2.1. Summary and comparison of the physical attributes of the lakes in the study area.

	Low lakes n = 9	High lakes n = 22
Altitudinal zone	lower subalpine	3 lower subalpine, 7 upper subalpine, 5 treeline, 7 alpine
Elevation	1539 m (Kingfisher, McNair) to 1692 m (Lost)	1731 m (Louise) to 2423 m (Sentinel) nearly 60% in 2100 - 2400 m zone
Basin types	basins mostly in drift, some with bedrock outcrops	basins mostly bedrock and drift; 1 on a landslide, one deepened by a rockslide dam
Drainage basin: bedrock composition	100% Miette Group	4 basins Devonian carbonate (42 - 100% of area), 15 quartzite - Cambrian carbonate (quartzite $\bar{x}$ = 67%, R 41 - 85%; carbonate $\bar{x}$ = 32%, R 19 - 59%), 3 quartzite - Miette (quartzite 69 - 93%, Miette 7 - 31%)
coverage	100% forest	forest 0 - 24% of area, rock and low plants 51 - 100%; 7 basins with glaciers ($\bar{x}$ = 19.4% of area, R 8 - 27%)
Inlet / outlet (surface)	usually with neither, or intermittent. Inflow mainly groundwater, outflow mainly seepage	nearly all with both. 4 with subsurface outlet, 3 with no apparent surface inlet but with surface outlet
Water level fluctuation	little	little in 18 lakes, extreme in 4 lakes (3 of these with subsurface outlet only, 1 with both a subsurface and a surface outlet)
Water renewal times	measurable only in spring, if at all. Fairly short then, but long considering whole year	usually short, often very short ($\bar{x}$ = 64 days, R 1-314, n = 18)

Table 2.1 (continued)

	Low lakes n = 9	High lakes n = 22
Ice-free period	mid-May to mid- or late October, about 160 days	period variable, depending on volume, depth, elevation, exposure of the lake, and annual variations in the weather lower subalpine 140 - 160 days upper subalpine 100 - 130 days treeline and alpine 90 - 120 days
Morphometry:		
maximum depth	$\bar{x}$ = 6.9 m, R 3.5 - 13.3 m	$\bar{x}$ = 17.8 m, R 1.5 - 70.1 m
mean depth	$\bar{x}$ = 2.3 m, R 0.5 - 4.5 m	$\bar{x}$ = 7.4 m, R 0.7 - 36.5 m
area	$\bar{x}$ = 3.7 ha, R 0.4 - 14.9 ha	$\bar{x}$ = 19.1 ha, R 0.2 - 99.6 ha
Temperature[1] and stratification ≤10 °C: cold >14 °C: warm	most stratified, all with warm surface waters in summer	18 cold (5 stratified), 4 moderately warm (3 stratified), 0 warm in summer. Louise always cold below 2 m, upper 2 m may become warm at times
Secchi depth	3.7 m to >7 m	glacially-silted lakes: 0.8 - 4.3 m; up to 13.5 m when not silted non-glacially-silted lakes: 3 m to 16.6 m; >maximum depth in 7 lakes
Sediments	usually flocculent or jelly-like, light-coloured in shallow water, dark in deep. Rocky areas rare or absent. Organic content $\bar{x}$ = 56%, R 21.1 - 78.6%	usually firmer except sometimes in shallow areas (e.g., parts of Tilted and Boom); rarely loose or jelly-like in deep water. Much of near-shore area often rock, especially talus or avalanche debris. Organic content $\bar{x}$ = 15.7%, R 4.4 - 46.2%, n = 19

1. refers only to upper 5 m

Water transparency of lakes in the study area appears to be typical of Rocky Mountain lakes (cf. Anderson 1974b). Boom Lake, with a Secchi depth of more than 16m, is unusually clear, however. Secchi depths greater than 16m were recorded in only four of the Rocky Mountain lakes previously examined.

The temperature characteristics of high lakes in the study area resemble those of ten high lakes in the Cascade area of Banff Park (Anderson 1968a) and of many high lakes in adjacent Yoho National Park (Mudry and Anderson 1975). Most such lakes in all three areas could be classed as cold and unstratified in summer. One of the high lakes studied, Upper Consolation, is among the coldest yet examined in the Rocky Mountains, but most of the remaining high lakes appear to be typical of those in the region (Anderson 1974b).

The low lakes are similar in their thermal properties to a few montane lakes in Jasper and Waterton Lakes National Parks (Anderson 1970c, Anderson and Donald 1976), and perhaps also to other lakes in the Bow Valley of Banff Park. They are no more than moderately warm relative to many other Rocky Mountain lakes (Anderson 1974b).

Data on water renewal times, ice-free periods and sediment organic contents are available for too few Rocky Mountain lakes to establish the representativeness of the study area lakes with respect to those parameters.

B. Water Chemistry

The water chemistry of the low lakes differs from that of the high lakes mainly in the quantity, rather than quality of dissolved substances (Table 2.2). Dissolved matter in low waters is

Table 2.2. Summary and comparison of the water chemistry of the lakes in the study area.

	Low lakes n = 9	High lakes n = 22
Conductivity (µmho/cm @ 25C)	$\bar{x}$ = 260.6 (201 - 369)	all: $\bar{x}$ = 109.8 (35.3 - 172) n = 21 Q - MG: $\bar{x}$ = 55.5 (35.3 - 95.3) n = 3 Q - CC: $\bar{x}$ = 111.4 (53.3 - 145) n = 14 DC: $\bar{x}$ = 152.0 (141 - 172) n = 3
Sum of constituents (mg/l) (TDS)	$\bar{x}$ = 142.0 (111.7 - 193.6)	all: $\bar{x}$ = 59.7 (17.4 - 99.1) n = 21 Q - MG: $\bar{x}$ = 31.5 (17.4 - 59.3) n = 3 Q - CC: $\bar{x}$ = 59.9 (26.6 - 82.0) n = 14 DC: $\bar{x}$ = 85.4 (76.7 - 85.4) n = 3
Total alkalinity (mg/l as $CaCO_3$)	$\bar{x}$ = 130.5 (87.1 - 174)	all: $\bar{x}$ = 51.7 (12.0 - 80.7) n = 21 Q - MG: $\bar{x}$ = 18.3 (12.0 - 30.6) n = 3 Q - CC: $\bar{x}$ = 53.2 (22.1 - 78.0) n = 14 DC: $\bar{x}$ = 74.7 (71.1 - 80.7) n = 3
Total hardness (mg/l as $CaCO_3$)	$\bar{x}$ = 140.7 (105 - 188)	all: $\bar{x}$ = 60.4 (17 - 98.0) n = 22 Q - MG: $\bar{x}$ = 29.9 (17 - 54.5) n = 3 Q - CC: $\bar{x}$ = 59.8 (34.2 - 85.5) n = 14 DC: $\bar{x}$ = 84.6 (77.0 - 98.0) n = 3
pH	$\bar{x}$ = 8.3 (8.0 - 8.6)	all: $\bar{x}$ = 8.0 (7.4 - 8.7) n = 22 Q - MG: $\bar{x}$ = 8.0 (7.7 - 8.7) n = 3 Q - CC: $\bar{x}$ = 8.0 (7.4 - 8.6) n = 14 DC: $\bar{x}$ = 8.4 (8.3 - 8.5) n = 3
Major ion composition	Ca > Mg (>> Na), HCO_3 > SO_4 except for Herbert, which had Ca > Mg >> Na, HCO_3 > Cl > SO_4	Ca > Mg, HCO_3 > SO_4 except for Taylor and O'Brien, which had Mg > Ca, HCO_3 > SO_4, and Temple with Ca > Mg, HCO_3 > SO_4 > Cl

Q - MG: quartzite - Miette Group bedrock in drainage basin
Q - CC: quartzite - Cambrian carbonates in drainage basin
DC: Devonian carbonates only in drainage basin

Ranges are in parentheses.

2.3 - 2.5 times greater than in the waters of the high lakes. The ionic composition of both groups of waters is similar, with Ca > Mg and $HCO_3 > SO_4$ in nearly all cases.

Taylor and O'Brien are exceptional in that Mg > Ca; these lakes also had the lowest TDS of any lake in the study area. A third exception is Herbert Lake, in which $HCO_3 > Cl > SO_4$. It has been suggested that the high chloride content in Herbert might be due to the use of road salt on the Banff-Jasper Parkway, via ditch runoff (Anderson 1969a).

The water chemistry of a lake in large measure reflects the attributes of the drainage basin. In the study area, waters of the high lakes contain calcium, magnesium and bicarbonate derived from the Devonian or Cambrian limestones and dolomites in their drainage basins, or from carbonates in Miette Group rocks where these occur in significant quantity. The high proportion of quartzite, which is primarily insoluble silica, in the drainage basins of most of the high lakes mitigates against high concentrations of dissolved minerals in their waters. Furthermore, the steepness of the drainage basins and the relative impermeability of the exposed bedrock which comprises much of their areas leads to rapid runoff of precipitation, allowing little opportunity for the water to pick up large mineral loads. In some high lakes the small size of the drainage basin means that runoff water has still less opportunity to dissolve minerals.

In contrast to the high lakes, the low lakes have flat and permeable drainage basins. It is unknown how far influent water to these lakes has travelled, but it has done so certainly at a much slower rate than has that of the high lakes. Furthermore, it has travelled through rather than over the drift, in intimate contact with the minerals in it, giving the water plenty of opportunity to pick up ions.

The waters of the great majority of Rocky Mountain lakes are dominated by calcium and magnesium cations and bicarbonate and sulphate anions, with the order of dominance usually Ca > Mg and $HCO_3 > SO_4$ (Anderson 1968b, 1969a, 1970c; Mudry and Anderson 1975; Anderson, Donald and Krochak 1972). Thus, the ionic composition of waters in the study area is typical of Rocky Mountain lakes with respect to their major constituents.

The waters of the high lakes are distinctly more dilute than those of ten lakes in the Cascade area of Banff Park (Anderson 1968b), but are generally higher in dissolved solids than those of 24 subalpine and alpine lakes in Jasper National Park (Anderson 1969c). They most nearly resemble the waters of ten lakes in a quartzite area of Yoho National Park (Mudry and Anderson 1975).

The mean TDS of 299 Rocky Mountain lake waters analyzed by Anderson (1974b) is 93.7 mg l^{-1} (range 2-513 mg l^{-1}). It therefore appears that the waters of the high lakes in the study area are somewhat lower in dissolved solids than are those of Rocky Mountain lakes in general, but that those of the low lakes are somewhat higher.

Minor constituents in waters of the study area were most frequently at undetectable levels. The generally very low concentrations may be owing to their rarity in the drainage basins, lack of opportunity to be dissolved in lake influent waters, or to rapid biological uptake. Some of the minor constituents such as phosphorus are of considerable biological importance, and their scarcity might be an important factor limiting the productivity of the study area lakes.

Only incidental observations of dissolved oxygen levels were made in this survey, because detailed studies had been carried out earlier in Herbert (a low lake) and Snowflake (a high lake east of the study area; Anderson 1968a, 1969b, 1970b). Survey results were available for some lakes in and near the study area as well (Rawson 1939, Anderson 1969a). The available data indicate that surface D.O. values are nearly always near saturation, and that levels usually decline only slightly, if at all, in the deep waters of the high lakes. In contrast, the low lakes can sometimes show very low values in deep water, particularly in winter.

C. Lake Biology

1. Plankton

Chrysophyceae and Diatomaceae dominated the phytoplankton of lakes in the study area, comprising on the average 50 to 60% of the total numbers of cells (Table 2.3). Cryptophytes and chlorophytes together made up about 25 to 35% of the total number of cells on average.

The survey data reveal few, if any, differences in the relative abundance of major groups of algae between the low lakes and the high lakes. Cyanophyta appear to be more important in the low lakes, and Diatomaceae more important in the high lakes, but the data

Table 2.3. Summary and comparison of the phytoplankton of the lakes in the study area.

	Low lakes n = 8	High lakes n = 22
	mean % composition (range)	mean % composition (range)
Chlorophyta	15.4 (6.0 - 26.3)	16.0 (0 - 72.5)
Chrysophyceae	32.6 (2.1 - 75.0)	20.1 (1.9 - 86.5)
Diatomaceae	22.4 (1.6 - 54.3)	40.9 (1.4 - 98.1)
Cryptophyta	10.6 (1.0 - 36.8)	20.4 (0 - 93.7)
Cyanophyta	15.6 (0 - 23.8)	0.8 (0 - 16.1)
Other	3.4 (0 - 23.8)	0.6 (0 - 8.1)
mean total no. ml^{-1}	967 (304 - 2989)	831 (43 - 3195)

are based on too few samples to draw conclusions with confidence.

A large number of the algal species identified are undoubtedly new records for Alberta. This is more likely a reflection of the lack of attention paid to the nannoplankton of the region than an indication of rarity. Many of the species found in the study area are common to lakes in adjacent Yoho National Park (Mudry and Anderson 1975).

Total numbers of phytoplankters averaged 800 - 1000 cells ml^{-1}, but values varied widely. There was little apparent difference between the low and the high lakes in phytoplankton cell counts on the average, but there were too few samples to draw a firm conclusion on this point. The total numbers of phytoplankters per millilitre found in the study area lakes are similar to those found in 21 Yoho lakes ($\bar{x}$ = 852 cells ml^{-1}, range 1-5428; Mudry and Anderson 1975).

A detailed analysis of the phytoplankton in lakes of the study area is in preparation (Anderson and Green, unpublished data).

The zooplankton of the study area is summarized in Table 2.4. The zooplankton communities of the low lakes differed considerably from those of the high lakes. The zooplankton of the former typically had 4 to 8 rotifer species, 3 or 4 cladocerans, 1 (occasionally 2) calanoids and 1 cyclopoid. That of the high lakes was somewhat more variable, but usually had few or no rotifers, one or two calanoids, and occasionally 1 or 2 cladocerans. Four high lakes were essentially devoid of zooplankton, and the zooplankton of two consisted of two abundant rotifers and 1 cyclopoid[1]. Maximum numbers of crustacean zooplankters in the low lakes averaged 5.5 times higher than in the high lakes (low lakes $\bar{x}$ = 79.3 l^{-1}, range 10 - 228.2, n = 9; high

1. only species achieving densities of 1 l^{-1} or more were counted in this analysis.

Table 2.4. Summary and comparison of the zooplankton of the lakes in the study area. Only the major species are included.

Species	Low lakes n = 9 no. lakes (%)	Low lakes n = 9 modal abund.[1]	High lakes n = 22 no. lakes (%)	High lakes n = 22 modal abund.[1]
Rotifera				
Asplanchna priodonta	7 (78)	3	0 (0)	0
Conichilus and/or Conichiloides	6 (67)	1	1 (5)	3
Filinia	2 (22)	4,5	4 (18)	2
Kellicottia longispina	9 (100)	3	8 (36)	4
Keratella cochlearis	8 (89)	4	2 (9)	1
Keratella quadrata	9 (100)	3,4	7 (32)	2
Polyarthra vulgaris	9 (100)	3,4	9 (41)	4
Synchaeta	3 (33)	4	5 (23)	3,4
Cladocera				
Polyphemus pediculus	7 (78)	3	0 (0)	0
Daphnia rosea	5 (56)	4	1 (5)	4
D. galeata mendotae	2 (22)	3		
D. middendorffiana	0 (0)	0	8 (36)	1,2
D. pulex	5 (56)	3	3 (14)	1
D. pulicaria	2 (22)	3	0 (0)	0
D. schødleri	2 (22)	3,4	0 (0)	0
Ceriodaphnia spp.	4 (44)	4	0 (0)	0
Bosmina longirostris	6 (67)	4	2 (9)	3
Calanoida				
Acanthodiaptomus denticornis	8 (89)	3	0 (0)	0
Diaptomus sicilis	2 (22)	3	0 (0)	0
D. leptopus	1 (11)	3	0 (0)	0
D. arcticus	0 (0)	0	11 (50)	3
D. tyrrelli	0 (0)	0	10 (45)	3,4
Cyclopoida				
Acanthocyclops vernalis	5 (56)	2	7 (32)	2
Diacyclops bicuspidatus thomasi	3 (33)	2	1 (5)	2
Orthocyclops modestus	6 (67)	1	2 (9)	2,3

1. the most frequently-observed index of maximum abundance in the lake group. The index numbers refer to the following densities (animals l^{-1}):

1: < 0.1
2: 0.1 - 1
3: 1 - 10
4: 10 - 100
5: 100 - 1000

lakes $\bar{x} = 14.4\ l^{-1}$, range 0 - 52.7, n = 22).

The species composition of the zooplankton communities in the two groups of lakes differed markedly. The rotifers *Keratella cochlearis*, *K. quadrata*, *Polyarthra vulgaris*, *Kellicottia longispina* and *Asplanchna priodonta* were common to abundant in most of the low lakes. In the 10 high lakes having significant rotifer populations, *P. vulgaris*, *K. longispina*, *Synchaeta oblonga* and *Keratella quadrata* occurred most frequently, though the latter species was never abundant. *A. priodonta* was not found in any of the high lakes, *Keratella cochlearis* was rare in the two high lakes in which it occurred, and all other rotifers occurred at higher frequency and/or were more abundant in the low lakes.

Daphnia spp., *Bosmina longirostris*, *Polyphemus pediculus* and *Ceriodaphnia* spp. were the most frequently-occurring and abundant cladocerans in the low lakes. *D. rosea* and *D. pulex* were the most frequently-occurring daphnids. In the high lakes, *D. middendorffiana* was the most frequently-occurring cladoceran. It was not found in the low lakes, and the species common in the low lakes were rare in (*B. longirostris*, *D. rosea*, *D. pulex*) or absent from (*P. pediculus*, *Ceriodaphnia* spp.) the high lakes.

The calanoid faunas of the two lake types were completely different. *Acanthodiaptomus denticornis* was the characteristic calanoid of the low lakes, and was sometimes accompanied by *Diaptomus sicilis* or *D. leptopus*. None of these three species was found in the high lakes, which were typically inhabited by *D. arcticus*, *D. tyrrelli*, or both. Neither *D. arcticus* nor *D. tyrrelli* occurred in the low lakes.

Cyclopoids, frequently scarce in both groups of lakes, occurred in all low lakes but in significant numbers in fewer than half of the high lakes. *Orthocyclops modestus* and *Acanthocyclops vernalis* were the most widespread cyclopoids in the former; *A. vernalis* was the most widespread in the latter.

The zooplankton communities of the high lakes closely resemble those of most Yoho Park lakes in both species composition and abundance (cf. Mudry and Anderson 1975). Such communities are common and widespread in the subalpine and alpine zones of the Rocky Mountain region (Anderson 1971, 1974b).

In contrast, the zooplankton communities of low lakes appear to have no real counterpart in Yoho, although such communities exist in several other Bow Valley lakes in Banff Park outside of the present study area (cf. Mudry and Anderson 1975; Anderson 1974b). These communities, characterized by the presence of the calanoid *Acanthodiaptomus denticornis*, in the Rocky Mountain region appear to be confined to the Bow River watershed. However, similar communities with other species of calanoids do occur in the region, and a few other *A. denticornis* communities exist in Canada outside the Rocky Mountains (Anderson 1974b, Carl 1940, Wilson 1958, Mayhood et al. 1973).

Predation by fish has been shown to be an important determinant of the species composition of zooplankton communities in Rocky Mountain lakes (Anderson 1972). More specifically, *Diaptomus arcticus* can be eliminated from a community when trout are introduced into a previously fish-free lake.

In the study area, some fish-stocked lakes that would be expected to contain *D. arcticus* do not; and in one case, a large species of *Diaptomus*[1] formerly abundant in a lake before the introduction of fish is now absent. There is reason to believe that in some cases the zooplankton communities would not revert to their natural condition if the fish populations were to be removed (see discussion in Mudry and Anderson 1975, p. F-25; and Anderson 1972).

Fish and *D. arcticus* coexist in several lakes in the study area. Where they do the calanoid is rare, or the lake is relatively large or deep, has silty water, has relatively abundant alternative food and usually has a relatively sparse fish population. All of these conditions would favour the persistence of *D. arcticus* by making it difficult to find, or by subjecting it to only light predation pressure.

2. Bottom and Shoreline Organisms

a. Macrophytes

Macrophytes were found in all of the low lakes. *Chara* was particularly frequent, covering considerable portions of the bottom in several lakes. *Potamogeton* spp. were sparsely-distributed in most lakes. Other submergent species occurred infrequently, but emergent sedges and the trailing *Menyanthes trifoliata* grew sparsely at the edge of many low lakes.

In contrast, few of the high lakes were inhabited by macrophytes. Sparsely distributed sedges, *Myriophyllum* or clumps of moss were found in only four high lakes.

Only two high lakes, Baker and Ptarmigan, had substantial

1. Undoubtedly the species was *D. arcticus* - see discussion of Lake Agnes (p. 13).

numbers of macrophytes. An unidentified Characeae covered extensive areas of the bottom in both lakes and *Potamogeton* (*praelongus ?*) covered small areas of the bottom in Baker as well.

With respect to the occurrence of aquatic macrophytes, the lakes of the study area are similar to those of Yoho National Park, where macrophytes were rarely found except in low-elevation lakes (Mudry and Anderson 1975). Scarcity or absence of macrophytes is characteristic of high-elevation Rocky Mountain lakes in general (Anderson 1971).

b. Shoreline fauna

The data concerning the shoreline fauna of the lakes in the study area are summarized in Table 2.5.

The typical shoreline community of the low lakes included Odonata, the amphipod *Hyalella azteca*, Chironomidae, Trichoptera, small numbers of *Caenis* (Ephemeroptera), Hemiptera and Cladocera. Hydracarina and Gastropoda were sometimes found as well. Oligochaeta and Coleoptera were seldom found in, and *Gammarus lacustris* was absent from, shoreline samples from the low lakes.

Trichoptera, Chironomidae, Oligochaeta and Coleoptera were typical of the shoreline communities of the high lakes. Hydracarina, Sphaeriidae, *Gammarus lacustris*, Turbellaria, Ephemeroptera, Plecoptera and copepods frequently occurred also. Notably absent from the shorelines of the high lakes were Odonata and Hemiptera[1]. *Hyalella azteca* occurred in shoreline samples from only one high lake, where it was rare.

1. Corixidae made up a small proportion of the stomach contents of one brook trout caught in Temple Lake, one of the high lakes.

Table 2.5. Summary and comparison of the shoreline fauna of the lakes in the study area.

Taxon	Low lakes n = 9		High lakes n = 18	
	no. lakes (%)	modal abund.[1]	no. lakes (%)	modal abund.[1]
Hydra	2 (22)	R	0 (0)	
Bryozoa	1 (11)	R	0 (0)	
Oligochaeta	3 (33)	R	10 (56)	A
Hirudinoidea	1 (11)	R	1 (6)	R
Cladocera	5 (56)	R	3 (17)	R
Ostracoda	2 (22)	R,A	0 (0)	
Copepoda	2 (22)	R	6 (33)	Oc,C
Gammarus lacustris	0 (0)		7 (39)	R
Hyalella azteca	8 (89)	C,A	1 (6)	R
Ephemeroptera	8 (89)	R	7 (39)	A
Plecoptera	1 (11)	R	6 (33)	R
Odonata	9 (100)	C,A	0 (0)	
Hemiptera	6 (67)	R	0 (0)	
Coleoptera	2 (22)	R	9 (50)	R
Trichoptera	6 (67)	C	15 (83)	R
Chironomidae	8 (89)	C	15 (83)	R
Hydracarina	3 (33)	A	8 (44)	R
Gastropoda	4 (44)	C	2 (11)	Oc,C
Sphaeriidae	3 (33)	R	8 (44)	R
Turbellaria	0 (0)		7 (39)	R

1. The most frequently-observed index of abundance within the lake group.
R - rare, Oc - occasional, C - common, A - abundant.

Although some groups of animals were common to both lake types, they were often represented by different genera. The Ephemeroptera were represented by *Caenis* in the low lakes, and most frequently by *Ameletus* and *Siphlonurus* in the high lakes. *Caenis* was not found in the high lakes, *Ameletus* was not found in the low lakes, and *Siphlonurus* occurred in only one low lake (McNair Pond), an artificial pond atypical of the group in several respects. Similarly, some unidentified types of Limnephilidae (Trichoptera) were clearly restricted to the rocky shorelines of the high lakes. Some other Limnephilidae and *Polycentropus*, on the other hand, were found only in the low lakes. The water beetles *Agabus tristis* and *Hydroporus compertus*, though widespread in the study area, were found only in high lakes.

Generally speaking, the shoreline faunas of the lakes in the study area were similar to those of Yoho lakes (Mudry and Anderson 1975), many other lakes in Banff Park (Rawson 1939) and small, high lakes in Waterton Park (Anderson and Donald 1976).

Of the shoreline animals identified to species two are noteworthy. The ostracode *Notodromas monacha* found in Kingfisher Pond is rare in North America, being known in Canada from a small number of waters in the boreal forest zone of the central plains (Delorme 1970). The water strider *Gerris incognitus* found in Little Herbert Lake and McNair Pond apparently has not been reported before from Alberta (cf. Brooks and Kelton 1967), though its occurrence in the area is not entirely unexpected (Usinger 1956). Its apparent rarity in the province may merely reflect inadequate collections from the Rocky Mountain region.

c. Bottom fauna

As in many other features, the low and the high lakes differed in the composition and quantity of their bottom faunas. Characteristic benthic groups in the low lakes included Chironomidae 53%[1], *Hyalella azteca* 11%, Oligochaeta 9%, Sphaeriidae 18%, Ceratopogonidae 4% and Trichoptera 0.5%. The benthic communities of the 19 high lakes sampled were characterized by Chironomidae 84%, Sphaeriidae 9% and Oligochaeta 2%. Chironomidae made up an average of 66.0% of the benthic standing crop on a preserved wet weight basis in the high lakes. For the low lakes, the comparable figure was only 46.2%.

Several groups, some of considerable importance in the low lakes, were rare in or absent from the benthos in the high lakes. These included *Hyalella azteca*, Odonata and Ceratopogonidae. The benthic communities of the low and high lakes are summarized and compared in Table 2.6.

The mean standing crop of bottom fauna, in terms of both numbers and preserved wet weight, tended to be higher in the lakes of the study area than in many comparable Canadian and European alpine or northern lakes (cf. Wetzel 1975, p. 257; Rawson 1939, 1942, 1953; Donald 1975; Anderson, Donald and Krochak 1972; Mudry and Anderson 1975). The data are not strictly comparable, however, because of differences in the methods used in sorting, preserving and weighing the samples. For example, samples were sorted in the field or often were weighed minus mollusc shells in the other studies. In the present study, samples were sorted microscopically and weighed with the molluscs plus their attached shells. These differences would tend to favour

1. mean percentage composition of the bottom fauna by numbers per square metre

Table 2.6. Summary and comparison of the bottom fauna of the study lakes. Only the most frequently-occurring groups are included.

Taxon	Low lakes n = 9		High lakes n = 19	
	no. lakes (%)	no. m^{-2} $\bar{x}$ (range)	no. lakes (%)	no. m^{-2} $\bar{x}$ (range)
Nematoda	2 (22)	8 (4 - 11)	8 (42)	38 (6 - 161)
Oligochaeta	8 (89)	337 (22 - 1913)	11 (58)	218 (14 - 764)
Hirudinoidea	4 (44)	18 (5 - 43)	2 (10)	5 (4 - 6)
Cladocera	2 (22)	16 (6 - 26)	3 (16)	58 (22 - 129)
Ostracoda	2 (22)	14 (6 - 22)	2 (10)	38 (32 - 43)
Copepoda	2 (22)	6 (6 - 7)	7 (37)	419 (4 - 2648)
Gammarus lacustris	3 (33)	164 (14 - 409)	6 (32)	178 (11 - 603)
Hyalella azteca	8 (89)	400 (12 - 947)	1 (5)	55
Ephemeroptera	2 (22)	52 (29 - 75)	0 (0)	0
Odonata	4 (44)	14 (12 - 16)	0 (0)	0
Trichoptera	5 (56)	30 (6 - 100)	5 (26)	18 (4 - 43)
Chironomidae	9 (100)	1691 (174-8529)	19 (100)	4760 (244-30204)
Ceratopogonidae	7 (78)	174 (12 - 867)	0 (0)	0
Hydracarina	1 (11)	237	3 (16)	35 (6 - 86)
Gastropoda	1 (11)	2	1 (5)	4
Sphaeriidae	7 (78)	716 (4 - 3884)	13 (68)	788 (57-2465)
Total no. organisms per square metre:				
$\bar{x}$	3175		5688	
range	582 - 9412		409 - 33,089	
Total preserved wet weight per square metre:				
$\bar{x}$	9.592 gm		12.636 gm	
range	1.162 - 18.408 gm		1.034 - 27.284 gm	

higher weights and numbers for the benthic samples in the present study. Considering these facts, it seems likely that the benthic standing crops found in the study area lakes are little different from those found in other Rocky Mountain, northern or European alpine lakes.

The proportion by numbers of Chironomidae in the total bottom fauna in the high lakes was similar to, or slightly higher than that of 22 Yoho lakes (77%, calculated from the data of Mudry and Anderson 1975), and of three lakes in Banff and Jasper Parks (57 - 79%) studied by Rawson (1942). This proportion in the low lakes is lower in comparison. A high proportion of Chironomidae in the bottom fauna is typical of oligotrophic lakes (Wetzel 1975, pp. 520-521), there being a trend of a decreasing proportion of chironomids with increasing eutrophy.

Because of their importance in the benthos and in the diet of fish (see below), the Chironomidae were examined in greater detail than were the other benthic groups. The chironomid faunas of the low and the high lakes are summarized and compared in Table 2.7[1].

The characteristic chironomids of the low lakes were *Procladius* s. str., *Tanytarsus, Pagastiella, Dicrotendipes, Chironomus* and *Psectrocladius;* those of the high lakes were *Procladius* s. str., *Tanytarsus, Chironomus, Stictochironomus* and *Paracladius.* *Psectrocladius* was also found in a large minority of the high lakes.

Although they were not found in a majority of the lakes within a group, certain genera of chironomids occurred only in one or

1. See Appendix E for comments on the taxonomy and identification of the group in relation to this survey.

Table 2.7. Summary and comparison of the Chironomidae of the study lakes. Only the most frequently-occurring genera are included.

Genus	Low lakes n = 7 no. lakes (%)	Low lakes n = 7 no. m^{-2} $\bar{x}$ (range)	High lakes n = 19 no. lakes (%)	High lakes n = 19 no. m^{-2} $\bar{x}$ (range)
Procladius s. str.	7 (100)	192 (18 - 775)	15 (79)	1627 (11-6265)
Tanytarsus	6 (86)	244 (22 - 457)	13 (68)	2939 (7-23767)
Micropsectra	0 (0)		6 (32)	295 (43 - 484)
Paratanytarsus	3 (43)	+	3 (16)	711 (22-1281)
Chironomus	4 (57)	208 (5 - 409)	11 (58)	757 (11-2863)
Dicrotendipes	5 (71)	84 (7 - 237)	1 (5)	90
Phaenopsectra s. str.	0 (0)		8 (42)	505 (29-1931)
Stictochironomus	1 (14)	4865	10 (53)	234 (18-1044)
Paracladopelma	1 (14)	43	4 (21)	20 (8 - 37)
Pagastiella	5 (71)	483 (54 - 1679)	1 (5)	180
Protanypus	0 (0)		3 (16)	42 (6 - 108)
Pseudodiamesa	0 (0)		2 (10)	+
Psectrocladius	4 (57)	26 (16 - 43)	9 (47)	619 (12-1607)
Cricotopus and/or Orthocladius	0 (0)		9 (47)	148 (8 - 388)
Heterotrissocladius	0 (0)		4 (21)	285 (12-983)
Corynoneura	1 (14)	57	5 (26)	184 (7 - 334)
Paracladius	0 (0)		10 (53)	250 (7-1141)
Parakiefferiella?	1 (14)	5	6 (32)	165 (43-334)

"+" - numbers m^{-2} not available for some lakes, so a mean and range could not be found the other group, and on that basis might also be considered "characteristic". Thus, *Guttipelopia* was found only in 3 low lakes and *Micropsectra, Cricotopus* and/or *Orthocladius, Phaenopsectra* s. str., and *Heterotrissocladius* were found only in 4 to 9 high lakes.

Four genera were each found in one lake outside of its typical lake group. In each of these cases, the organism occupied a habitat within the atypical lake that was more characteristic of its own lake type. The high lake forms *Stictochironomus* and *Paracladopelma* were each found in the low McNair Pond at a station with relatively firm, sandy or gritty low-organic-content sediments reminiscent of those in many high lakes. *Pagastiella* and *Dicrotendipes,* characteristic of the low lakes, were found in the shallow end of the high Boom Lake, where the sediments were light-coloured and flocculent, closely resembling those in such low lakes as Kingfisher and Mud.

The two groups of lakes differed strikingly in the relative importance in their chironomid faunas of the two subfamilies Orthocladiinae and Diamesinae, both of which are primarily cold-adapted (Oliver 1971). Only one orthoclad genus, *Psectrocladius,* was of any importance in the low lakes, where it was present in small numbers in 4 lakes. In contrast, at least 6 orthoclad genera were important in the high lakes, 3 of these plus the two genera of Diamesinae occurring there exclusively.

It is difficult to judge how the lakes of the study area relate to others in the Rocky Mountains with respect to their chironomid faunas. Ecological investigations of this important group of insects are particularly rare in western Canada, and have been discouraged mainly by the lack of adequate taxonomic keys for their identification. While it is now possible for non-specialists to identify most larval chironomid genera using unpublished keys, specific identification of larvae remains a major problem even for the specialist. Further complications arise in survey studies from the impossibility of sampling all types of habitat in any area. It can at least be said that many of the most important chironomid genera in lakes of the study area are common to the Rocky Mountain lakes of Waterton Park (cf. Anderson, Donald and Krochak 1972) and Yoho Park (cf. Mudry and Anderson 1975). To this extent, the lakes of the study area are not unusual with respect to the generic composition of their chironomid faunas. Reasons for the differences in the occurrence of many genera among the lakes of the three areas studied remain to be resolved.

3. Fish

a. Species distribution and abundance

Table 2.8 lists the species of fish that occur, or have occurred, in the 31 lakes of the study area.

Brook trout and cutthroat trout were the most abundant species in the study lakes, occurring in 18 and 10 lakes, respectively. Rainbow trout were found in 8 lakes, but were seldom abundant. The remaining species listed were found in no more than 3 lakes each. Eight lakes, three of them formerly with stocked fish populations, were fish-free.

Based on catch per unit effort statistics, the population density of fish varied widely from lake to lake (Table 2.9[1]). Temple ,

1. Accurate estimates of actual fish numbers in lakes require detailed studies (Robson and Regier 1971); consequently we were unable to obtain such estimates in this survey. Catch per unit effort data such as those used here can give only a rough indication of abundance.

Table 2.8. Fish species found in the lakes of the study area.

Species	Presently found in	Formerly found in
Cutthroat trout	Annette?, Baker, Little Baker*, Boom, Lower Consolation, Hidden*, Louise?, Moraine, O'Brien, Taylor	Brachiopod, Herbert, Island, Kingfisher, Lost, Mud, Ptarmigan, Redoubt, Tilted
Rainbow trout	Annette?, Herbert, Little Herbert, Kingfisher, Kingfisher Pond* Louise?, McNair, Moraine*	Boom, Island, Mud, Temple?
Brook trout	Baker, Little Baker*, Lower Consolation, Upper Consolation, Herbert, Little Herbert*, Hidden, Kingfisher Pond*, Lost*, Louise?, McNair, Moraine, Mud, Ptarmigan, Redoubt, Temple, Tilted	Brachiopod, Island, Kingfisher
Splake trout	Agnes?, Louise?[1], Moraine	Herbert
Dolly Varden trout	Louise?	Moraine?, Boom[2]
Lake trout	Moraine*, Ptarmigan*	
Mountain whitefish	Herbert*, Louise?	Boom[2], Moraine[2]
Longnose dace	Mud	
Longnose sucker	Herbert*	

? the assigned status requires verification

* scarce

1. Ward (1974)

2. Vick (1913, in Paetz and Nelson 1970)

Redoubt and perhaps Hidden Lakes appeared to have rather dense fish populations; Agnes, Little Baker, Lost and Moraine evidently had small populations of fish. Additional sampling would be required to assess the relative population densities of fish in some lakes from which few fish were caught, for reasons discussed earlier for each lake.

Virtually all the fish populations in lakes of the study area were introduced. Waterfalls or torrential reaches of lake outlet streams, or absence of surface outlets would have prevented natural colonization of most lakes by fish. The presence now or formerly of mountain whitefish and Dolly Varden trout (both native to the Bow drainage) in Boom, Moraine and Louise, however, suggests that those three lakes may have had natural fish populations. Neither species is particularly esteemed by anglers, so it seems unlikely that they would have been introduced to the lakes. In any case, mountain whitefish have apparently disappeared from Boom and Moraine, as have Dolly Varden from the former lake (Ward 1974; present study). The present status of Dolly Varden in Moraine and Lake Louise, and of mountain whitefish in Louise requires further evaluation by additional sampling.

Stocked cutthroat trout formerly occurred in many lakes in the study area in which they are now rare or absent (National Parks stocking records; Ward 1974; Smiley 1976; present study). It has been suggested for some cases in the study area (Smiley 1976) and others elsewhere (Carlander 1969, pp. 165-166) that competition from introduced brook trout may have been responsible for their reduction or elimination. Smiley also suggested that introduction of infectious pancreatic necrosis (IPN) with stocked brook trout, and predation by brook trout could have eliminated cutthroat from some lakes.

Another possibility exists. There is evidence that brook trout are capable of successful spawning in lakes as long as there is a moderate current (Scott and Crossman 1973, p. 210), whereas cutthroat apparently spawn only in gravelly streams (Carlander 1969, p. 166; Scott and Crossman 1973, p. 180). In many of the study lakes from which cutthroat have disappeared, suitable stream spawning sites are limited or absent, but springs or small inlet brooks do occur and could provide adequate spawning sites within the lakes for brook trout.

b. Natural recruitment

There is good natural recruitment of fish in no more than 10 of the 23 lakes containing fish. There is a small amount of recruitment, probably inadequate to maintain a population in 6 others. There is evidently no natural recruitment in the remaining 7 lakes (Table 2.9).

Mention has already been made of the spawning requirements of brook and cutthroat trout (section (a), above). Like cutthroats, rainbow trout also seem to require a gravelly stream in which to spawn (Carlander 1969, p. 191). Few of the lakes in the study area have such inlet or outlet streams, or at most have only limited areas suitable for spawning. While small inlet brooks and springs do occur in some of the lakes and might provide for successful spawning and egg development by brook trout, they too are usually limited in extent. We believe the generally low natural recruitment in fish populations of the study lakes is owing to the absence of adequate spawning habitat. Natural

Table 2.9. Relative abundance and natural recruitment in fish populations in the study lakes.

+ natural recruitment - no natural recruitment ? uncertain

Lake	Species	Catch 100 m^{-1} h^{-1}	Natural Recruitment
Agnes	splake	0.16	+?
Annette	rainbow cutthroat	} 0.000	? ?
Baker	cutthroat brook	} 1.06	+ +
Baker, Little	cutthroat brook	} 0.22	-? -?
Boom	cutthroat	1.50	+
Consolation, Lower	cutthroat brook	} 2.94	+ +
Consolation, Upper	brook	1.15	-
Herbert	rainbow brook	} 1.54	- -
Herbert, Little	rainbow brook	caught by angling	- -
Hidden	cutthroat brook	} 3.51	- +?
Kingfisher	rainbow	0.61	-
Kingfisher Pond	rainbow brook	} 0.20	- -
Lost	brook	0.11	-?
Louise	several species mountain whitefish	} 0.000	? +
McNair	rainbow brook	} 1.12	-? +?
Moraine	several species	0.20	?
Mud	brook longnose dace	} 1.14	+ +?
O'Brien	cutthroat	1.31	+
Ptarmigan	brook	2.06	little
Redoubt	brook	5.24	-?
Taylor	cutthroat	0.79	+
Temple	brook	6.33	little
Tilted	brook	1.48	+

recruitment may be hampered additionally by the failure of the trout to spawn every year, as appears to be the case in some lakes (Lower Consolation, for example).

c. Age, growth and condition

Mean fork length at various ages are illustrated in Figures 2.129 and 2.130 for brook and cutthroat trout in the study lakes, the only two species for which we obtained adequate comparable data. Anomalous points (i.e. apparent decrease in length with an increase in age) are due to small sample size for a particular age group. Virtually all populations exhibited a wide range in length at any given age, a common characteristic of fish populations in general (for example, Tesch 1971, p. 111; Rawson 1953, Figure 5).

In terms of individual growth rates, the brook trout populations ranked as follows: Baker > Tilted > Herbert ≃ Mud > Little Baker(?) > Redoubt > Little Herbert(?) > Hidden ≃ Lower Consolation ≫ Ptarmigan > McNair > Temple > Upper Consolation. The cutthroat populations ranked in similar fashion were: Baker ≃ Taylor > O'Brien ≃ Little Baker(?) > Boom ≃ Hidden(?) ≫ Lower Consolation. The question marks (?) indicate uncertainty in the rank of the population due to small sample size.

As Figure 2.130 shows, growth rates of cutthroat trout in the study lakes were no higher than the lowest known for the species. Similarly, growth rates of brook trout in lakes of the study area were little more than average relative to those of a large number of other populations throughout the native and introduced range of the species.

Figure 2.129. Growth of brook trout in lakes of the study area.

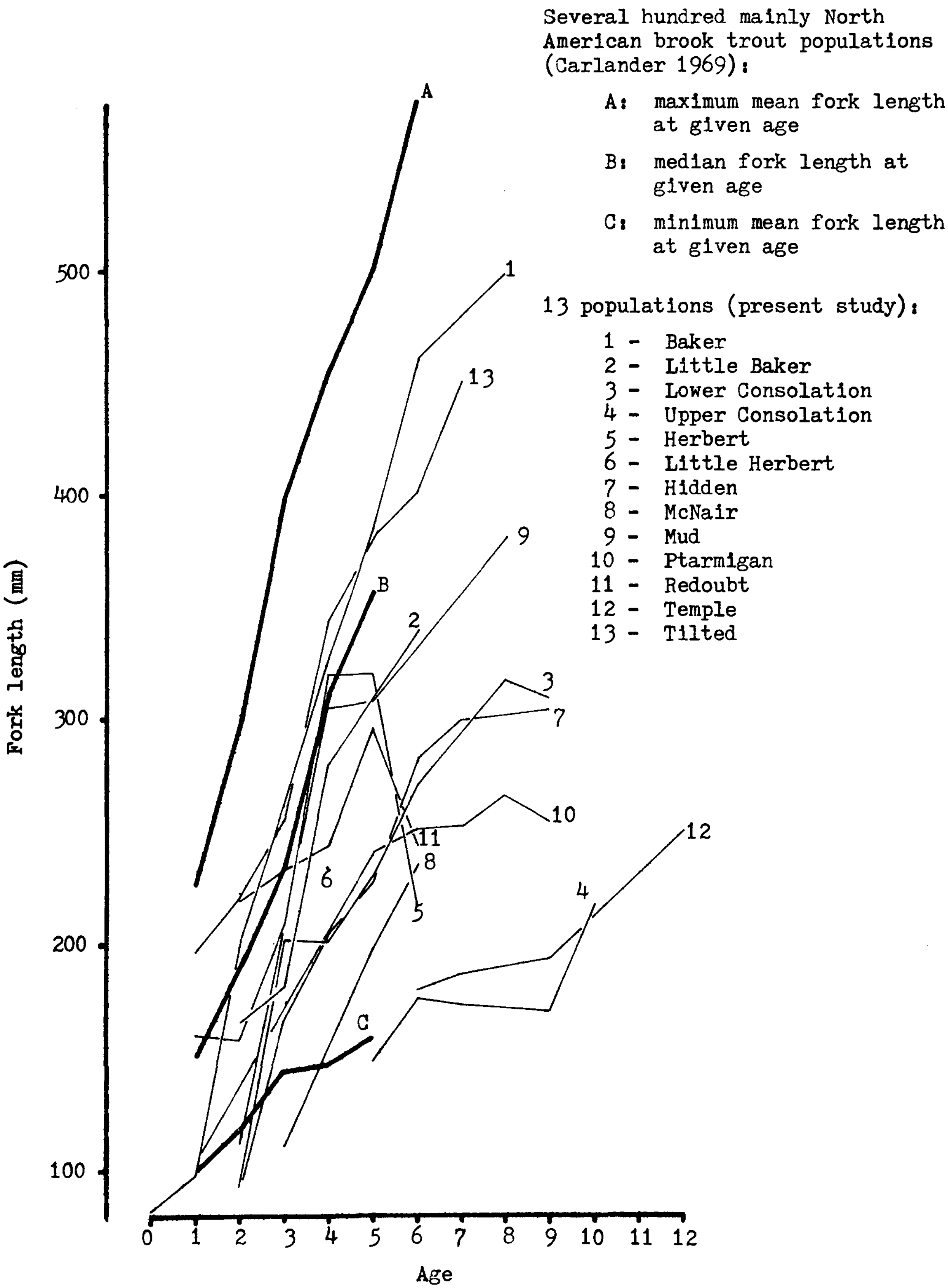
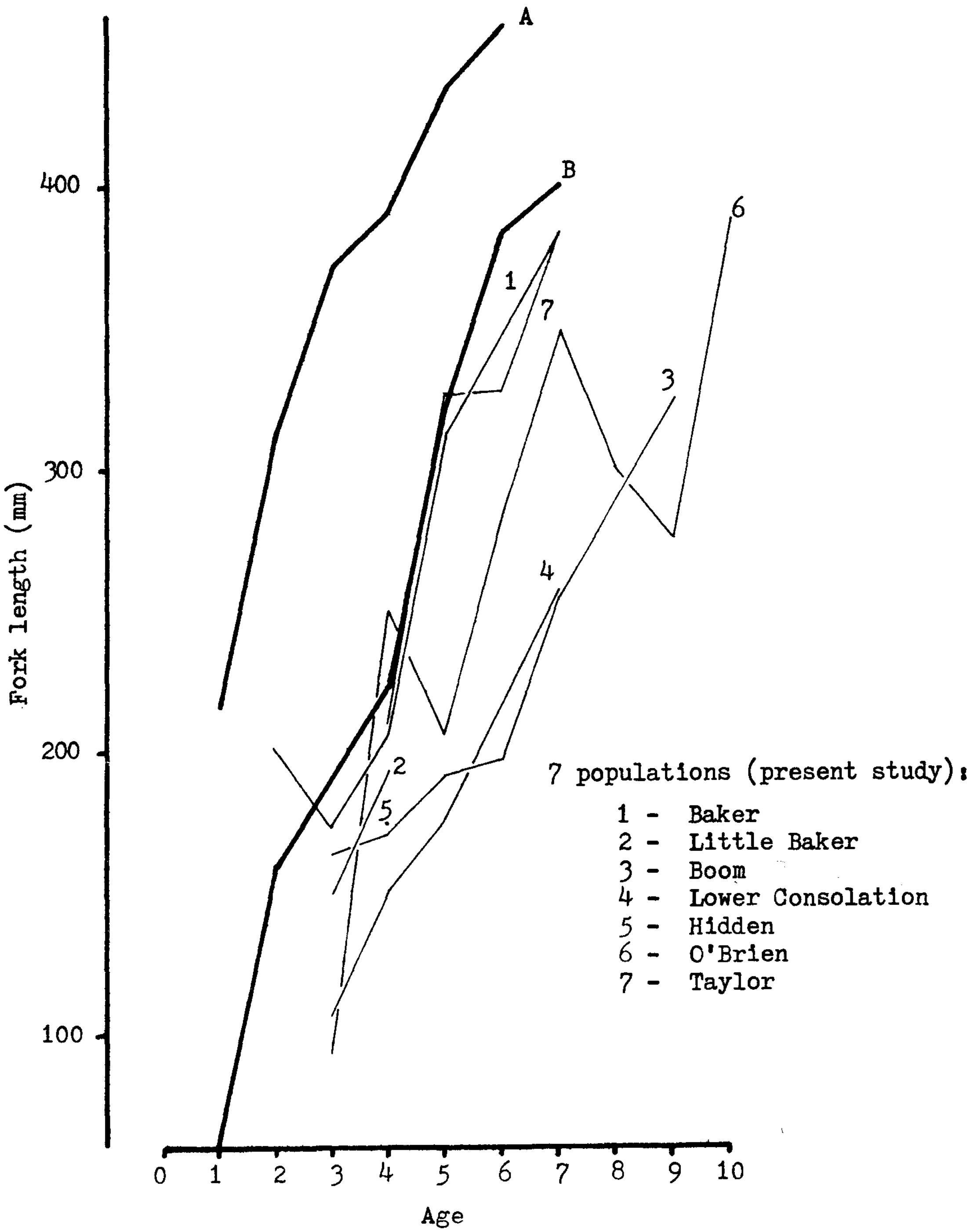


Figure 2.130. Growth of cutthroat trout in lakes of the study area.

Several dozen North American cutthroat trout populations (Carlander 1969):

A: maximum mean fork length at given age

B: minimum mean fork length at given age



In fact, two were among the lowest ever found and several others were well below average (Figure 2.129).[1]

The growth data in Figure 2.129 illustrate another interesting feature of brook trout in the study lakes: slow-growing fish live longer than fast-growing fish. This phenomenon has been observed in other studies of trout growth (eg; Carlander 1969, p. 262).

Brook trout seldom live longer than 4 or 5 years, although maximum ages of at least 15 years are known (Carlander 1969, p. 262; Scott and Crossman 1973, p. 211). Cutthroats commonly achieve ages of 4 to 7 years, 10 years being the apparent maximum (Scott and Crossman 1973, p. 181). Many brook trout and a few cutthroats of 8 years or more were found in the present study, placing them among the oldest recorded in the literature.[1]

Ages used in the present study were obtained exclusively from examination of otoliths, for which there are theoretical advantages over the more conventional scale method (Smiley 1976). As Carlander (1969, p. 15) has pointed out, estimation of age from growth rings on scales or otoliths can involve some errors, particularly among older fish. Although difficulties arising from the use of scales for age determinations in cutthroat and brook trout have been pointed out many times, the method has frequently been validated and corrected for use on both species (Carlander 1969; Scott and Crossman 1973). The scale method was undoubtedly used to provide most of the age data summarized by Carlander and used in Figures 2.129 and 2.130. It was seldom possible to validate the otolith method for any one population

1. While the fish in the study area lakes appear to grow more slowly and reach greater ages than do others of the same species elsewhere, we suspect that they are typical of fish in southern Canadian Rocky Mountain lakes in these respects (cf. Mudry and Anderson 1975, Anderson and Donald 1976).

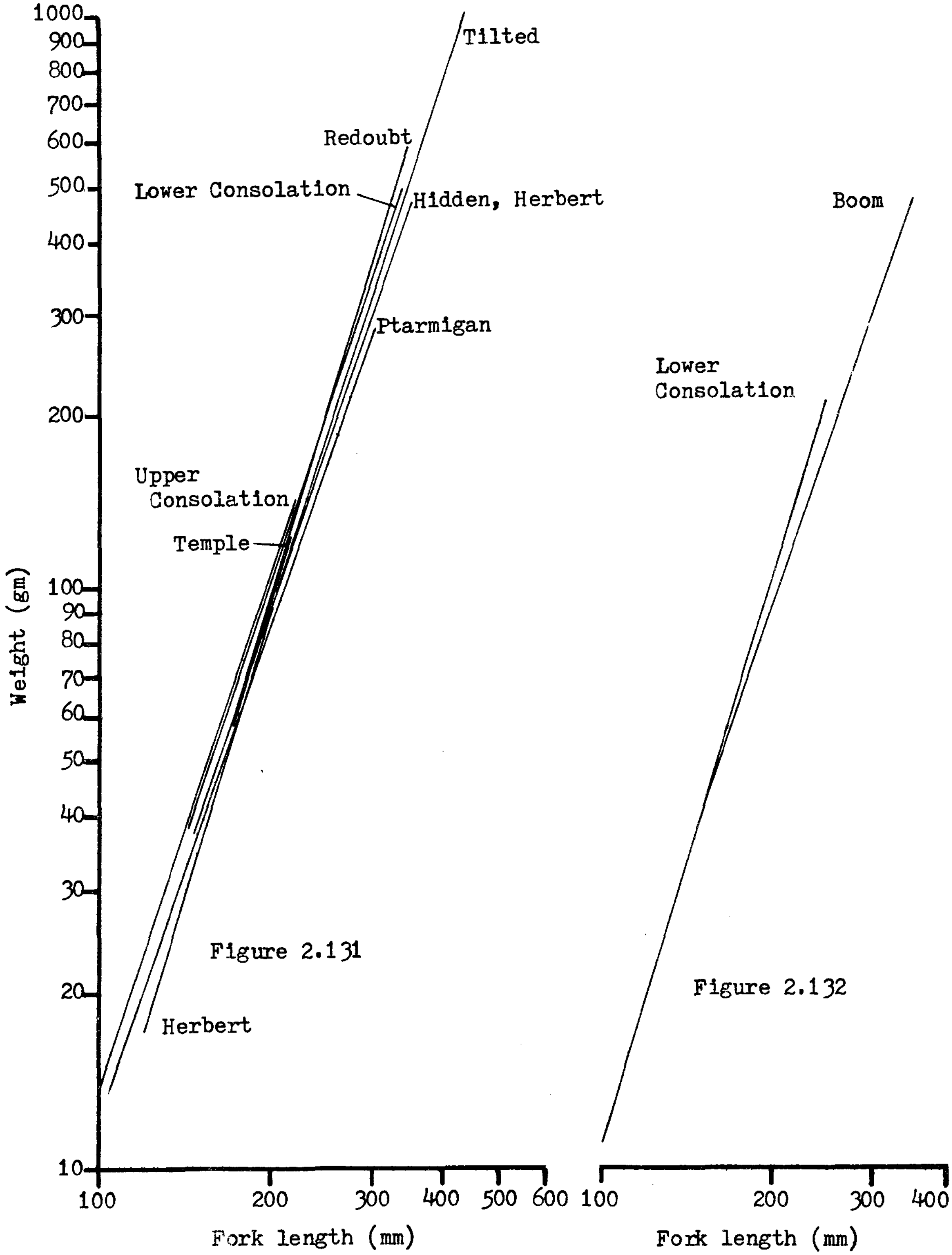
in the present study. However, where the ages of fish were known, agreement using the method was good (Smiley 1976, see also discussion of Temple findings in the present report). In summary, it is unlikely that there is any systematic bias in the method of age determination used in the study, or in the methods used to provide Carlander's comparative data shown in Figures 2.129 and 2.130, that would explain the relatively low growth rates and high maximum ages of fish in our study area. We feel that the data presented here reflect reasonably accurately the relative positions of the fish populations studied with respect to age and growth.[1]

There are many factors which determine the growth rate of fish, including food quality, food abundance, temperature, and genetic factors. We have no data concerning the latter for fish populations examined in this survey. Temperatures in many of the high lakes, however, would generally be considered optimal for growth of salmonids (eg; 7 - 18°C for brook trout, Carlander 1969, p. 260) for only a short time, if at all, each year. Low food abundance probably limits growth rates in several fish populations, particularly those that are clearly overcrowded. This topic is discussed in detail in Part 4. Finally, food quality appears to have an effect on fish growth rates in the study area, a topic discussed in section (d), below.

The "condition" (ie, weight at any given length) of trout from various populations is compared in Figures 2.131 and 2.132. The slight differences apparent among most of the lines appear to be insignificant when the scatter of points about the lines is considered, although this was not tested statistically. It is interesting to note that

1. Any bias in our data would likely be to underestimate ages and overestimate growth rates, because difficulties in ageing were associated with annuli being too closely-spaced to separate easily.

Length - weight relationships of brook trout (Figure 2.131) and cutthroat trout (Figure 2.132) from lakes of the study area.



even those populations with the lowest growth rates showed no evidence of poor condition as defined here; nor did the fastest-growing fish show relatively better condition. There are probably significant differences in fish condition between the highest and lowest lines, but the meaning of this is unclear. As Le Cren (1951) pointed out, many factors besides food supply or environmental quality can affect condition.

d. Food

The foods of fish collected in this study are summarized in Table 2.10.

Overall, trout in lakes of the study area ate mainly immature Chironomidae, immature Trichoptera and Amphipoda (either *Hyalella azteca* or *Gammarus lacustris* depending on their presence in the lake). Various other organisms were sometimes important items in the diet where they were available. Generally speaking, the most important animals in the diet were the more abundant types in the shoreline and benthic communities. However, sphaeriids and oligochaetes, though common in the lakes, were rare in or absent from the fish stomachs examined. In the case of the latter group, it is possible that the lack of large hard parts prevented us from identifying them in partly-digested stomach contents.

It is probably significant that populations that included *G. lacustris* as a major part of the diet also had relatively high growth rates. Use of this large crustacean as food has resulted in high growth rates in other trout populations (Scott and Crossman 1973, p. 190) and has been credited for the same in some lakes in the study area (Rawson 1939, Smiley 1976).

Part of the reason that *G. lacustris* could be a superior food

Table 2.10. Food of trout in lakes of the study area.

"Food item rank" refers to the order of importance of an item in the stomach contents. The numbers opposite the food item rank are the number of population collections in which the food item had that rank. A rank of one received 3 points, 2 received 2 points and 3 received 1 point. The score listed is the sum of all points; thus the higher the score, the greater the importance of the food item in the diet.

		Chironomidae	Trichoptera	*Gammarus*	*Hyalella*	Diptera imm.	Entomostraca	Ephemeroptera	Plecoptera	Odonata	Terrest. insects	Gastropoda	Hydracarina	Dytiscidae ad.
Brook trout	Food item rank 1:	5	1	2	1	2	1	1					1	
15 populations examined	2:	5	4			2	1							
298 fish examined; 20 empty stomachs	3:		1	1		2		1		1			1	
	score:	25	12	10		12	5	4		1			4	
Cutthroat trout	Food item rank 1:	3	1			1	1					1	1	
7 populations examined	2:		1	2				1						
78 fish examined; 6 empty stomachs	3:		1											
	score:	9	6	4		3	3	2				3	3	
Other trout	Food item rank 1:	1			3				2	1				
6 rainbow, 1 splake population examined	2:	1	1			1				1	2			
43 fish examined	3:	1		1								1		1
1 empty stomach	score:	6	2	10		2			6	5	4	1		1
All species: 29 populations examined, 419 fish examined, 27 empty stomachs	Overall score:	40	20	24		17	8	6	6	6	4	4	7	1

for trout growth is that this amphipod is relatively large and can form dense populations. This means that, in comparison to fish using less abundant and/or smaller food organisms, fish using *G. lacustris* would expend less energy in finding and capturing food, leaving more energy available for growth. Of course, the influence of such a food source would be modified by the other factors influencing growth discussed in section (c) above, including large populations of fish relative to food supplies.

e. Parasites

Only three species of fish parasite were found in the study area lakes: Nematode larvae, and the flatworms *Diphyllobothrium* sp. and *Crepidostomum farionis* (Mudry and Anderson 1976, in press). In addition the flatworm *Eubothrium salvelini* was reported from Dolly Varden trout in Moraine Lake by Rawson (1939).

According to Freeman (1964), flatworms have been reported to have adverse effects on their hosts, but extensive mortalities of fish are uncommon. Infections generally affect young fish more seriously than old fish, and crowding usually aggravates any problem the infections cause. However, parasite loads were usually low in the fish examined from the study lakes, probably too low to have any serious adverse effects on the hosts.

At least one species of *Diphyllobothrium*, *D. latum*, infects man and can cause disease (Cheng 1964). The type found in this study could not be assigned to species because only the larval form occurs in fish, the intermediate host. The normal practices of personal and food hygiene (evisceration and washing of fish, washing of hands after cleaning fish, quick-freezing, and complete cooking) will prevent any possible infection of humans by the parasites found.

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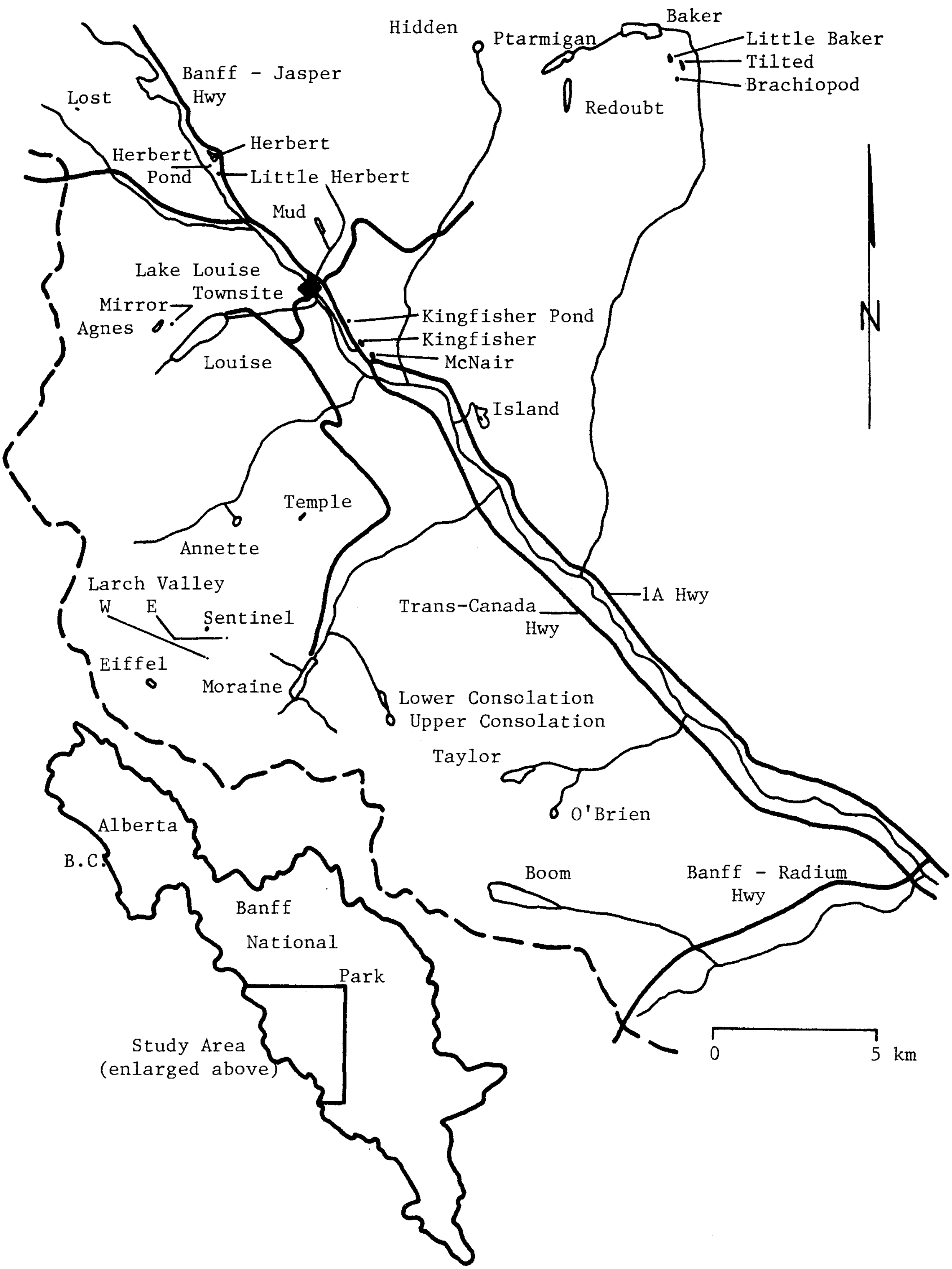
Hidden
Ptarmigan
Baker
Little Baker
Tilted
Brachiopod
Redoubt
Banff - Jasper Hwy
Lost
Herbert
Herbert Pond
Little Herbert
Mud
Lake Louise Townsite
Mirror
Agnes
Louise
Kingfisher Pond
Kingfisher
McNair
Island
N
Temple
Annette
Larch Valley
W
E
Sentinel
Eiffel
Moraine
Trans-Canada Hwy
1A Hwy
Lower Consolation
Upper Consolation
Taylor
O'Brien
Alberta
B.C.
Boom
Banff - Radium Hwy
Banff National Park
Study Area (enlarged above)
0
5 km