A FISHERIES AND WATER QUALITY SURVEY OF TEN LAKES IN THE RICHARDSON TOWER AREA, NORTHEASTERN ALBERTA
VOLUME I: METHODOLOGY, SUMMARY, AND DISCUSSION

by

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for

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

Project WS 1.4.1

August 1980

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

Sir:

Enclosed is the report "A Fisheries and Water Quality Survey of Ten Lakes in the Richardson Tower Area, Northeastern Alberta. Volume I: Methodology, Summary, and Discussion".

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

Respectfully,

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

A FISHERIES AND WATER QUALITY SURVEY OF TEN LAKES IN THE RICHARDSON TOWER AREA, NORTHEASTERN ALBERTA VOLUME I: METHODOLOGY, SUMMARY, AND DISCUSSION

DESCRIPTIVE SUMMARY

BACKGROUND

One of the major effects of the development of the oil sands area of northeastern Alberta has been an increase in population size. With this increase has come a demand for recreational opportunities such as camping and fishing. Government agencies, such as the Northeast Alberta Regional Commission, Alberta Fish and Wildlife, and Alberta Parks and Recreation, are concerned with planning and providing such opportunities. Information on fish productivity would be useful for their planning needs.

The region near Richardson Tower has a large number of lakes and therefore has been identified as a prime recreational area. Only a small number of these lakes have received any attention from a fisheries viewpoint (AOSERP Project WS 1.5.2; W.R. Turner, "A Preliminary Survey of Waters in the Maybelle River, Keane Creek, Crown Creek, Old Fort River, Richardson River Drainages"; and G.M. Bradley, "Preliminary Biological Survey of Six Lakes in Northern Alberta").

In September 1979, a fisheries and water quality survey was conducted on 10 lakes in the Richardson Tower region. The major objectives of this study can be found in the Introduction.

ASSESSMENT

This report has been reviewed by scientists in Alberta Environment and Environment Canada. The report was well received by the user agencies and the authors are thanked for their contribution.

The Alberta Oil Sands Environmental Research Program accepts the report as a valuable document which has generated a lot of information. The report is presented in two volumes: the first volume provides a description of the methodology used and a summary and discussion of the results and will be widely distributed; the second volume is a compilation of data and colour photographs of the study lakes and will be distributed to selected Canadian libraries.

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ABSTRACT

A fisheries and water quality survey was conducted in September 1979 on 10 small lakes (67.4 to 338.9 ha) in the vicinity of Richardson Tower, approximately 140 km north of Fort McMurray, Alberta. The major objectives were: (1) to determine morphometric and water quality characteristics in relation to habitat requirements for indigenous and possible introduced species of fish; (2) to assess potential fish yield; and (3) to determine the susceptibility of the lakes to acidification.

Maximum lake depth ranged from 6 to 16 m; mean depth varied from 1.9 to 8.0 m. Morphoedaphic indices varied from 16.7 to 54.3. Water quality was fairly uniform with moderate concentrations of dissolved solids total filterable residue slightly above 100 mg/L), calcium and bicarbonate at the major ions, and low phosphorus levels. Waters were clear, largely unstained, and generally well oxygenated. Water quality in most lakes was highly suitable for fish production.

Ten species of fish were recorded. All lakes supported northern pike while only five contained walleye. Lake whitefish was present in all but one lake. Yellow perch, although recorded in seven of the lakes, were slow growing and small in size. Estimates of potential fish yield varied from 4.8 to 6.5 kg/ha/yr to 8.2 to 10.9 kg/ha/yr.

Mean total alkalinity of the study lakes was 77 mg/L (1.53 meq/L). Although terrestrial buffering responses were uncertain, it appeared that lakes are not highly susceptible to acidification (i.e., at precipitation acidities foreseeable for the study area).

ACKNOWLEDGEMENTS

The authors would like to thank the many people who have provided assistance during the course of this study. Field assistance was provided by W. Wisener. Assistance in data analysis and manuscript preparation was provided by J.P. O'Neil, C.L. McLeod, J. Davis, T. Clayton, L. Hildebrand, and D. Atwood of R.L. & L. Environmental Services Ltd.

The support and assistance of C. Closs and D. Hadler of the AOSERP Fort McMurray office are acknowledged and greatly appreciated.

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1. INTRODUCTION

As a result of recent population increases in northeastern Alberta associated with oil sands development, there is presently a high demand for recreational opportunities such as sport fishing. This demand is expected to rise as further developments proceed. One location that has been identified as a possible recreational area is the region near Richardson Tower, situated approximately 140 km north of Fort McMurray. While this area contains numerous lakes, only a few have been surveyed for their fishery potential. In order to obtain necessary information to assist in recreational planning and fishery management within this area, the Alberta Oil Sands Environmental Research Program (AOSERP) in August 1979 initiated a fisheries and water quality survey of 10 of the lakes.

The major objectives of the study were:

1. To describe harvestable fish production of 10 lakes near Richardson Tower;
2. To describe the depth and physical setting of each lake with regard to habitat requirements of aquatic biota; and
3. To describe the major ion regime of each lake with particular regard to its susceptibility to acidification.

To meet these objectives, information regarding the morphometry, water quality, and fish fauna was collected from each of the 10 lakes.

This report consists of two volumes. Volume I provides a description of the methodology used, a summary of the results of the study, and a discussion of these results. Volume II is a compilation of data including a computer printout of fisheries data and colour photographs of the study lakes.

2. STUDY AREA

The 10 lakes surveyed during this study are situated in northeastern Alberta in the vicinity of Richardson Tower (Figures 1 and 2). A winter road, running north from Fort McMurray, passes through the group of lakes. With upgrading, it could provide summer access. This road is also situated near a site proposed for the new town in the Fort Hills.

Since none of the lakes has been named officially, the lakes were numbered to facilitate discussion. In cases where the investigators were able to determine local names, the names have been indicated in the appropriate section. The majority of these lakes drain west to the Athabasca River, while the two most easterly lakes, Unnamed Lakes #9 and #10, drain north via the Richardson River to the Athabasca River. The group of lakes lies across the boundary of the Canadian Shield and Saskatchewan Plain (Atlas of Alberta 1969). Surficial geological deposits, consisting mostly of sand, are fairly similar surrounding each lake; consequently, the boundary of the two divisions does not influence the settings or nature of the 10 lakes.

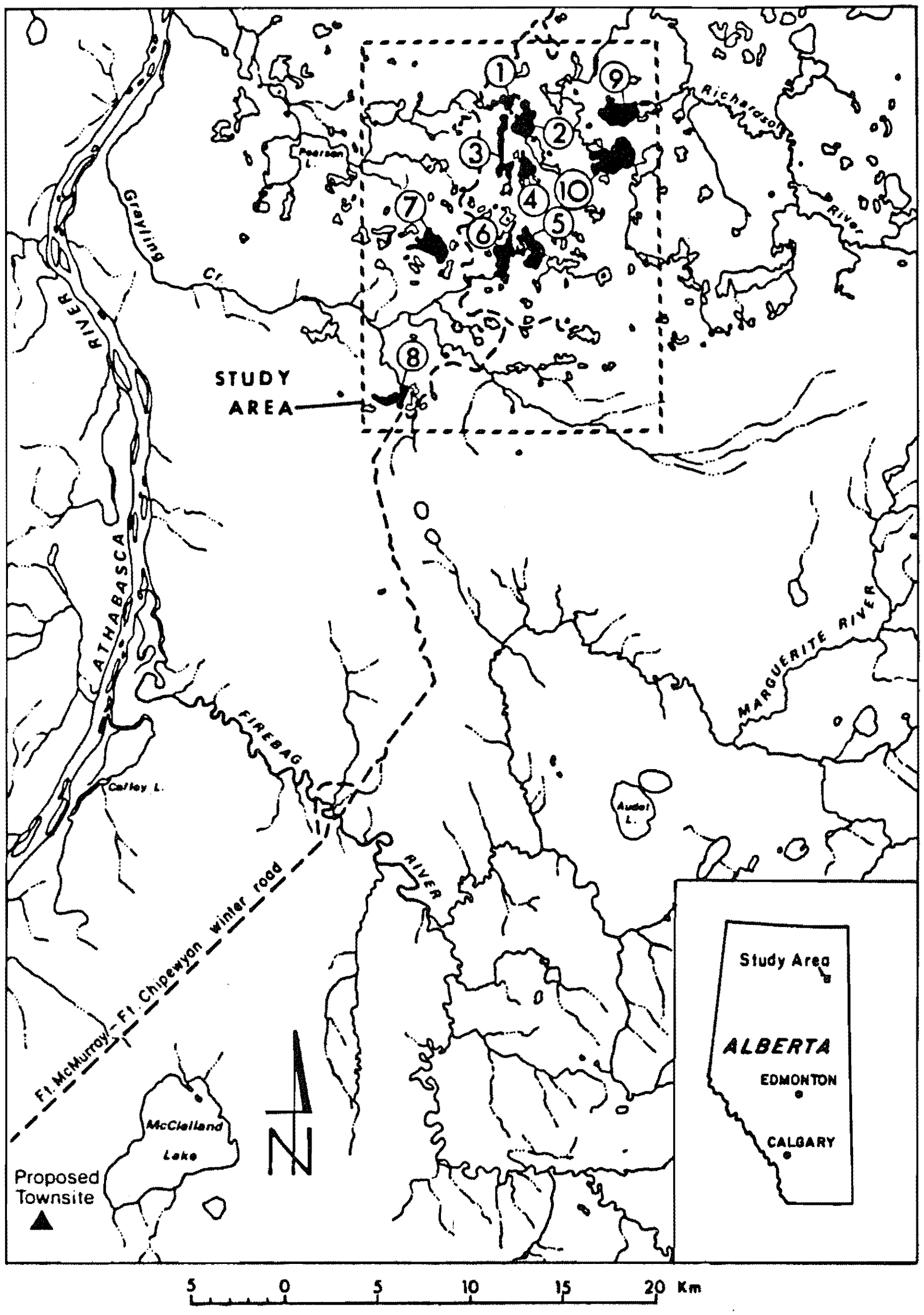

Figure 1. Map showing the location of the 10 study lakes.

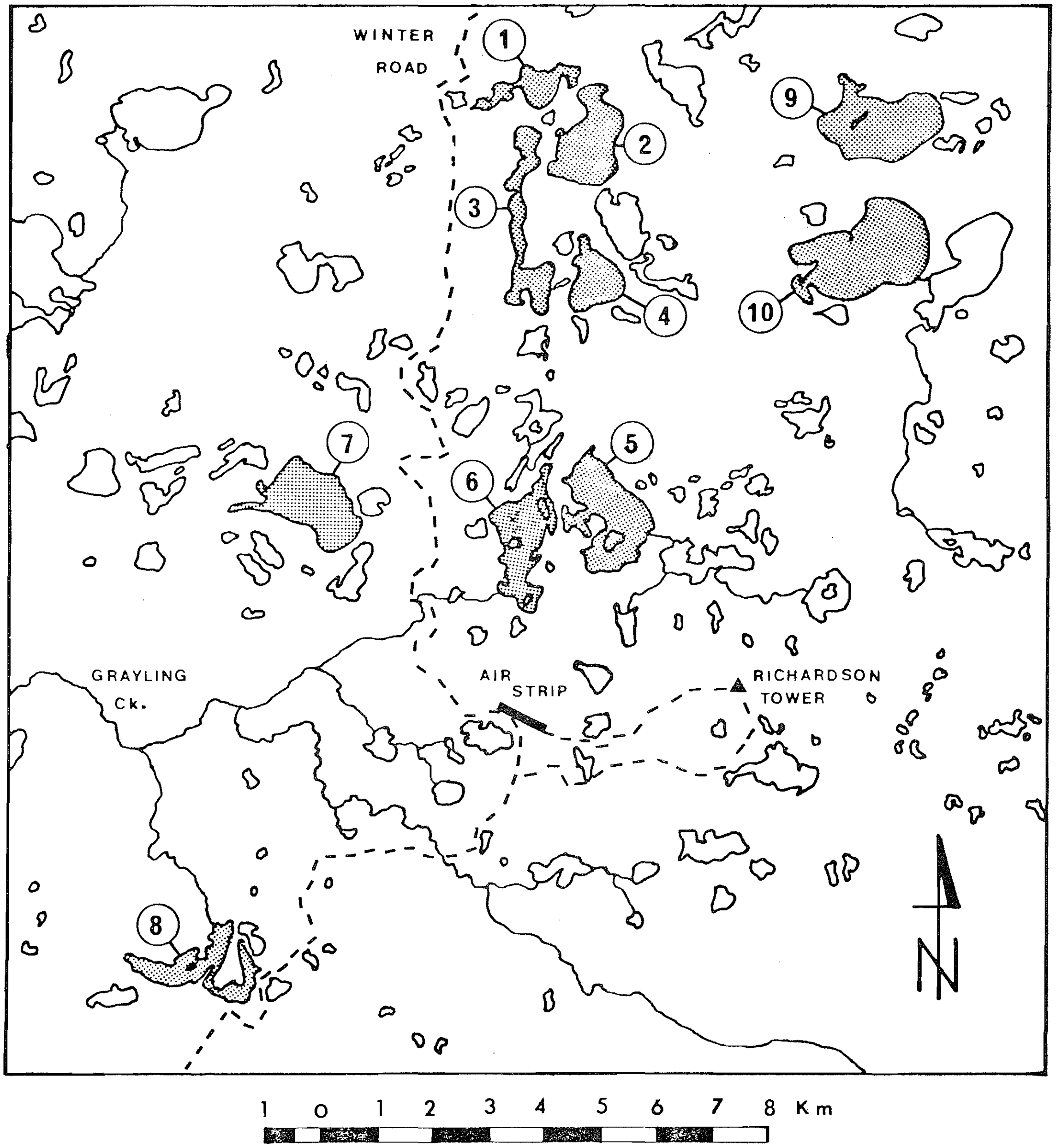

Figure 2. Large-scale map of the 10 study lakes.

3. METHODOLOGY

Field sampling was conducted between 5 and 25 September 1979. Equipment and personnel were transported to each lake in float-equipped aircraft and a tent camp was established. Sampling was conducted from an inflatable boat (Zodiac Mark II Compact) with a 9.9 hp outboard motor.

Depth soundings in each lake were taken with an electronic echo sounder (Model FG200A, Furuno Electric Co. Ltd.). A graphical depth profile was obtained along predetermined transects which were run at a constant speed. A minimum of two transects down the long axis of the lake and six across the lake, perpendicular to the long axis of the lake, were surveyed. On lakes of irregular shape or depth, more transects were chosen. A bathymetric map was constructed for each of the lakes. The area encompassed by each contour was determined using a planimeter, and the lake volume was calculated according to the "frustrum method" as described in Lind (1974). Other morphometric parameters were measured or calculated using standard limnological procedures (Welch 1948; Lind 1974).

The general distribution of lake substrate types was determined using a 4 m long wooden dowel with a metal cap to "feel" the bottom during a boat survey of the shorelines. An Ekman dredge was used to confirm findings obtained with the pole and was also used in deeper water. The information on substrate type was plotted on a map for each lake. The approximate area of each of the major substrate types (i.e., sand, silt, gravel-rubble) was determined by planimetry. Although project time allotments did not allow intensive substrate transects, the general distribution of substrate types obtained from these surveys are useful in assessing fish habitat in the lakes and may be useful in preliminary recreational planning. Major concentrations of emergent and floating-leafed aquatic vegetation were mapped also. The density of growth was assessed on a scale of one to three, with three being the highest.

Samples for water quality analyses were collected from each lake using a plastic 2 L Van Dorn water bottle. Samples were usually taken in the centre of the main basin of the lake; however, where the lake had two main basins, water samples were taken in both basins. Water samples were composited from separate samples taken at 2 m intervals throughout the water column. Dissolved oxygen and temperature were measured in situ at each of these sites and Secchi disc visibility was determined.

Water samples destined for laboratory analyses were preserved in the field according to Alberta Environment (1977) recommended procedures, kept cool and in the dark, and shipped to Edmonton by air. Alkalinity and pH were measured in the field camp the same day the samples were collected. Analyses were conducted within 4 to 6 days of collection by Chemical and Geological Laboratories Ltd., Edmonton using methods outlined by Alberta Environment (1977). Water quality parameters and methods of analysis are shown in Table 1.

Fish[a] samples were collected from each lake using overnight gillnet sets; a set consisted of equal lengths (45.7 m) of 3.8 cm, 5.1 cm, 6.4 cm, 7.6 cm, 8.9 cm, 10.2 cm, 11.4 cm, and 14.0 cm mesh (stretched measure). The nets which were constructed of monofilament nylon were generally set with the smaller mesh sizes near shore. Additional fish samples were collected in most lakes from nearshore areas using a beach seine (9.1 m long, 1.5 m deep, 1.3 cm nylon mesh). High water resulting from beaver activity produced precipitous shorelines and/or inundated vegetation on three of the lakes such that beach seining was not practical.

A sample of the fish catch from each lake was measured (fork length), weighed, and examined to determine sex and state of maturity. A scale sample was taken from each of the sport or commercially important species. Aging was accomplished by viewing scale samples at 42 X

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[a] See Table 2 for list of common and scientific names of the fish collected.

Table 1. Water quality parameters and methods of analysis.

Parameter	Method or Instrument
Field	
Dissolved oxygen, temperature	Oxygen-temperature meter (Model 490-051, Int. Biophysics Corp.)
pH	Meter (Model PHM 29, Radiometer Ltd.)
Alkalinity	Potentiometric titration to pH 4.5
Visibility	Secchi disc
Laboratory	
Na, K, Ca, Mg, Fe	Atomic emission (Model 975 Plasma atomcomp, Jarrell-Ash Ltd.)
CO_3, HCO_3, Hardness	Calculation
Cl	Automated thiocyanate
SO_4	Automated methylthymol blue
Total filterable residue	Filtration, evaporation @ 105°C
Fixed	Ignition @ 550°C
Conductivity	Meter (Type CDM2e, Radiometer Ltd.)
Turbidity	Nephelometer
Total P	Persulphate digestion, automated colourimetry
Ammonia-N	Automated colourimetric phenate
Reactive silica	Automated heteropoly blue
Total organic carbon	Automated flame ionization (Dohrmann Model DC-50A/52A)

Table 2. Common and scientific names[a] of fishes collected from 10 lakes in the Richardson Tower area.

Common Name	Scientific Name
Walleye	*Stizostedion vitreum vitreum* (Mitchill)
Yellow perch	*Perca flavescens* (Mitchill)
Northern pike	*Esox lucius* Linnaeus
Lake whitefish	*Coregonus clupeaformis* (Mitchill)
Cisco	*Coregonus artedii* Lesueur
White sucker	*Catostomus commersoni* (Lacépède)
Spottail shiner	*Notropis hudsonius* (Clinton)
Ninespine stickleback	*Pungitius pungitius* (Linnaeus)
Iowa darter	*Etheostoma exile* (Girard)
Burbot	*Lota lota* (Linnaeus)

[a] Source: American Fisheries Society 1970.

magnification on a 3M microfiche reader. To ensure that ages were assigned accurately, two independent readings were made; when differences were obtained the issue was resolved with a third reading. Pectoral fin rays were collected from walleye and white sucker; however, due to time constraints, they were not used for aging. A representative sample of lake whitefish and cisco (when available) from each lake was dissected and examined to determine the infestation rate of the plerocercoids of the cestode *Traienophorus crassus*. In situations where fish catches were sufficient, a minimum of 15 fish were sampled to determine the infestation rate. Fish data were subsequently keypunched onto computer cards and analyzed using an in-house computer program package (FISHPAK) on the University of Alberta computer.

A number of models have been proposed relating physical, chemical or biological data to harvestable fish production (Rawson 1952; Ryder 1965; Jenkins and Morais 1971; Henderson et al. 1973; Ryder et al. 1974; Allan 1975; Melack 1976; Welcomme 1976; Oglesby 1977; and others). Some of these relate fish yield to primary productivity or summer phytoplankton standing crop (Oglesby 1977; Melack 1976), while others relate yield to morphoedaphic factors (Ryder 1965; Jenkins and Morais 1971; Ryder et al. 1974; Welcomme 1976). Due to the scope and timing of the present study, it was not possible to collect data describing summer phytoplankton standing crops or annual primary production estimates. As a result, an estimate of the annual harvestable fish resources of each lake surveyed was made using the morphoedaphic index (MEI - the ratio of total dissolved solids to mean depth). Ryder (1965) developed a regression equation relating MEI to harvestable fish production for a set of north-temperate lakes. Allan (1975) has since modified the regression equation to more closely fit a group of northern Alberta lakes. His equation is as follows.

$$y = 1.945\ (x^{0.43246}) \qquad r = 0.82$$

Where: y = annual harvestable fish production in kg/ha/yr, and
x = morphoedaphic index (in metric units).

Since the constants in this model were derived using a set of fairly productive lakes in the boreal mixedwood zone of the interior plains of Alberta, its appropriateness for the 10 study lakes is not precisely known but is probably better than Ryder's original equation. For comparative purposes, both models were used to estimate harvestable fish production. Ryder's regression equation is as follows:

$$y = 1.381\ (x^{0.44610}) \qquad r = 0.86$$

Where: y = potential fish production in kg/ha/yr, and

x = morphoedaphic index (in metric units).

An approximation of total potential sportfish harvest was calculated based on the relative proportion of sportfish by weight in the samples obtained in the gillnet catches during this study. Only northern pike, walleye, and yellow perch were classed as sportfish in this assessment.

4. RESULTS

4.1 UNNAMED LAKE #1

4.1.1 Introduction

This lake is located in Township 103, Range 6, West of the Fourth Meridian (57°59'N; 111°02'W). The surface elevation is approximately 283.5 m above mean sea level (m.s.l.). A small creek, draining the lakes to the south, enters Lake #1 at the south end and an outflowing creek drains west to Eleanor Creek.

The main body of the lake is situated in a medium density forested area (Intera Environmental Consultants Ltd. 1979). Jack pine (*Pinus banksiana*) is the dominant species, although white birch (*Betula papyrifera*) and willow (*Salix* sp.) are common along the shoreline.

In the summer, Lake #1 is accessible only by aircraft while in the winter access may be made from the Fort McMurray-Fort Chipewyan winter road which passes within 0.6 km of the west end of the lake.

Sampling on this lake was conducted during the period 7 to 9 September 1979. Locations of the sampling sites are shown in Figure 3.

4.1.2 Morphometry

Lake #1 has a surface area of 67.4 ha and an estimated volume of 3.5×10^6 m^3, giving it a mean depth of 5.2 m (Table 3). The maximum depth (8.5 m) noted during 14 sounding transects was recorded near the centre of the main basin of the lake (Figure 4). Over 59% of the surface area of the lake is deeper than 4 m.

Lake #1, with its long axis situated in an ENE-WSW direction, had a maximum effective length of 1.6 km, a maximum effective width of 0.9 km, and a total shoreline length of 6.8 km. The shoreline development factor (comparison of the actual shoreline length to the shortest length which would enclose the same area) was 2.3, which indicates that the lake had a moderately irregular shoreline.

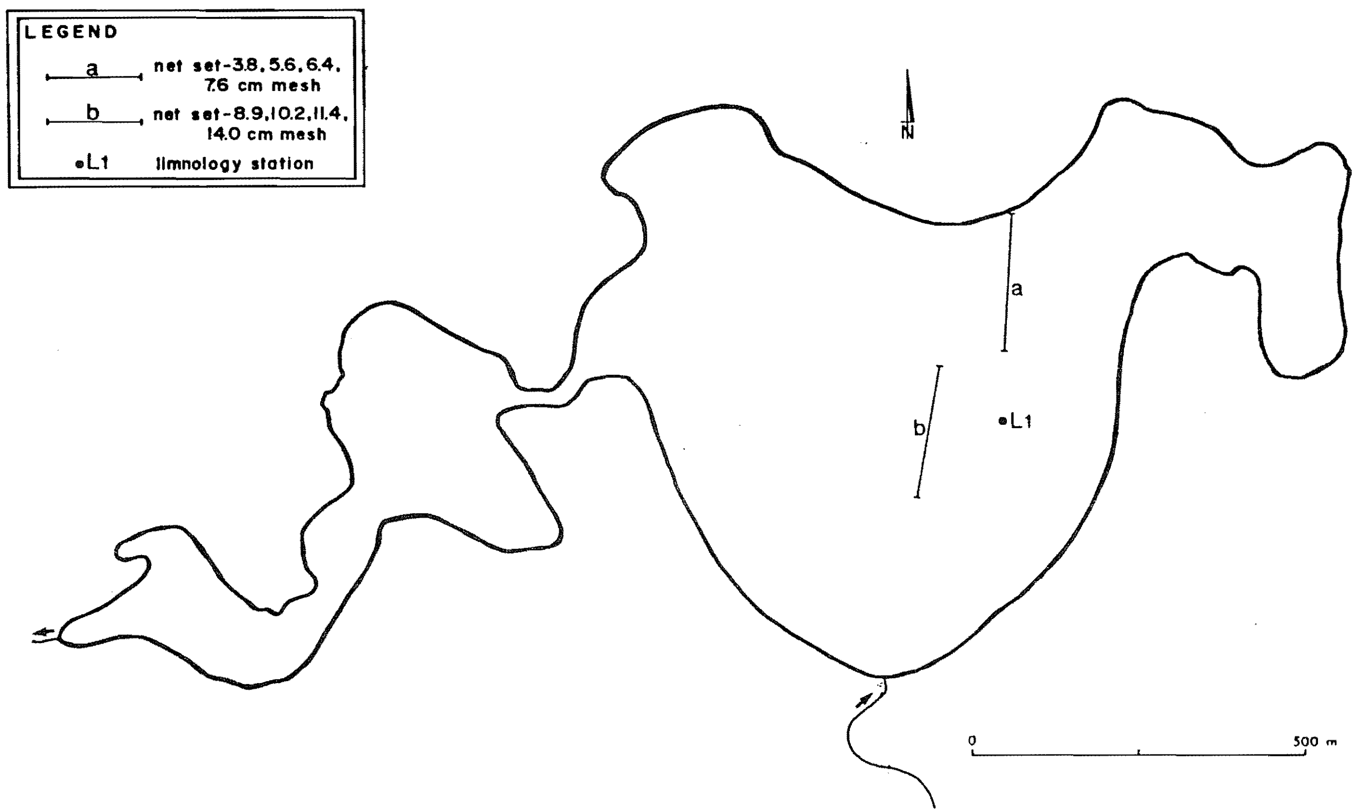

Figure 3. Sampling site locations in Unnamed Lake #1, September 1979.

Table 3. Morphometry of Unnamed Lake #1.

Location		Tp. 103, Rg. 7, W4
Area		67.4 ha
Volume		3.5×10^6 m^3
Shoreline length		6.8 km
Shoreline development factor		2.3
Maximum length		2.1 km
Maximum effective length		1.2 km
Maximum width		0.9 km
Maximum effective width		0.9 km
Mean width		0.3 km
Depth Distribution:		
	ha	% Surface Area
Surface area	67.4	100
2 m+	47.0	70
4 m+	40.0	59
6 m+	34.1	51
8 m+	17.6	26

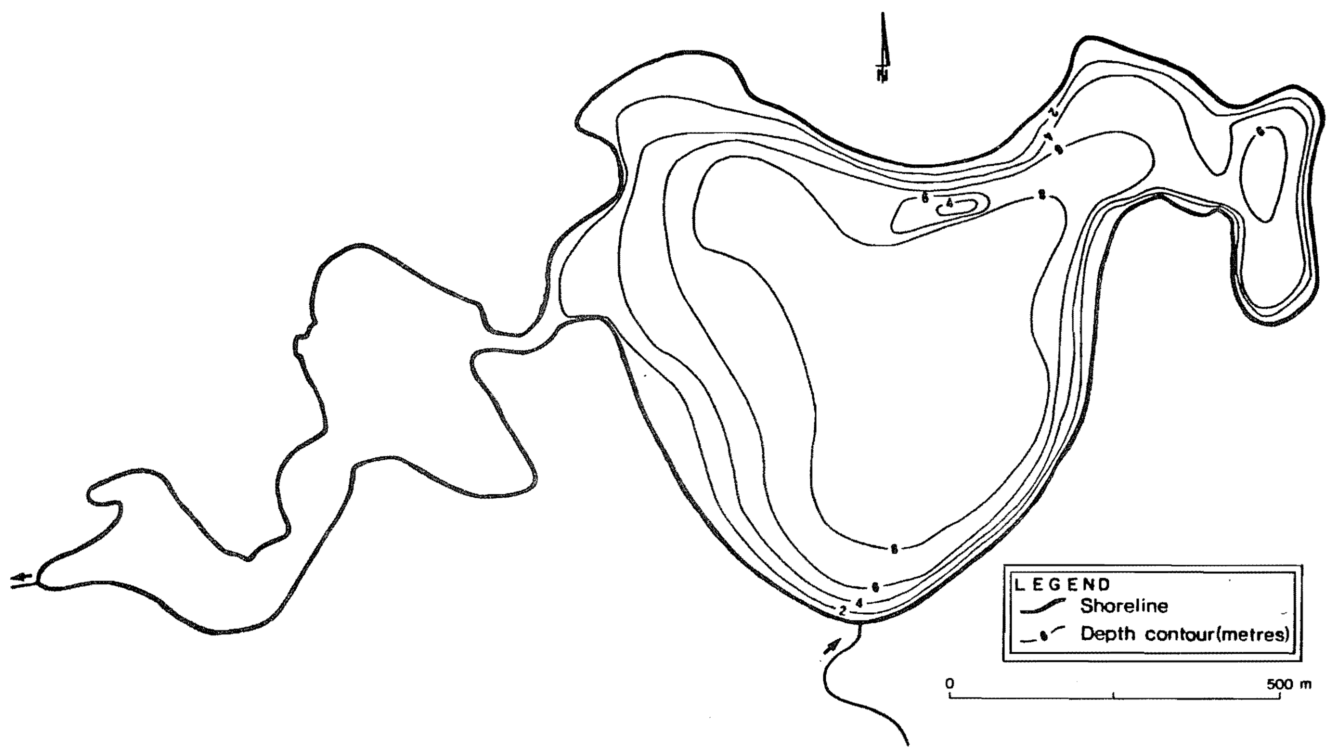

Figure 4. Bathymetric map of Unnamed Lake #1.

4.1.3 Water Quality

Lake #1 was isothermal when sampled (Figure 5) and dissolved oxygen saturation was about 80%. A slight decline in oxygen was recorded in the bottom metre of water. The water was fairly clear and unstained. Turbidity was low, the major dissolved ions were calcium and bicarbonate, and total filterable residue was 84 mg/L (Table 4). Total alkalinity, as $CaCO_3$, was 65 mg/L.

4.1.4 Substrate

Approximately 95% of the lake had a substrate of silt or a thick layer of silt over sand, while only 4% consisted of sand (or thin layer of silt over sand) (Figure 6). Less than 1% consisted of gravel or rubble. Sand was predominant near shore around most of the east basin of the lake. The bays on the west had a silt substrate extending to the shore. The only gravel-rubble area noted during this survey was a small patch situated along the north shore near the east narrows.

4.1.5 Aquatic Vegetation

Most of the shoreline of the lake was vegetated with shrubs. The shrub component extended from shore over the water surface. The shoreline, around most of the east basin, dropped off immediately to a depth of 0.5 m. A narrow band of *Carex* was characteristic around much of the periphery of the main basin, with patches of *Phragmites* along the southeast, north, and southwest shores (Figure 7). A few small, localized stands of *Scirpus* were also noted along the shoreline of the main body of the lake.

Bays on the west end of the lake featured a greater density of aquatic vegetation, likely as a result of shallower depth. Medium to dense growths of *Nuphar* were present throughout most of these bays. *Carex* was predominant around the shoreline and often extended back from shore in marshy areas for up to 100 m. *Typha, Scirpus,* and *Menyanthes* were the other predominant emergent plants. Flooded trees

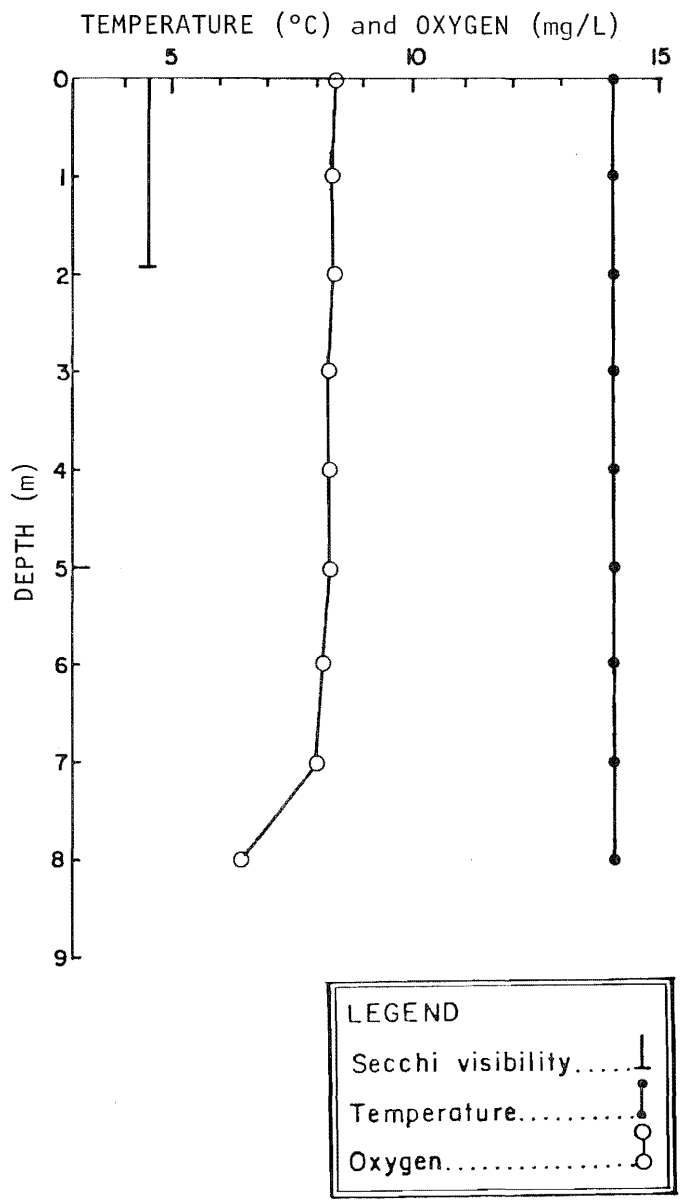

Figure 5. Temperature, dissolved oxygen, and Secchi visibility in Unnamed Lake #1, Site L1, 9 September 1979.

Table 4. Water quality analyses for Unnamed Lake #1.

9 September 1979	Site L1			
Na	4.0	mg/L	0.17	meq/L
K	0.6	mg/L	0.02	meq/L
Ca	17.7	mg/L	0.883	meq/L
Mg	4.9	mg/L	0.40	meq/L
SO_4	3.7	mg/L	0.077	meq/L
Cl	0.3	mg/L	0.008	meq/L
CO_3	0	mg/L	0	meq/L
HCO_3	79	mg/L	1.3	meq/L
Alkalinity				
Total	65	mg/L ($CaCO_3$)	1.3	meq/L
P'thalein	0	mg/L ($CaCO_3$)		
pH (pH units)	8.0			
Hardness, total (as $CaCO_3$)	64.4	mg/L		
Total filterable residue				
Evap. @ 105°C	84	mg/L		
Ignit. @ 550°C	54	mg/L		
Conductivity	138	µS/cm		
Turbidity	4.2	NTU		
Total P	<0.016	mg/L		
Ammonia-N	<0.05	mg/L		
Reactive silica	7.0	mg/L		
Total organic carbon	6.3	mg/L		
Fe (total)	0.37	mg/L		

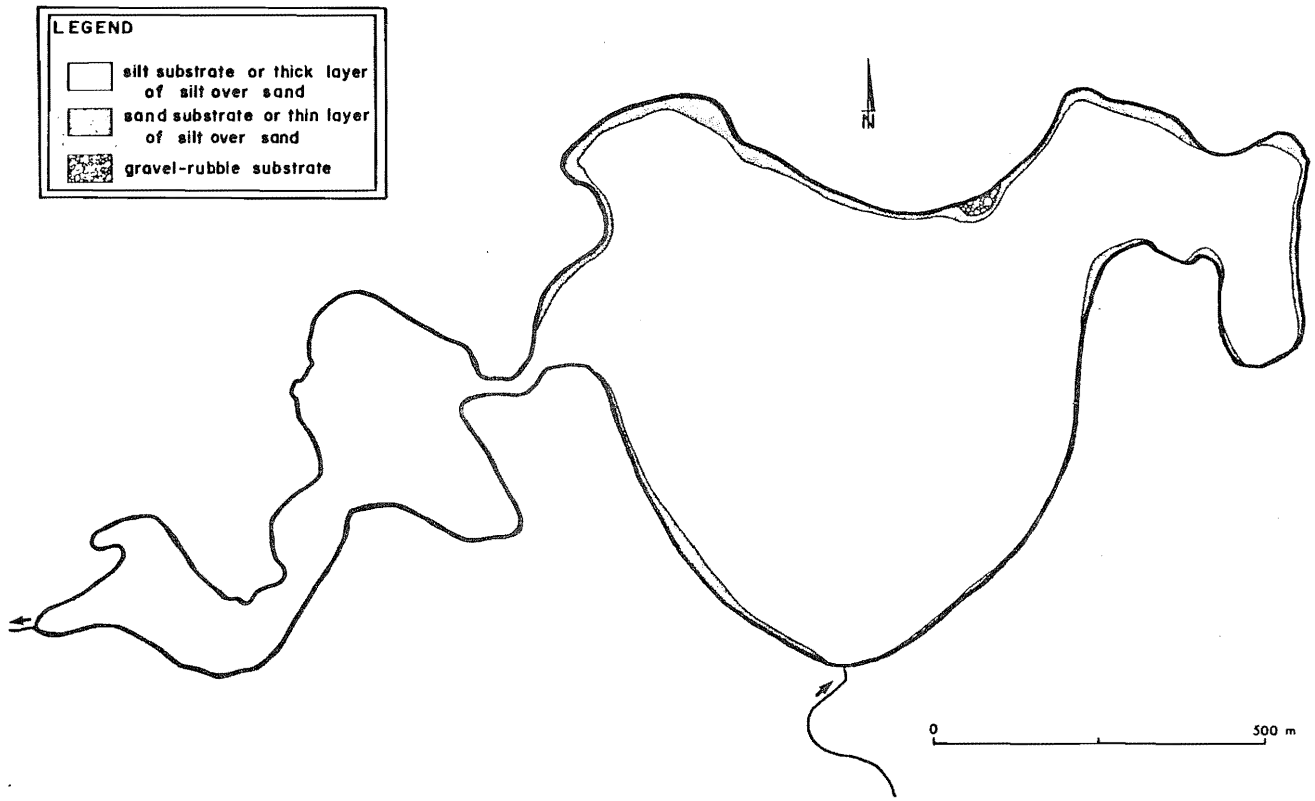

Figure 6. Approximate distribution of surficial lake sediment types in Unnamed Lake #1.

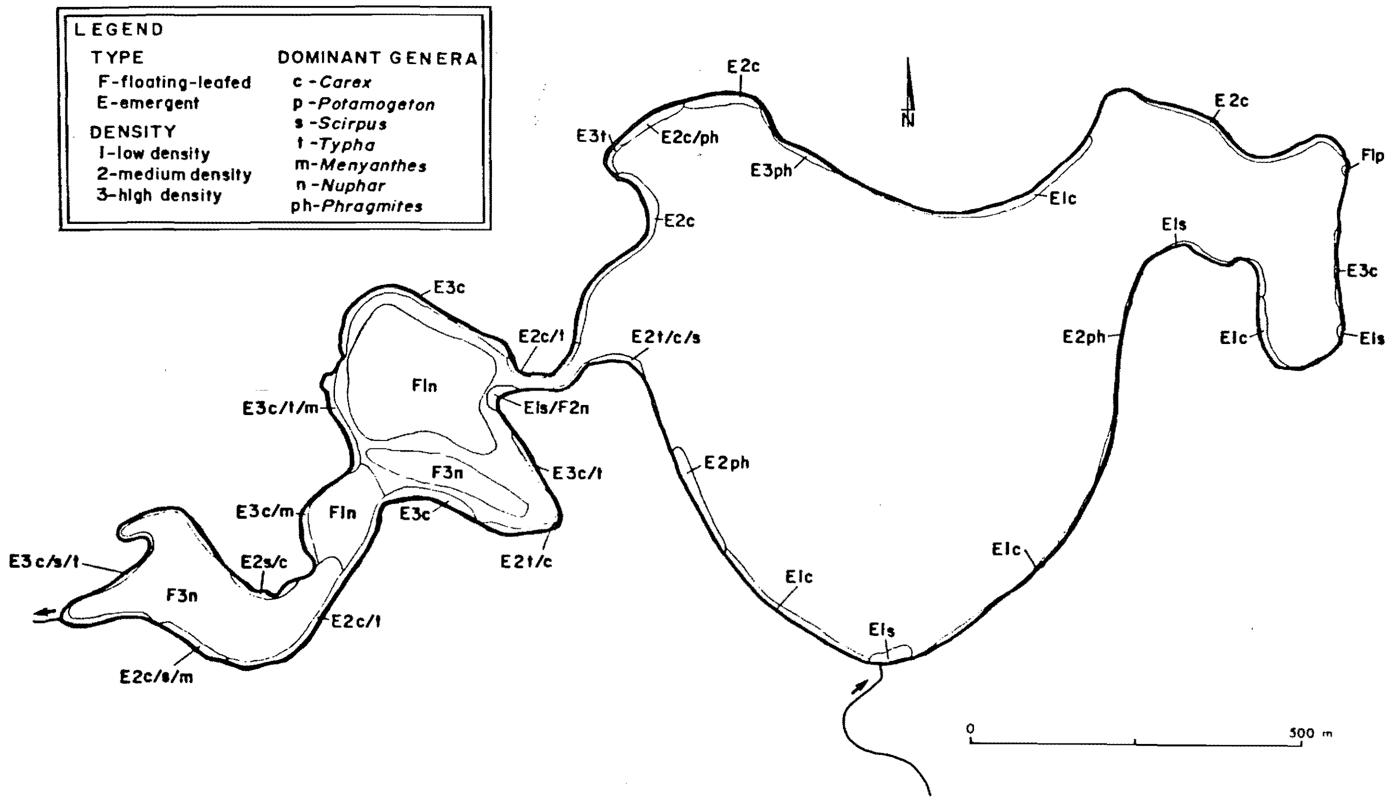

Figure 7. Approximate distribution of aquatic vegetation in Unnamed Lake #1.

(birch and willow) within these bays indicated beaver activity on the outlet stream. Due to the shallow and marshy nature of this area, the outlet stream was not investigated in detail. High water levels due to beaver activity would explain the sharp dropoff near the shoreline around most of the lake.

4.1.6 Fish

Only two species of fish were collected in the overnight gillnet set in Lake #1. Lake whitefish constituted 89% of the catch by numbers, while northern pike made up the remaining portion (Table 5). No seining was conducted due to the unsuitable shoreline (i.e., 0.5 m deep immediately off shore, overhanging brush and trees, and submerged log debris). Stomach content analysis of the northern pike captured showed that the ninespine stickleback was also present in substantial numbers in the lake. It is likely that other species such as yellow perch, white sucker, Iowa darter, and spottail shiner also occur in the lake since they occur in adjacent lakes that are connected to Lake #1.

4.1.6.1 Lake Whitefish. Of the 170 lake whitefish taken in gillnets, 52 were sampled for life history information. Length ranged from 145 to 514 mm and weight from 30 to 2080 g. Age varied from 1 to 8 years, but no age 2 and only one age 3 fish were sampled. Thirty-one of the fish sampled (59%) were age 6 (Figure 8).

The mean condition factor of the sample of lake whitefish was 1.38 ± 0.02 (SE) indicating that they were in good physical condition. The length(mm)-weight(g) regression was:

$$W = 1.835 \times 10^{-6} L^{3.342} \text{ where } r^2 = 0.99, N = 52.$$

Three out of four of the 5-year-old males and both of the 5-year-old females sampled were mature. One 8-year-old male and one 6-year-old female were classified as being "alternate year spawners"; that is, they appeared to have spawned previously but were not going to spawn during the current year. This is a common occurrence in northern fish populations (Kennedy 1953).

Table 5. Test net results for Unnamed Lake #1.

Date Set	Duration of Set (h)	Water Depth (m)	Mesh Size (cm)	Species and Number		Total
				Lake Whitefish	Northern Pike	
7 September 1979	12.5	5.0	3.8	19	0	19
			5.1	11	4	15
			6.4	22	9	31
		1.5	7.6	17	7	24
		5.0	8.9	35	0	35
			10.2	34	0	34
			11.4	28	0	28
		5.0	14.0	4	0	4
Total				170	20	190

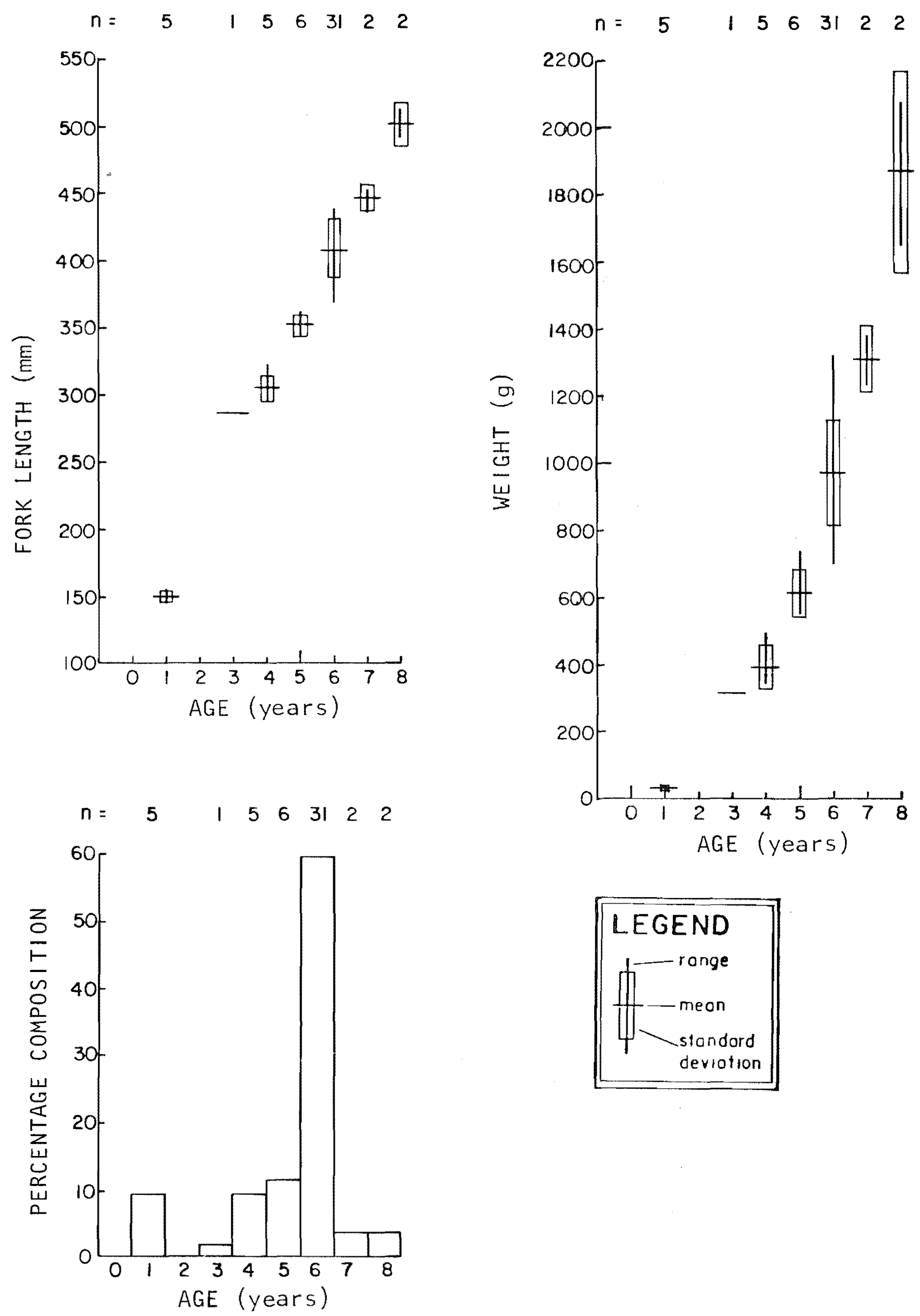

Figure 8. Age composition and age-growth relationships for lake whitefish from Unnamed Lake #1, September 1979.

The primary food item present in the lake whitefish stomachs was Chironomidae larvae (67% of the stomachs). Pelecypoda (two stomachs), *Nostoc* (one stomach), and small ninespine stickleback (one stomach) were present also. Twenty-two of the 49 stomachs examined were empty.

Twenty-two lake whitefish were examined to determine the infestation rate of the plerocercoids of the tapeworm *Triaenophorus crassus*. Twenty (91%) were infected with a total of 119 cysts, giving an infestation rate of 253 cysts/45.4 kg of fish. Due to the high infestation rate, these fish would not be marketable for human consumption.

4.1.6.2 Northern Pike. All 20 northern pike taken in the gillnet catch were sampled for life history information. Length ranged from 408 to 598 mm and weight from 450 to 1260 g. Age ranged from 4 to 8 years, with age 4 fish being predominant (Figure 9). The mean condition factor of the sample was 0.64 ± 0.02 (SE). The length(mm)-weight(g) regression was:

$$W = 8.671 \times 10^{-4} L^{2.205} \text{ where } r^2 = 081, N = 20.$$

All of the sampled fish were mature (i.e., they would have spawned during the coming spring). The primary food item was ninespine stickleback which was present in 45% of the stomachs. Ten of the pike collected had empty stomachs.

4.1.6.3 Potential Production. Applying the models developed by Ryder (1965) and Allan (1975) to estimate the lower and upper limits of potential harvestable fish production, respectively, it was estimated that Lake #1 could sustain a fish harvest of between 4.8 and 6.5 kg/ha/yr (320 and 440 kg/yr). Using the percentage (by weight) of sportfish in the catch (10%), 30 to 50 kg of sportfish harvest could be sustained annually. It is likely, however, that the estimate of the percentage of sportfish (northern pike) is low, due to the fact that the gillnets were set in the open-water portion of the lake. If

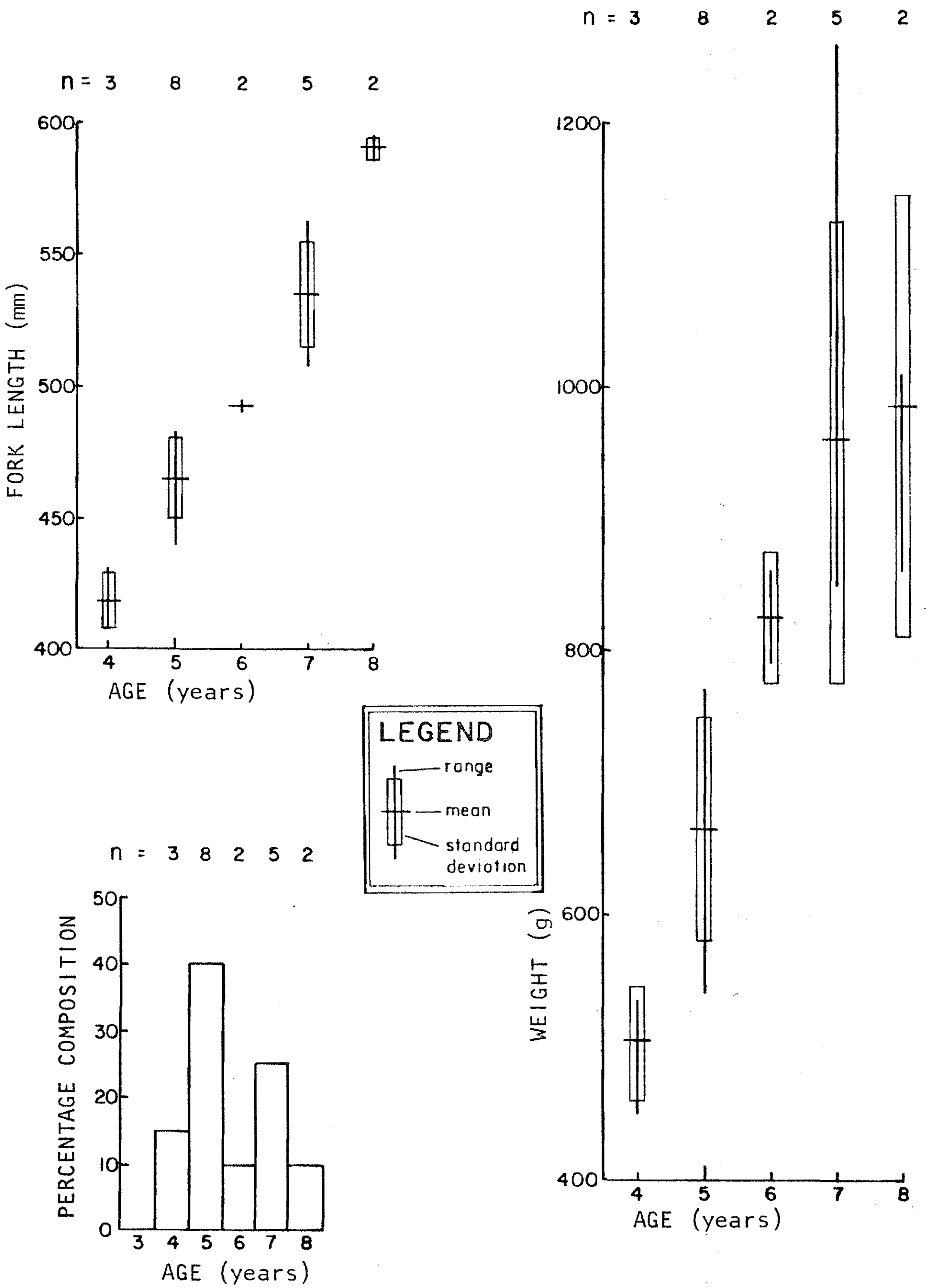

Figure 9. Age composition and age-growth relationships for northern pike from Unnamed Lake #1, September 1979.

more intensive sampling had been conducted (including sampling in the shallow, weedy bays on the west end of the lake), the percentage of the total fish production contributed by sportfish would likely have been higher.

4.1.7 Discussion

Due to the small size of the lake (67.4 ha) and the presence of only one sport fish species (northern pike) it is felt that this lake could support only a very limited sport fishery. While extensive spawning and rearing habitat for this species is present at the west end of the lake, intensive sport fishing could quickly reduce the stock of the larger adult fish and could thereby limit recruitment.

4.2 UNNAMED LAKE #2

4.2.1 Introduction

This lake is located in Township 103, Range 7, West of the Fourth Meridian (57°59'N; 111°01'W). The surface elevation is approximately 287.7 m above m.s.l. A small creek, draining a lake to the southeast, enters Lake #2 at the southeast corner. A small outflow creek drains to Unnamed Lake #3, part of the Eleanor Creek drainage.

The surrounding terrain is moderately forested with jack pine; birch trees are present around much of the shoreline. Exposed sand hills occur along the northwest and the east edge of the lake.

The lake is accessible only by aircraft in the summer, although the Fort McMurray-Fort Chipewyan winter road passes within 2 km of the lake.

Sampling on this lake was conducted during the period 9 to 11 September 1979. The locations of the sampling sites are shown in Figure 10.

4.2.2 Morphometry

Lake #2 has an area of 156.3 ha, an estimated volume of 6.6 x 10^6 m^3, and a mean depth of 4.2 m (Table 6). The maximum depth

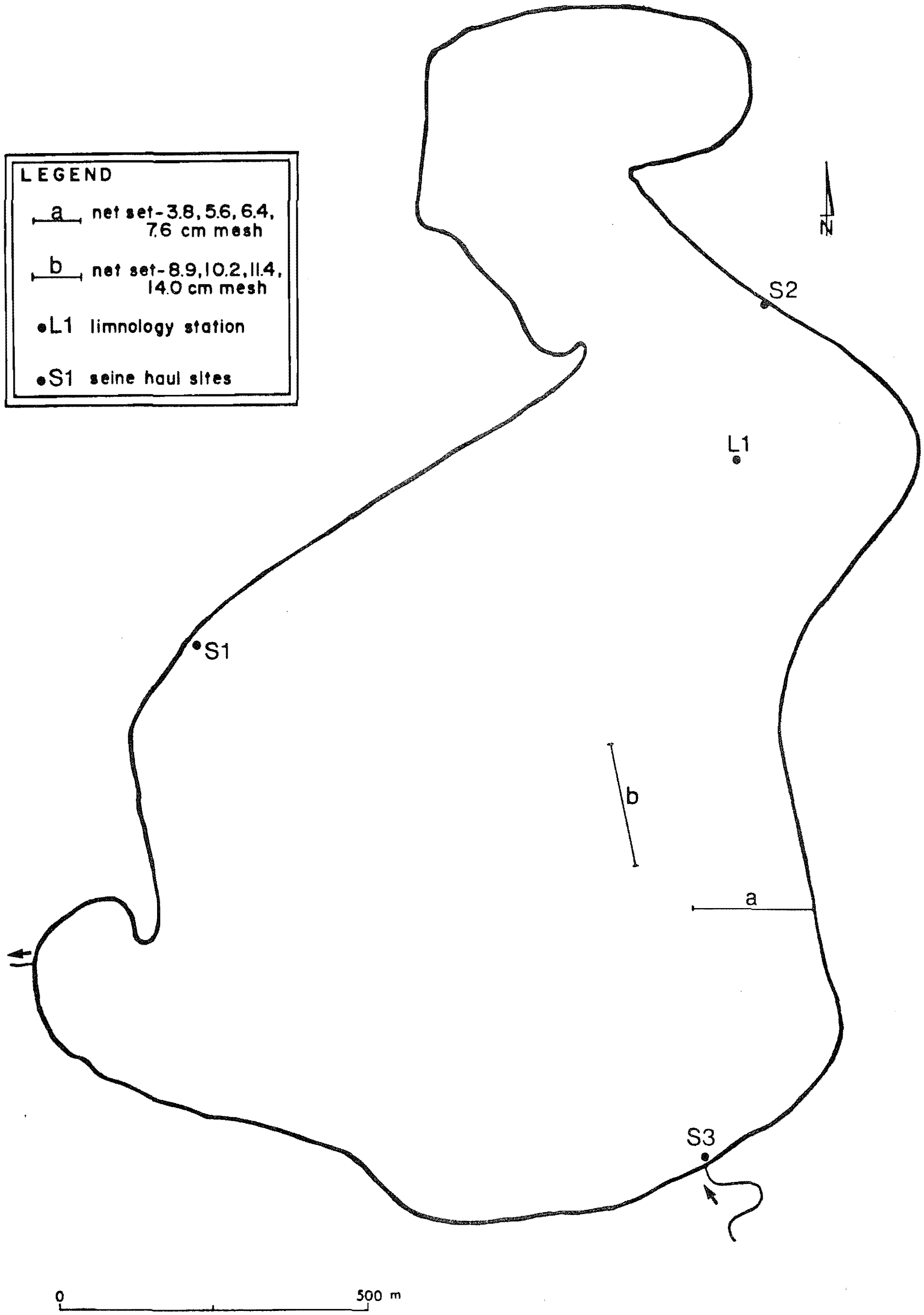

Figure 10. Sampling site locations in Unnamed Lake #2, September 1979.

Table 6. Morphometry of Unnamed Lake #2.

Location	Tp. 103, Rg. 7, W4
Area	156.3 ha
Volume	6.6×10^6 m^3
Shoreline length	6.4 km
Shoreline development factor	1.5
Maximum length	2.0 km
Maximum effective length	2.0 km
Maximum width	1.4 km
Maximum effective width	1.4 km
Mean width	0.8 km
Maximum depth	15.5 m
Mean depth	4.2 m

Depth Distribution:

	ha	% Surface Area
Surface area	156.3	100
2 m+	128.0	82
4 m+	92.2	59
6 m+	25.8	17
8 m+	5.7	4
10 m+	3.3	2
12 m+	1.9	1
14 m+	0.6	<1

recorded during a total of 15 sounding transects was 15.5 m which occurred approximately 200 m off the west shore in the south-central part of the lake (Figure 11). Fifty-nine percent of the surface area of the lake was greater than 4 m deep.

The maximum effective length of the lake was 2.0 km and the maximum effective width was 1.4 km. The total shoreline length was 6.4 km. A shoreline development factor of 1.5 indicated that the lake has a highly regular shoreline.

4.2.3 Water Quality

The major dissolved ions in Lake #2 were calcium and bicarbonate (Table 7). When sampled, this lake had the highest pH recorded among the study lakes (9.1). Total alkalinity was 66 mg/L and total filterable residue was 118 mg/L. The lake water was fairly clear, isothermal, and well oxygenated (Figure 12).

4.2.4 Substrate

Approximately 59% of the lake had an organic/silt substrate (or thick layer of organic/silt over sand), 31% had a sand substrate, and less than 1% a gravel-rubble substrate (Figure 13). Most of the shoreline consists of sand beaches with the sand extending out from the shore. In most areas the sand was covered with a thin layer of organic material a short distance off shore. Much of the sand near shore had a crusty material on it resembling marl. Microscopic examination of a similar substance from Unnamed Lake #3 showed that this type of material contained considerable amounts of algae, microinvertebrates, and inorganic particles. Numerous sand spits or points extended out toward the centre of the lake. The only gravel-rubble area was on the northwest corner of the lake. The organic/silt substrate present in the centre of the basin was brown to orange in colour, indicating a high organic content. This type of substrate was much different from the black silt substrate found in Lake #1.

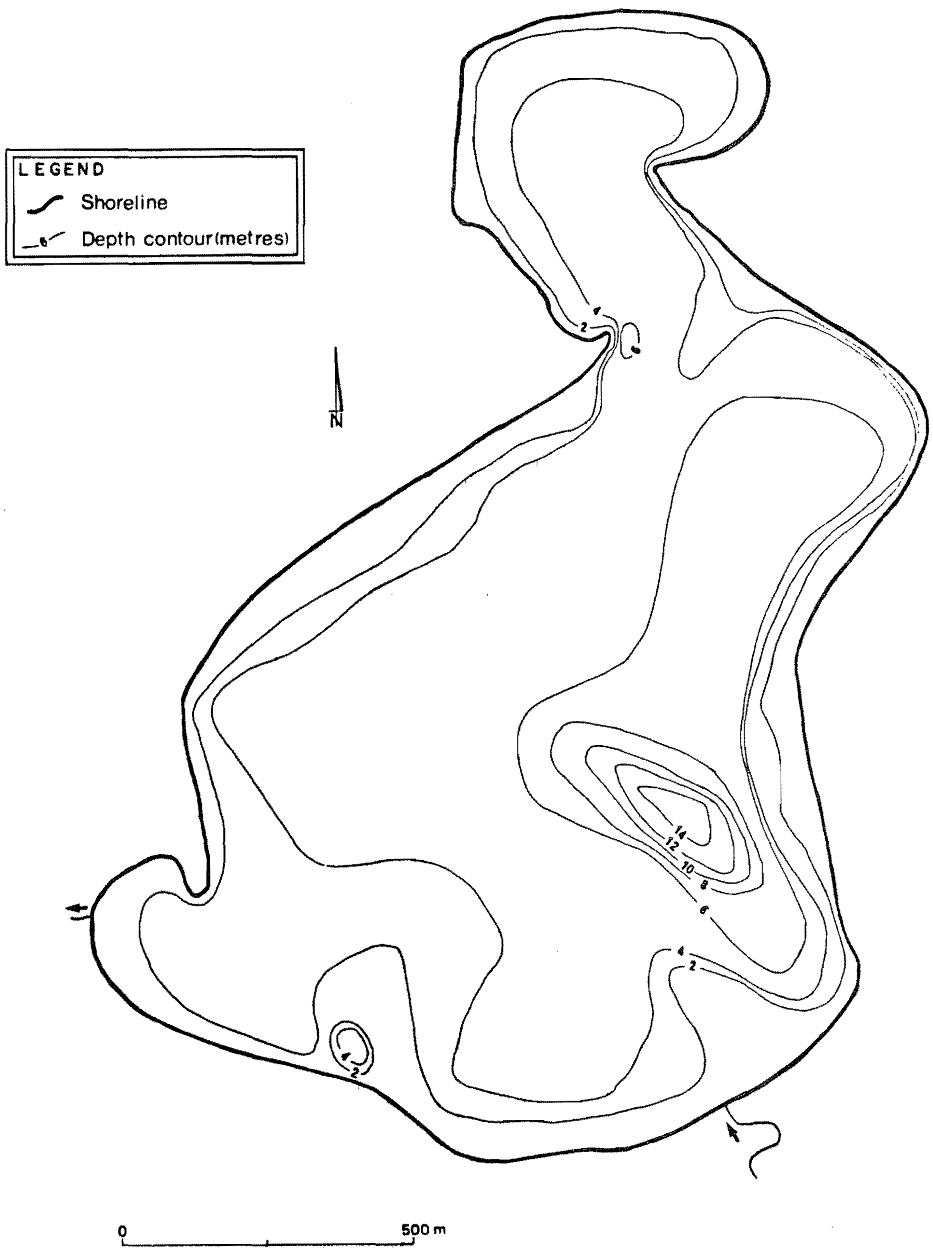

Figure 11. Bathymetric map of Unnamed Lake #2.

Table 7. Water quality analyses for Unnamed Lake #2.

11 September 1979	Site L1			
Na	3.1	mg/L	0.13	meq/L
K	0.6	mg/L	0.02	meq/L
Ca	17.7	mg/L	0.883	meq/L
Mg	5.8	mg/L	0.48	meq/L
SO_4	7.4	mg/L	0.15	meq/L
Cl	2.6	mg/L	0.073	meq/L
CO_3	11	mg/L	0.36	meq/L
HCO_3	59	mg/L	0.96	meq/L
Alkalinity				
Total	66	mg/L ($CaCO_3$)	1.32	meq/L
P'thalein	9	mg/L ($CaCO_3$)		
pH (pH units)	9.1			
Hardness, total (as $CaCO_3$)	68.1	mg/L		
Total filterable residue				
Evap. @ 105°C	118	mg/L		
Ignit. @ 550°C	78	mg/L		
Conductivity	136	µS/cm		
Turbidity	1.4	NTU		
Total P	<0.016	mg/L		
Ammonia-N	<0.05	mg/L		
Reactive silica	4.0	mg/L		
Total organic carbon	13.2	mg/L		
Fe (total)	0.17	mg/L		

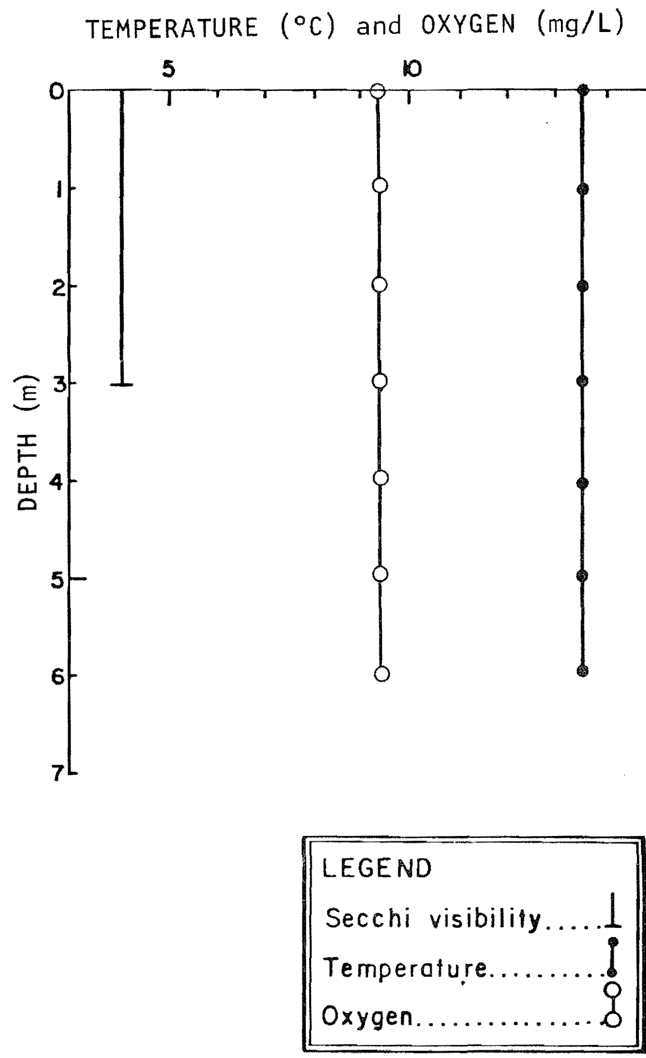

Figure 12. Temperature, dissolved oxygen, and Secchi visibility in Unnamed Lake #2, Site L1, 11 September 1979.

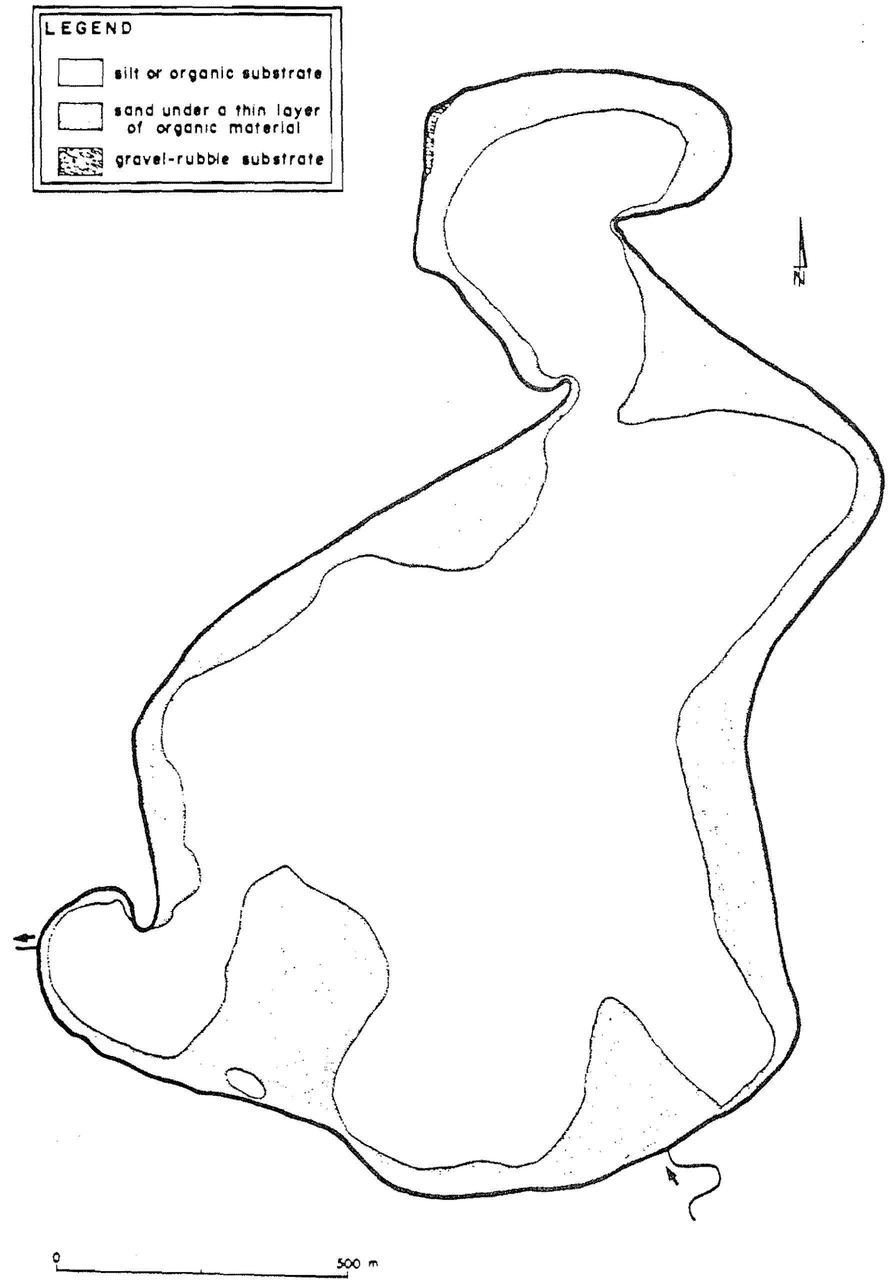

Figure 13. Approximate distribution of surficial lake sediment types in Unnamed Lake #2.

4.2.5 Aquatic Vegetation

Much of the shoreline of Lake #2 had little emergent or floating-leafed aquatic vegetation, a reflection of the exposure to wind action and an unstable sand substrate (Figure 14). *Carex* was the predominant emergent, occurring as a thin band along sections of the shoreline. It was often present only above the actual water edge. Stands of *Scirpus* occurred sporadically around the lake but were most abundant along the southwest and northeast corners.

4.2.6 Fish

Five species of fish were captured in one overnight gillnet set (Table 8). Lake whitefish composed 42% of the fish caught; walleye 32%; northern pike 14%; white sucker 10%; and yellow perch 2%. Three seine hauls in the lake revealed that spottail shiner (90% of the 122 fish captured in the hauls) and Iowa darter (1%) were also present. The remaining 9% of the seine catch was composed of yellow perch.

4.2.6.1 Lake Whitefish. Of the 87 lake whitefish captured in gillnets, 34 were sampled for life history information. Length ranged from 273 to 498 mm and weight from 220 to 1620 g. Age varied from 4 to 9 years with a mode of age 5 (39%) (Figure 15).

The mean condition factor of the lake whitefish sampled was 1.28 ± 0.01 (SE), indicating that they were in fair physical condition. The length(mm)-weight(g) regression was:

$$W = 1.026 \times 10^{-5} L^{3.038} \text{ where } r^2 = 096, N = 34.$$

The majority of the fish (38%) were mature at 5 years of age, and all were mature at age 6. One age 6 female was classified as an alternate year spawner.

The primary food items eaten by the lake whitefish were Gastropoda (present in eight of 34 stomachs), Trichoptera (two stomachs), Ceratopogonidae (two stomachs), and detritus (two stomachs). Sixty-five percent of the stomachs examined were empty.

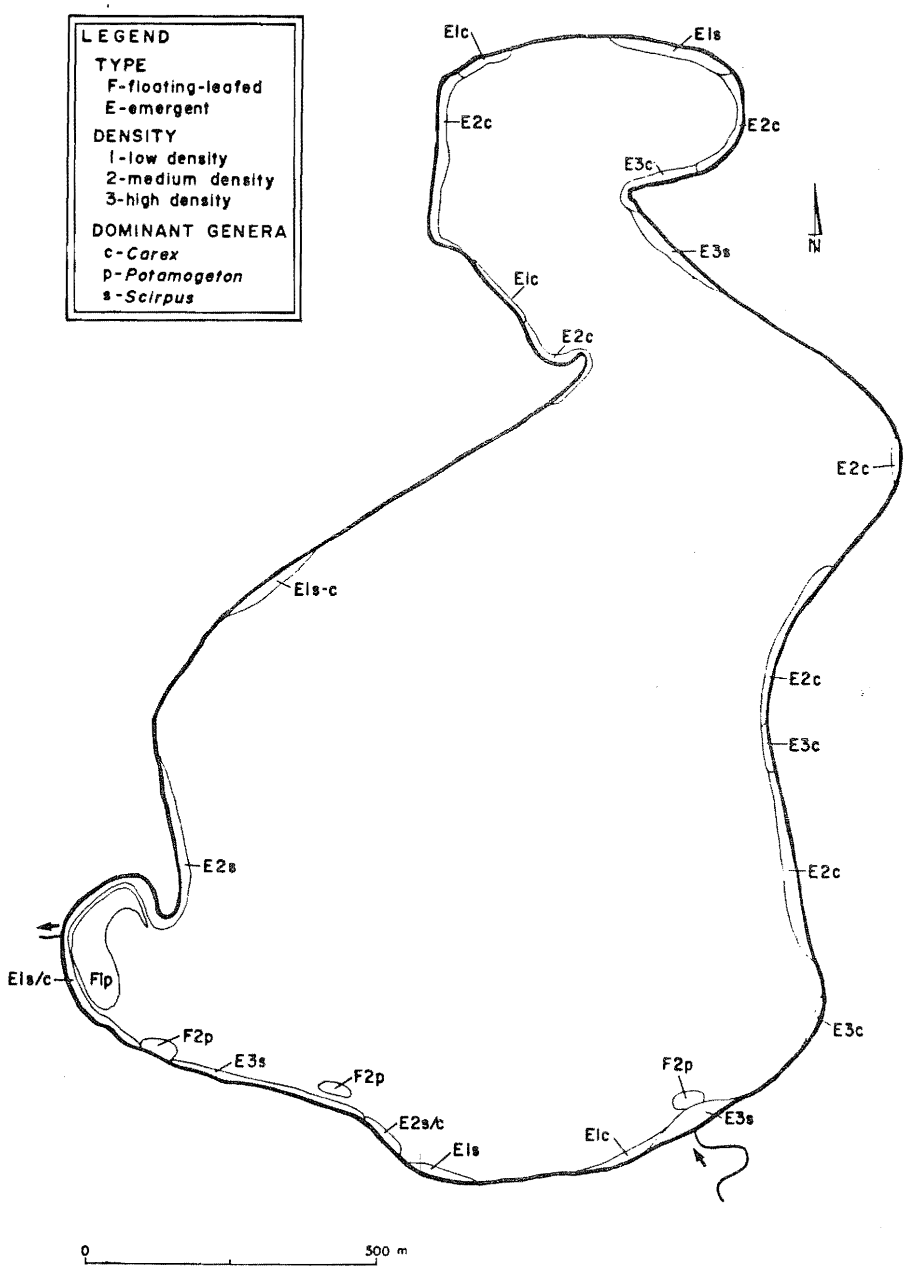

Figure 14. Approximate distribution of aquatic vegetation in Unnamed Lake #2.

Table 8. Test net results for Unnamed Lake #2.

Date Set	Duration of Set (h)	Water Depth (m)	Mesh Size (cm)	Species and Number					Total
				Lake Whitefish	Northern Pike	Yellow Walleye	Yellow Perch	White Sucker	
9 September 1979	14.5	7.5	3.8	11	5	13	5	4	38
			5.1	9	6	19	0	6	40
			6.4	20	4	10	0	4	38
		1.0	7.6	18	4	4	0	1	27
		10.0	8.9	16	4	11	0	3	34
			10.2	10	5	7	0	0	22
			11.4	3	2	3	0	2	10
		7.5	14.0	0	0	0	0	0	0
Total				87	30	67	5	20	209

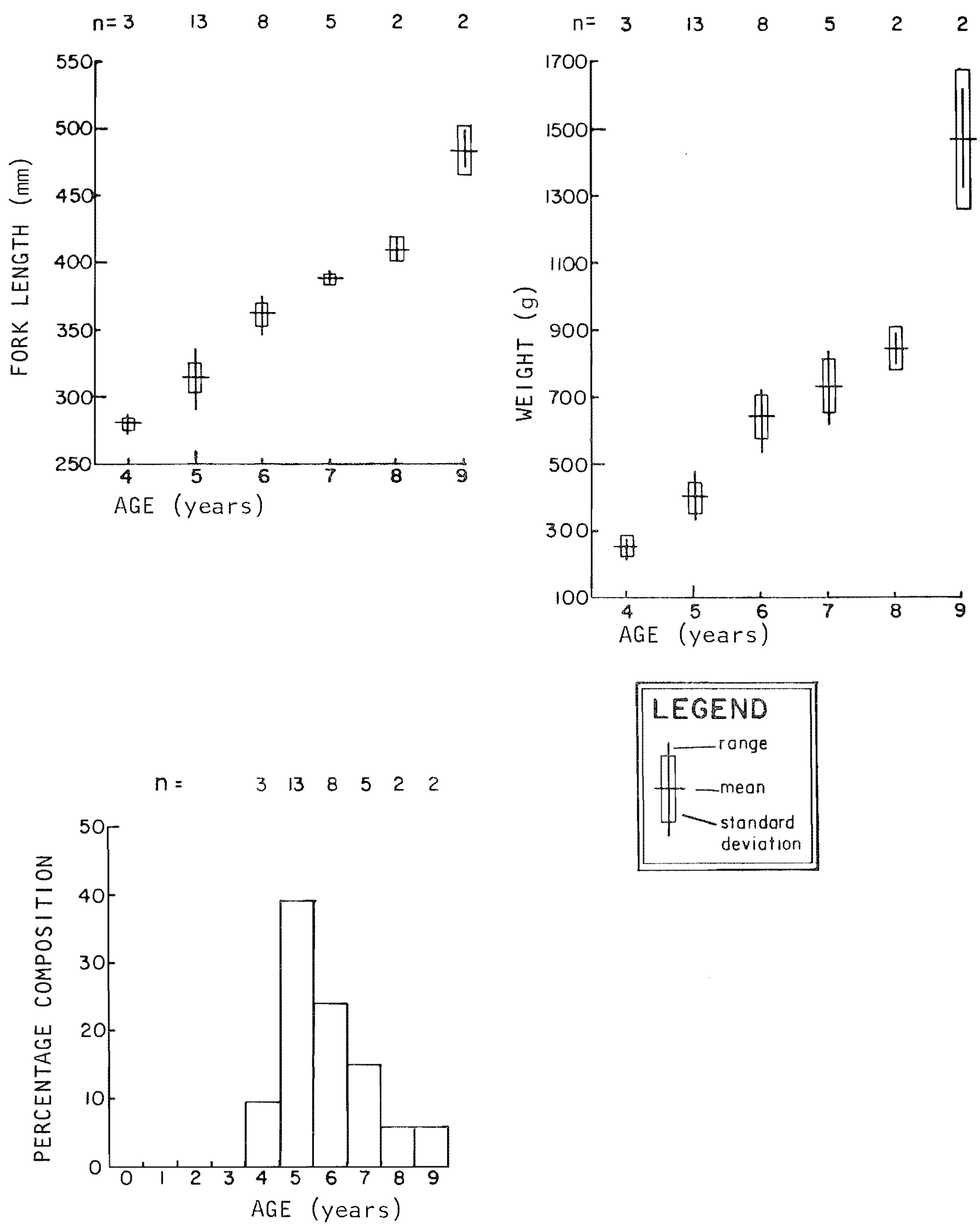

Figure 15. Age composition and age-growth relationships for lake whitefish from Unnamed Lake #2, September 1979.

Nineteen lake whitefish were dissected to determine the infestation rate of the plerocercoids of *Triaenophorus crassus*. Four (21%) were infected with a total of 16 cysts, giving an infestation rate of 54 cysts/45.4 kg. These fish likely would not be marketable for human consumption.

4.2.6.2 Northern Pike. Of the 30 northern pike taken in the gillnet catch, 22 were sampled for life history information. Length ranged from 467 to 932 mm and weight from 650 to 6250 g. Age ranged from 6 to 13 years, with age 7 fish being predominant (Figure 16). The mean condition factor of the sampled fish was 0.67 ± 0.02 (SE). The length(mm)-weight(g) regression was:

$$W = 8.126 \times 10^{-7} L^{3.330} \text{ where } r^2 = 0.97, N = 22.$$

All pike sampled were mature, with the youngest fish being 6 years old. A total of 22 stomachs were examined for food contents. The only food item recorded was a juvenile pike (225 mm long) from the stomach of an adult pike that was 545 mm long. The remaining 21 stomachs were empty. Northern pike are known to be cannibalistic and often prey heavily on juveniles of their own species (McPhail and Lindsey 1970).

4.2.6.3 Walleye. Of the 67 walleye taken in the gillnet samples, 33 were sampled for life history data. Length of the fish ranged from 119 to 532 mm and weight from 20 to 1660 g. Age varied from age 0 to age 11, with 4-year-old and 7-year-old fish being predominant (each comprising 15% of the catch) (Figure 17). No 2-year-old or 6-year-old fish were sampled. The mean condition factor was 1.04 ± 0.03 (SE), and the length(mm)-weight(g) regression was:

$$W = 3.553 \times 10^{-6} L^{3.180} \text{ where } r^2 = 0.98, N = 33.$$

All fish age 7 or older were mature. One 3-year-old and one 4-year-old male were also classed as mature and would likely spawn during the coming spring; however, three 5-year-old males and four 4-year-old males were classed as immature. Only one immature female was sampled,

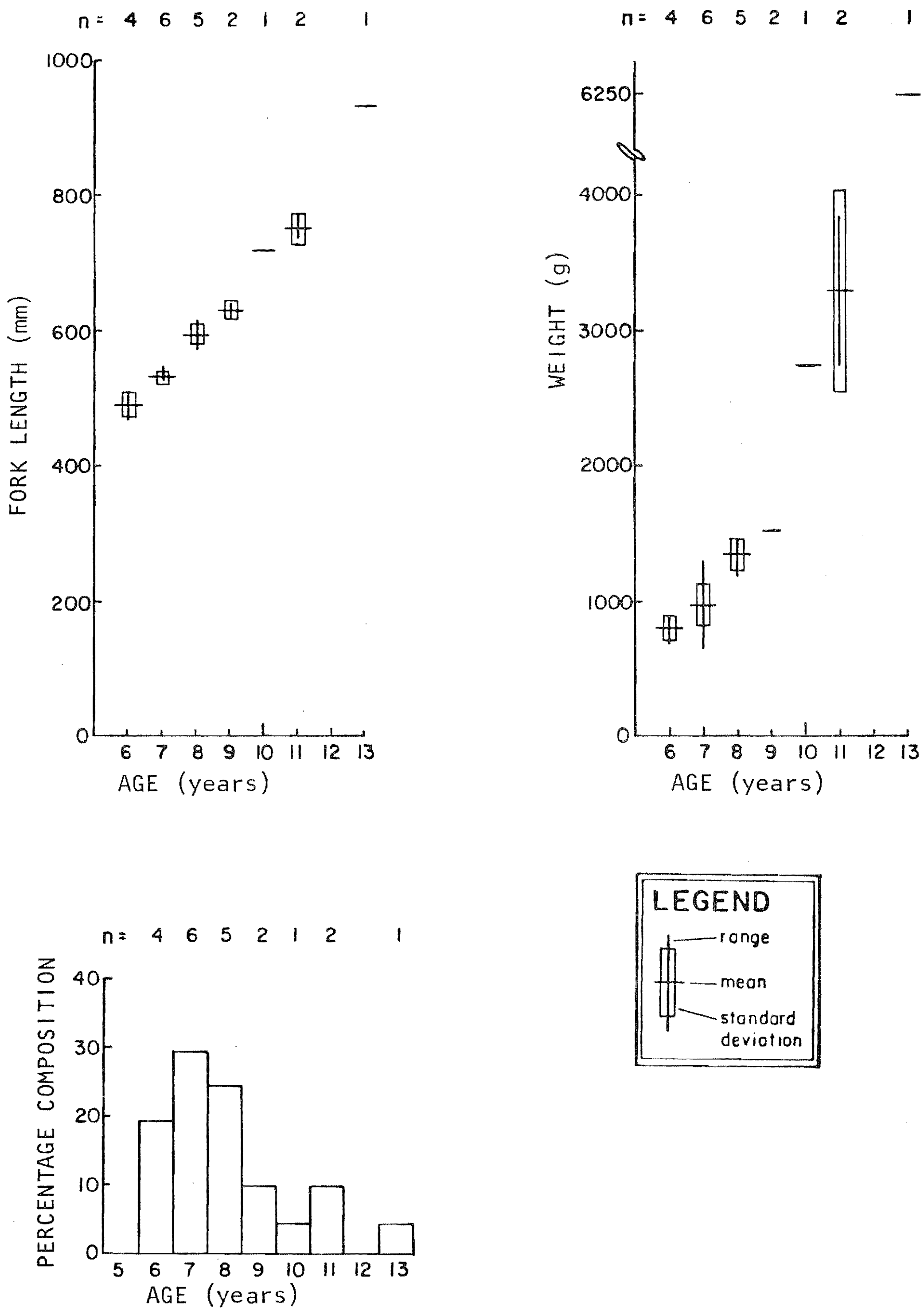

Figure 16. Age composition and age-growth relationships for northern pike from Unnamed Lake #2, September 1979.

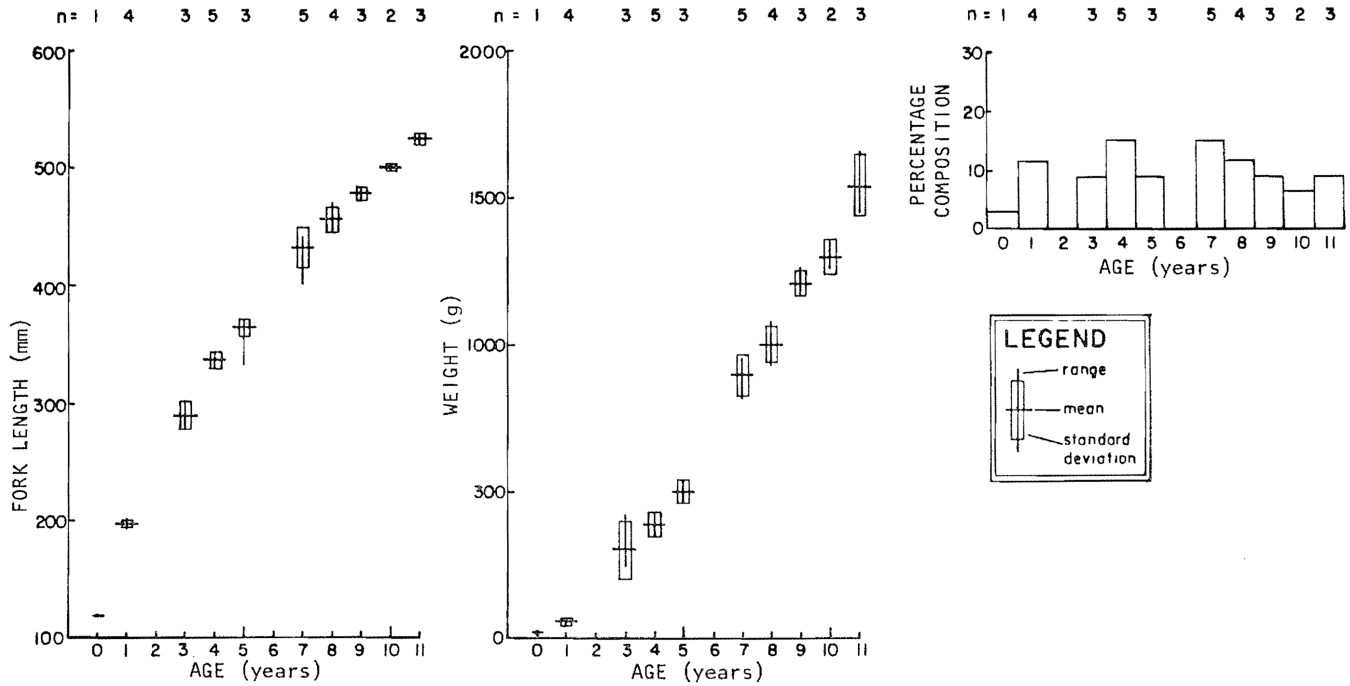

Figure 17. Age composition and age-growth relationships for walleye from Unnamed Lake #2, September 1979.

a 3 year old individual. The only identifiable food item in the 33 stomachs examined was yellow perch remains (one stomach), although unidentifiable fish remains were present in three others. Twenty-nine stomachs were empty.

4.2.6.4 Yellow Perch. Five yellow perch were present in the gillnet catch, all being taken in the 3.8 cm mesh size. In addition to these, 10 others from the beach seine collections were sampled for life history information. Length of the fish sampled ranged from 38 to 165 mm and weight from 1 to 50 g. The sample was made up of fish aged 1 (10 fish), 3 (one fish), and 4 (four fish) years. The mean length of the 1-year-old fish was 44.6 mm and the mean length of the 4-year-olds was 160 mm. The mean weight of the 4-year-olds was 42.5 g. Due to the slow growth rate and small sizes attained in this lake, the perch likely would not contribute significantly to a sport fishery.

4.2.6.5 White Sucker. Twenty white sucker were captured; of these, 13 were sampled for life history information. Length ranged from 178 to 486 mm and weight from 60 to 1700 g. Age varied from 2 to 6 years. The mean condition factor was 1.41 ± 0.06 (SE) and the length(mm)-weight(g) relationship was:

$$W = 2.142 \times 10^{-6} L^{3.328} \text{ where } r^2 = 0.99, N = 13.$$

4.2.6.6 Potential Production. Applying the regression equations of Ryder (1965) and Allan (1975), it was estimated that Lake #2 could sustain a fish harvest of between 6.1 and 8.2 kg/ha/yr or a total of 950 to 1280 kg/yr. Based on the percentage (by weight) of sportfish in the gillnet catch (62%), it was estimated that the harvestable sportfish production would be between 590 and 790 kg/yr. The sportfish catch would comprise primarily walleye and northern pike.

4.2.7 Discussion

The presence of sand beaches, clear water, and surrounding pine forest and sand hills make Lake #2 attractive as a recreational area. Walleye and large northern pike give this lake a fair sportfish potential. However, due to its small size and limited spawning and rearing habitat available to northern pike (i.e., limited development of aquatic vegetation), it could be susceptible to overfishing. Intensive management of these fish stocks may be required if heavy angling pressure is applied.

4.3 UNNAMED LAKE #3

4.3.1 Introduction

Lake #3 is located in Township 103, Range 7, West of the Fourth Meridian (57°57'N; 111°02'W). The surface elevation is approximately 285 m above m.s.l. A small creek enters the lake at the southeast end. A second stream draining Lake #2 enters at the northeast end. An outflowing creek flows from the north end of Lake #1, which is part of the Eleanor Creek drainage of the Athabasca River.

The main basin of the lake is bordered on the northwest and the northeast by a low-lying marshy area. The remainder of the lake is bordered by a medium to low density jackpine forest.

The lake is accessible only by aircraft during the summer. However, it is located within 1 km of the Fort McMurray-Fort Chipewyan winter road.

Sampling on this lake was conducted during the period 5 to 7 September 1979. The locations of the sampling sites are shown in Figure 18.

4.3.2 Morphometry

Lake #3 has a surface area of 116.3 ha and an estimated volume of 2.2×10^6 m^3, giving it a mean depth of 1.9 m (Table 9). The maximum depth recorded during a total of 21 sounding transects was 8.0 m. This occurred in the eastern part of the main basin

(Figure 19). Only 15% of the surface area of the lake was deeper than 4 m.

The long axis of Lake #3 is situated in a north-south direction. A long, narrow arm stretches to the north of the main body. The maximum length of the lake was 3.4 km, while the maximum effective length was only 1.8 km. The maximum width was 0.7 km. The total shoreline length was 11.0 km giving the lake a shoreline development factor of 2.7, indicating the presence of a highly irregular shoreline.

4.3.3 Water Quality

Because of the irregular basin configuration, two sites were sampled for water quality. The two locations had similar concentrations of major ions (calcium and bicarbonate) and total filterable residue (112 and 118 mg/L) (Table 10). However, total organic carbon (TOC) was noticeably higher at Site L2. This may be related to the shallower depth and greater littoral development at that site as compared to the main basin (Site L1), resulting in greater availability of organic compounds to the water column. Both sites were nearly isothermal and well oxygenated when sampled (Figure 20), and the lake water was fairly clear and unstained. Total alkalinity averaged 74 mg/L.

4.3.4 Substrate

Approximately 84% of the lake had an organic/silt substrate (or a thick layer of organic/silt over sand), 16% a sand substrate, and less than 1% a gravel-rubble substrate (Figure 21). Sand was predominant around the shoreline, with numerous sand spits or points extending into the main body. The organic/silt substrate present in the centre of the main basin and in the north arm was orange in colour and was very light and flocculent, indicating a high organic content. In the north arm, this organic layer often exceeded 2 m in depth.

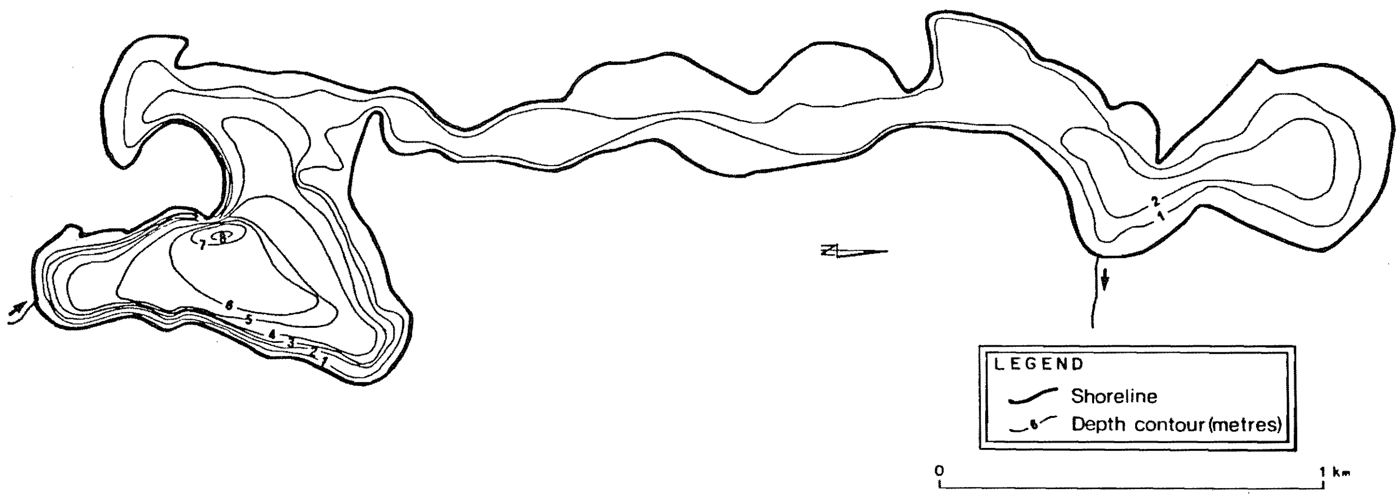

Figure 19. Bathymetric map of Unnamed Lake #3.

Table 10. Water quality analyses for Unnamed Lake #3.

	Site			
	L1		L2	
6 September 1979	mg/L[a]	meq/L	mg/L[a]	meq/L
Na	2.8	0.12	2.0	0.087
K	0.5	0.01	0.1	0.003
Ca	18.9	0.943	15.5	0.773
Mg	6.3	0.52	5.5	0.45
SO_4	4.9	0.10	6.6	0.14
Cl	1.5	0.042	2.2	0.062
CO_3	5	0.2	10	0.30
HCO_3	87	1.4	65	1.1
Alkalinity				
Total (mg/L $CaCO_3$)	79	1.58	69	1.38
P'thalein (mg/L $CaCO_3$)	4		8	
pH (pH units)	8.5		8.9	
Hardness, total (as $CaCO_3$)	73.1		61.3	
Total filterable residue				
Evap. @ 105°C	118		112	
Ignit. @ 550°C	64		38	
Conductivity	163 µS/cm		130 µS/cm	
Turbidity	1.6 NTU		2.6 NTU	
Total P	<0.016		<0.016	
Ammonia-N	<0.05		<0.05	
Reactive silica	4.3		5.0	
Total organic carbon	8.0		28.4	
Fe (total)	0.15		0.10	

[a] Values expressed as milligrams per litre unless indicated otherwise.

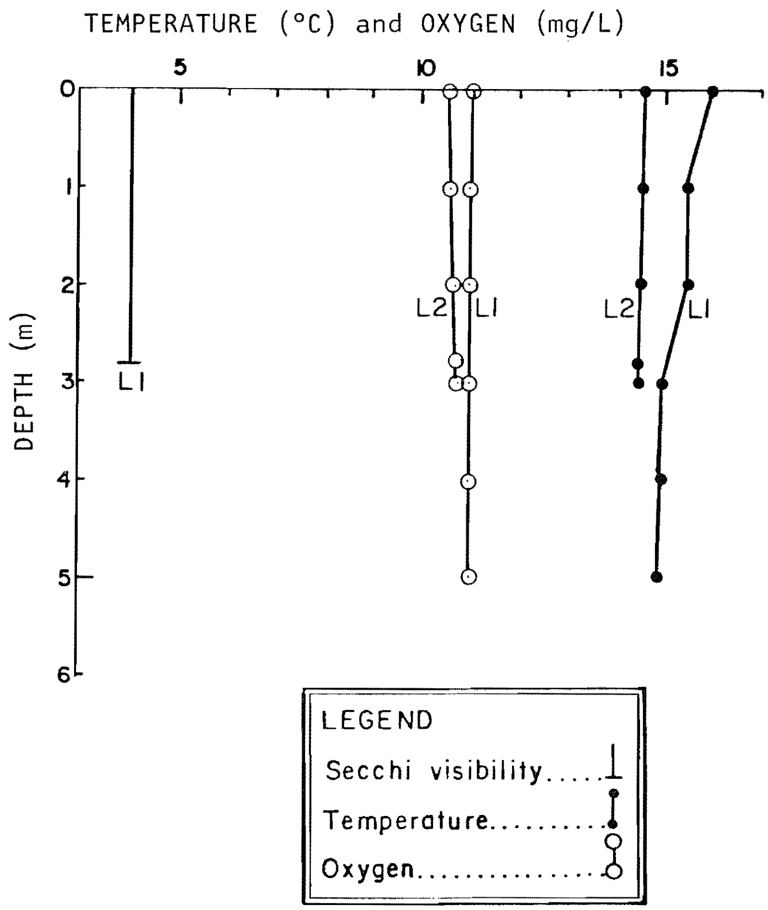

Figure 20. Temperature, dissolved oxygen, and Secchi visibility in Unnamed Lake #3, Site L1 and L2, 6 September 1979.

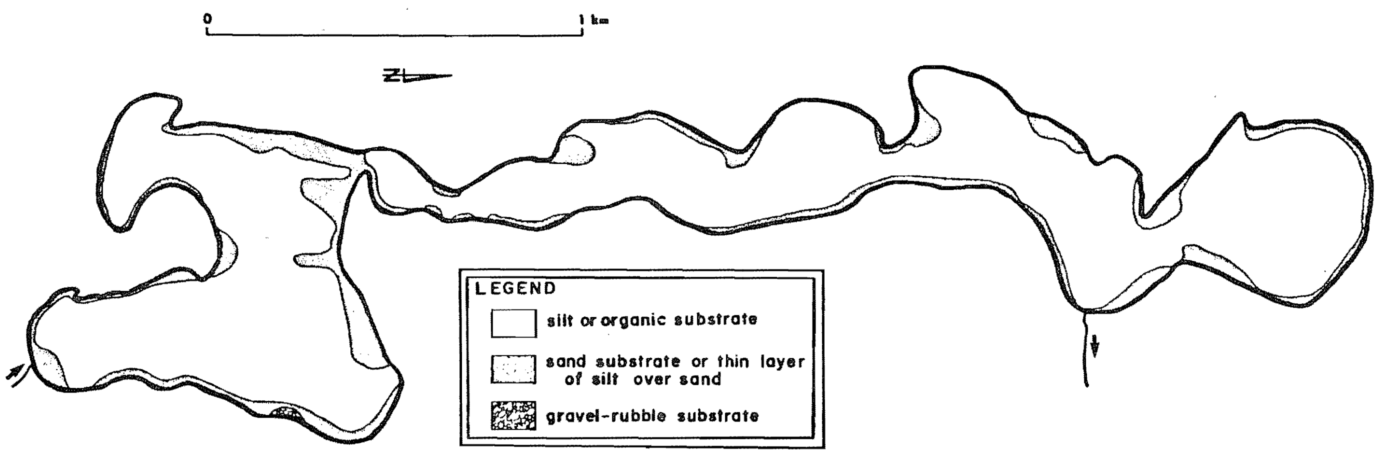

Figure 21. Approximate distribution of surficial lake sediment types in Unnamed Lake #3.

The only gravel or rubble substrate observed was along the east shore of the main basin; however, this rocky substrate had a high percentage of silt associated with it. Marl was present on much of the sand substrate in the lake.

4.3.5 Aquatic Vegetation

A narrow band of *Carex* was present around much of the shoreline of the lake (Figure 22). Small stands of *Scirpus* occurred in places around the lake. Major stands of *Phragmites* were present along the north and southeast shores of the main basin and along the east edge of the north arm of the lake. Moderate to sparse growths of *Potamogeton* occurred in the bay in the southwestern portion of the lake and also throughout much of the north arm. *Nuphar* was located primarily along the north shore of the main basin and along the southern portion of the north arm. *Sparganium, Menyanthes,* and *Typha* also grew in localized areas.

4.3.6 Fish

Four species of fish were collected in one overnight gillnet set in Lake #3 (Table 11). Lake whitefish composed 52% of the catch, while northern pike (30%), white sucker (17%), and yellow perch (<1%) made up the remainder. Beach seining revealed the presence of the spottail shiner and the Iowa darter. Of the 608 fish collected in the four seine hauls, spottail shiner made up 90% of the catch, yellow perch 8%, white sucker 1%, and Iowa darter 1%. One ninespine stickleback was noted in the stomach of a northern pike, indicating that this species also inhabits the lake.

4.3.6.1 Lake Whitefish. Of the 65 lake whitefish captured in gillnets, 48 were sampled for life history information. Length of the fish ranged from 209 to 532 mm and weight from 110 to 2100 g. Age varied from 2 to 8 years, although fish aged 3 to 5 were missing from the catch (Figure 23). The majority of the fish sampled (64%) were

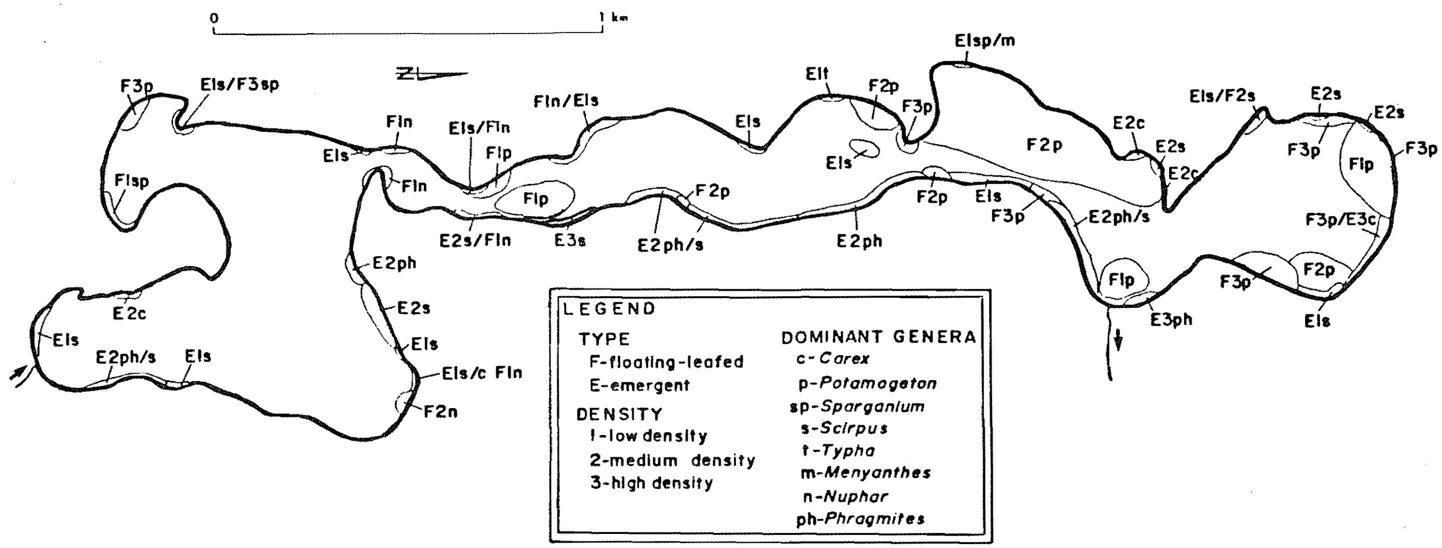

Figure 22. Approximate distribution of aquatic vegetation in Unnamed Lake #3.

Table 11. Test net results for Unnamed Lake #3.

Date Set	Duration of Set (h)	Water Depth (m)	Mesh Size (cm)	Species and Number: Lake Whitefish	Northern Pike	Yellow Perch	White Sucker	Total
6 September 1979	11	4.5	3.8	4	7	1	17	29
			5.1	12	6	0	3	21
			6.4	3	10	0	1	14
		1.5	7.6	8	6	0	0	14
		4.5	8.9	8	2	0	0	10
		4.0	10.2	10	3	0	0	13
		3.0	11.4	8	4	0	0	12
		2.0	14.0	12	0	0	0	12
Total				65	38	1	21	125

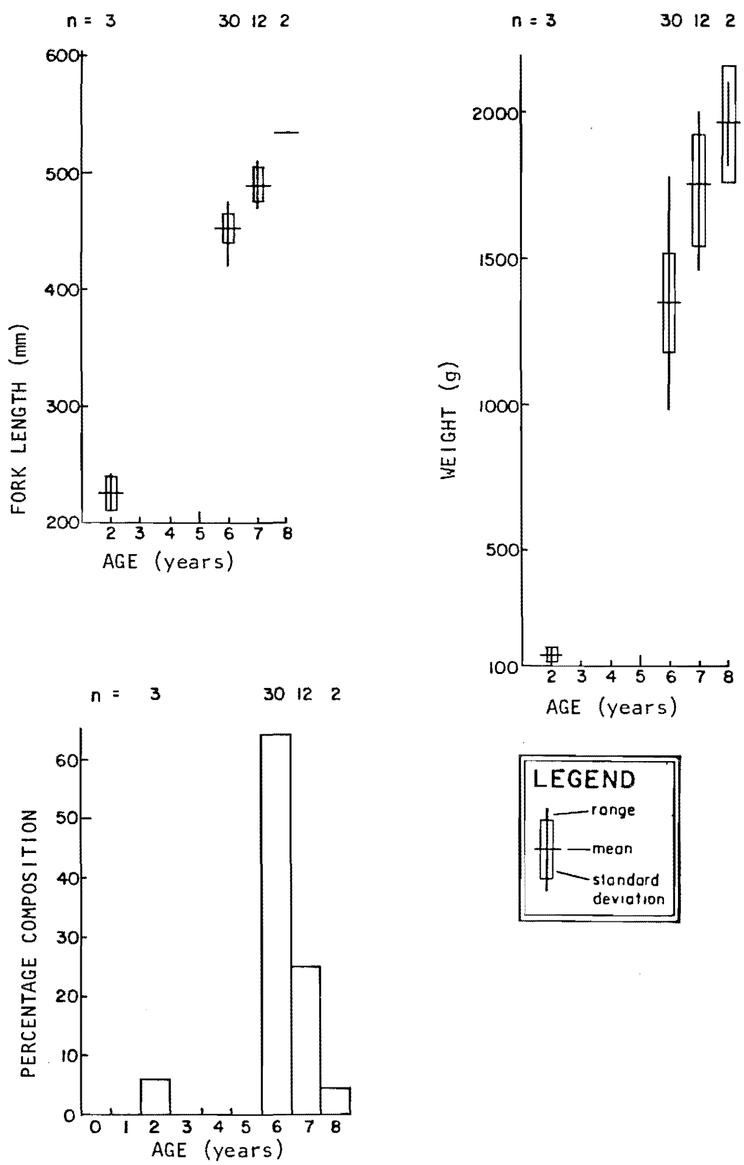

Figure 23. Age composition and age-growth relationships for lake whitefish from Unnamed Lake #3, September 1979.

age 6. It is likely that the missing age-classes reflect the limited sampling effort (i.e., one gillnet set), rather than poor year-class success. The lake whitefish showed a good growth rate, reaching a mean length of 452 mm and a mean weight of 1350 g by age 6. The mean condition factor of the sampled whitefish was 1.43 ± 0.02 (SE), indicating that these fish were in excellent physical condition. During dissection, it was noted that a large amount of fat tissue was present along the internal organs of most individuals. The length(mm)-weight(g) regression was:

$$W = 2.770 \times 10^{-6} L^{3.269} \text{ where } r^2 = 0.98,\ N = 48.$$

All of the sampled fish 6 years and older were mature.

Forty-seven lake whitefish stomachs were examined for food contents. The primary food items present were Pelecypoda (seven stomachs), Corixidae (two stomachs), and fish remains (two stomachs). Trichoptera, Gastropoda, and *Nostoc* were each recorded in one stomach. Seventy-four percent of the stomachs examined were empty.

Fourteen lake whitefish were examined for plerocercoids of *Triaenophorus crassus*. None was infected with this parasite.

4.3.6.2 Northern Pike. Of the 38 northern pike captured in the gillnet set, 34 were sampled for life history information. Length ranged from 404 to 580 mm and weight from 400 to 1360 g. Age ranged from 4 to 10 years, with age 6 fish being predominant in the catch (Figure 24). The mean condition factor of the sampled fish was 0.64 ± 0.01 (SE) and the length(mm)-weight(g) relationship was:

$$W = 2.502 \times 10^{-6} L^{2.778} \text{ where } r^2 = 0.74,\ N = 34.$$

All of the males captured were mature, the youngest being 4 years of age. All of the females, except one 6-year-old and one 8-year-old, were classed as mature. It is likely that the 8-year-old fish that was classed as immature was either an alternate year spawner or a sterile individual. Thirty-four northern pike stomachs were examined for food contents. The primary food items were yellow perch (six stomachs), ninespine stickleback (one stomach), and white sucker (one

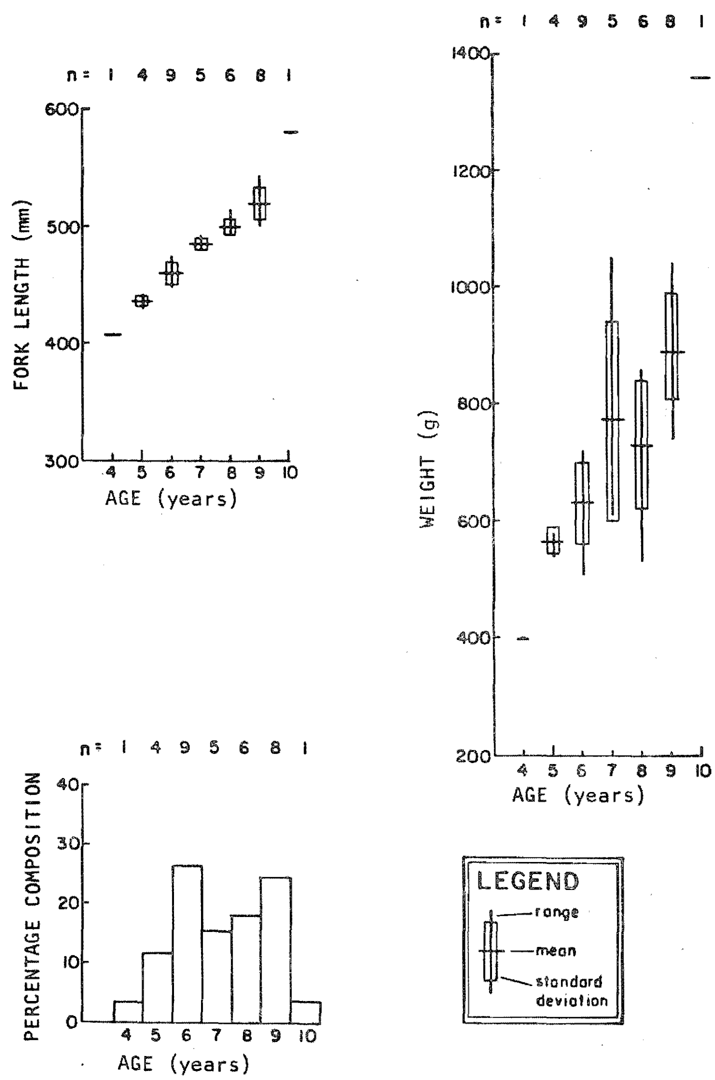

Figure 24. Age composition and age-growth relationships for northern pike from Unnamed Lake #3, September 1979.

stomach). Unidentifiable fish remains were noted in two other pike, while 25 stomachs were empty.

4.3.6.3 Yellow Perch. Fifty yellow perch were sampled for life history information. The single gillnet-captured fish was a 4-year-old female 146 mm in length and 30 g in weight. The remainder of the sample, captured by beach seine, were age 0, 1, and 2 individuals ranging in length from 31 to 82 mm. The mean lengths calculated for these three cohorts were 36.6, 47.7, and 69.3 mm, respectively. The extremely small sizes attained and the slow growth rate displayed by this population result in it having little potential value for sport fishing.

4.3.6.4 Potential Production. Applying the regression equations developed by Ryder (1965) and Allan (1975) relating the morphoedaphic index to harvestable fish production, it was estimated that Lake #3 could sustain an annual fish harvest of between 8.6 and 11.5 kg/ha. This represents a total annual harvestable production of between 1000 and 1340 kg/yr for the lake. Using the percentage (by weight) of sportfish in the gillnet catch (23%), the harvestable sportfish production would be in the order of 230 to 210 kg/yr. The sportfish catch would be composed primarily of northern pike, although small yellow perch could be taken also. Lake whitefish could contribute to a winter ice fishery on this lake. These fish were large, showed a good growth rate, and appeared to be free of *Triaenophorus crassus* plerocercoids.

4.3.7 Discussion

Lake #3 has a fair sport fishery potential for northern pike and possibly lake whitefish. Test net results indicated that northern pike were moderately abundant in the lake and appeared to have a fair growth rate. There were extensive areas of suitable spawning and rearing habitat for pike, primarily in the long, shallow north arm of the lake. Prime spawning habitat for lake whitefish (i.e., gravel-rubble) appeared to be limited, but the whitefish apparently were able to reproduce successfully in the lake, likely by spawning on the hard sand substrate which is abundant.

Due to the small size of the lake, it could be susceptible to overfishing if heavy angling pressure occurs. In order to sustain a fishery, the lake would have to be closely managed.

4.4 UNNAMED LAKE #4

4.4.1 Introduction

Lake #4 is located in Township 103, Range 7, West of the Fourth Meridian (110°57'N; 111°01'W). The surface elevation of the lake is approximately 286.5 m above m.s.l. Two small creeks enter the lake from the south. No outlet streams were noted on topographic maps or during the field investigation; however, the lake may drain through a marshy area at the northwest end to Unnamed Lake #3.

The surrounding terrain is forested on the north and the south with medium density jackpine and on the northeast with a medium density mixed aspen-coniferous forest. To the west, wetland communities are dominant in the lower areas and jackpine is common in the higher areas. A ridge of sand hills, lightly forested with jackpine, is located on the south edge of the lake.

During the summer, the lake is accessible only by aircraft but it is located within 2.3 km of the Fort McMurray-Fort Chipewyan winter road.

Sampling on the lake was conducted during the period 11 to 13 September 1979. Locations of sampling sites are shown in Figure 25.

4.4.2 Morphometry

Lake #4 has a surface area of 103.4 ha and an estimated volume of 5.0×10^6 m^3, giving it a mean depth of 4.8 m (Table 12). The maximum depth noted during eight sounding transects was 11.5 m

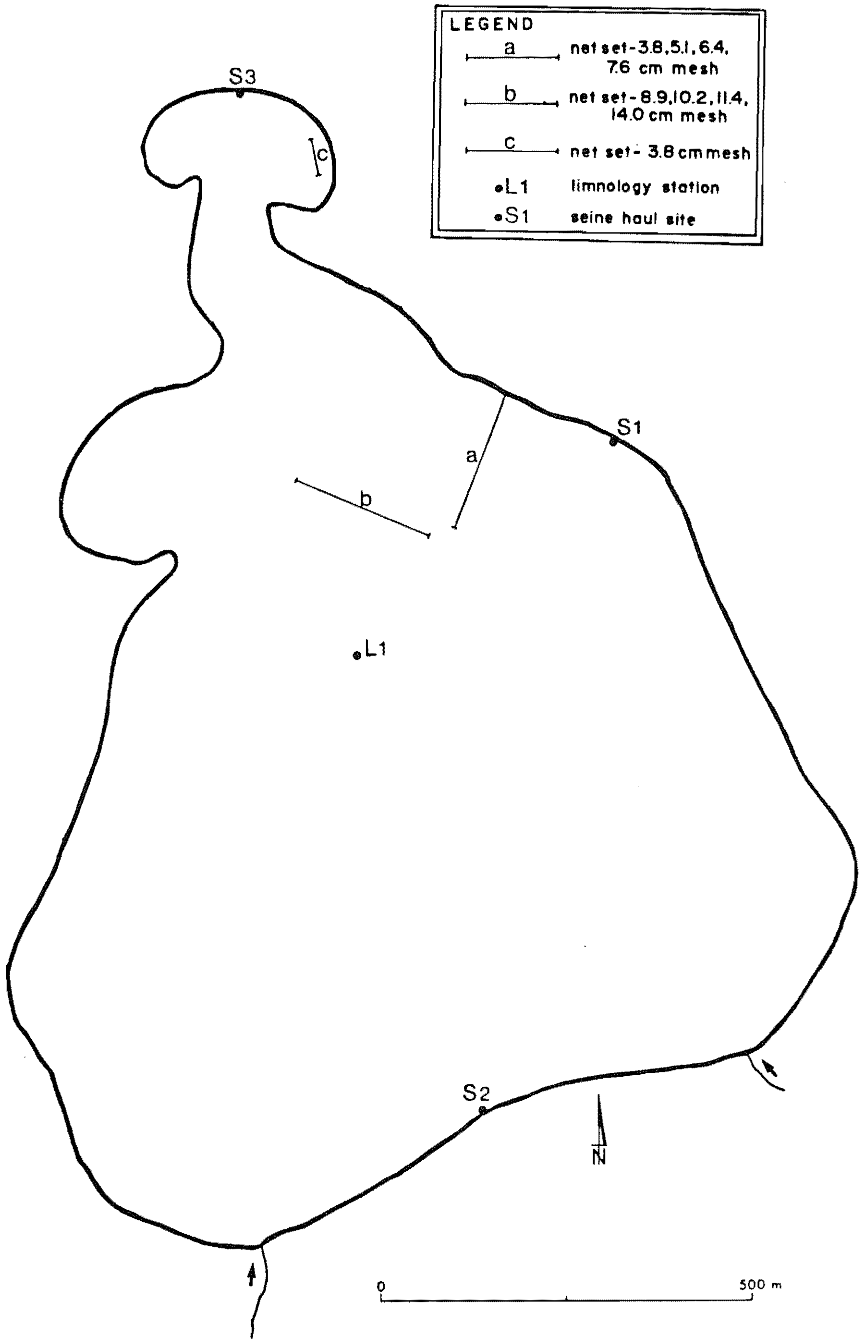

Figure 25. Sampling site locations in Unnamed Lake #4, September 1979.

Table 12. Morphometry of Unnamed Lake #4.

Location		Tp. 103, Rg. 7, W4
Area		103.4 ha
Volume		5.0×10^6 m^3
Shoreline length		4.9 km
Shoreline development factor		1.4
Maximum length		1.6 km
Maximum effective length		1.6 km
Maximum width		1.2 km
Maximum effective width		1.2 km
Mean width		0.7 km
Maximum depth		11.5 m
Mean depth		4.8 m
Depth Distribution:		
	ha	% Surface Area
Surface area	103.4	100
2 m+	84.9	82
4 m+	65.1	63
6 m+	48.3	47
8 m+	3.0	3
10 m+	1.6	2

which was recorded in the southwest part of the lake (Figure 26). The bottom profile was very irregular due to shallow sand points extending out from shore and shallow areas located considerable distances off shore. Approximately 63% of the surface area of the lake was greater than 4 m in depth.

The maximum effective length of the lake was 1.6 km (the long axis lying in a north-south direction) and the maximum effective width was 1.2 km. The total shoreline length was 4.9 km giving a shoreline development factor of 1.4, which indicates the presence of a highly regular shoreline. The regular shoreline and the long effective length and width (relative to the surface area) provide good exposure to wind action.

4.4.3 Water Quality

This lake is of the calcium bicarbonate type with a total filterable residue around 100 mg/L (Table 13). The lake had low turbidity and uncoloured waters which were isothermal and nearly saturated with oxygen when sampled (Figure 27). Total alkalinity was 78 mg/L.

4.4.4 Substrate

Approximately 67% of the lake had a silt substrate or a thick layer of silt over sand (Figure 28). The silt in this lake differed from the organic/silt substrate found in Lakes #2 and #3 in that it was much darker (i.e., being dark brown to black in colour). It appeared to have a higher organic content than the silt substrate encountered in Lake #1. Approximately 33% of the lake basin featured a sand substrate and less than 1% was gravel or rubble. Sand beaches were prominent, especially along the east and south shores. Sand extended considerable distances off shore in some areas. The gravel or rubble areas were located along the west or northwest shore.

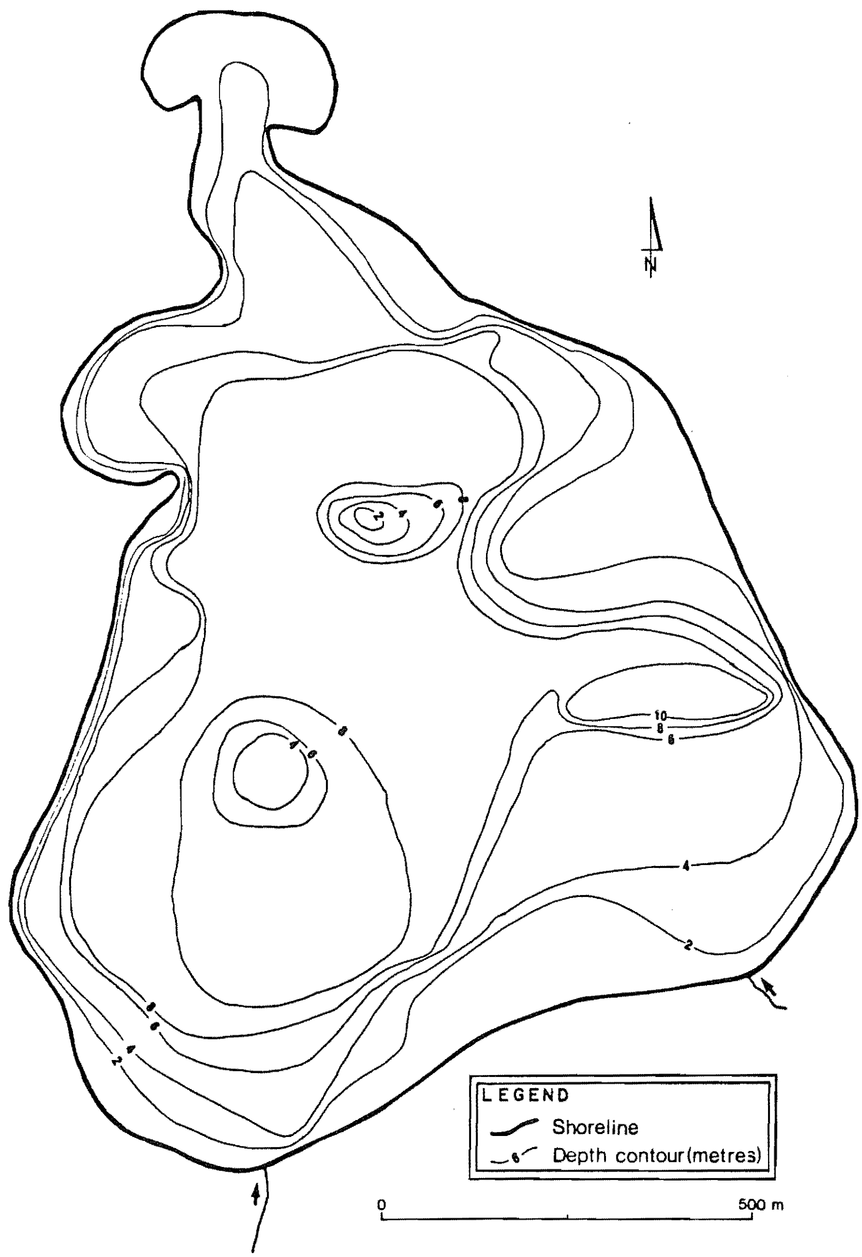

Figure 26. Bathymetric map of Unnamed Lake #4.

Table 13. Water quality analyses for Unnamed Lake #4.

13 September 1979	Site L1			
Na	2.0	mg/L	0.087	meq/L
K	0.1	mg/L	0.003	meq/L
Ca	21.0	mg/L	1.05	meq/L
Mg	6.3	mg/L	0.52	meq/L
SO_4	1.6	mg/L	0.033	meq/L
Cl	1.9	mg/L	0.054	meq/L
CO_3	0	mg/L	0	meq/L
HCO_3	95	mg/L	1.6	meq/L
Alkalinity				
Total	78	mg/L ($CaCO_3$)	1.56	meq/L
P'thalein	0			
pH (pH units)	8.2			
Hardness, total (as $CaCO_3$)	78.3	mg/L		
Total filterable residue				
Evap. @ 105°C	118	mg/L		
Ignit. @ 550°C	44	mg/L		
Conductivity	149	μS/cm		
Turbidity	2.8	NTU		
Total P	<0.016	mg/L		
Ammonia-N	<0.05	mg/L		
Reactive silica	5.7	mg/L		
Total organic carbon	7.6	mg/L		
Fe (total)	0.24	mg/L		

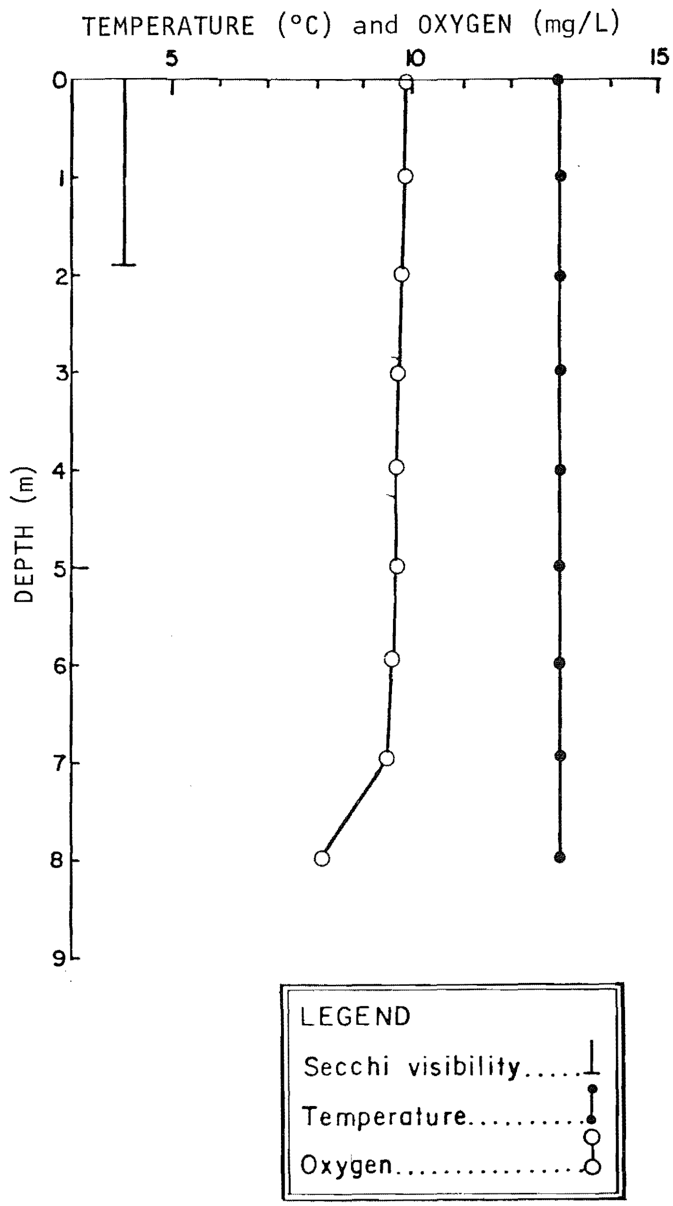

Figure 27. Temperature, dissolved oxygen, and Secchi visibility in Unnamed Lake #4, Site L1, 13 September 1979.

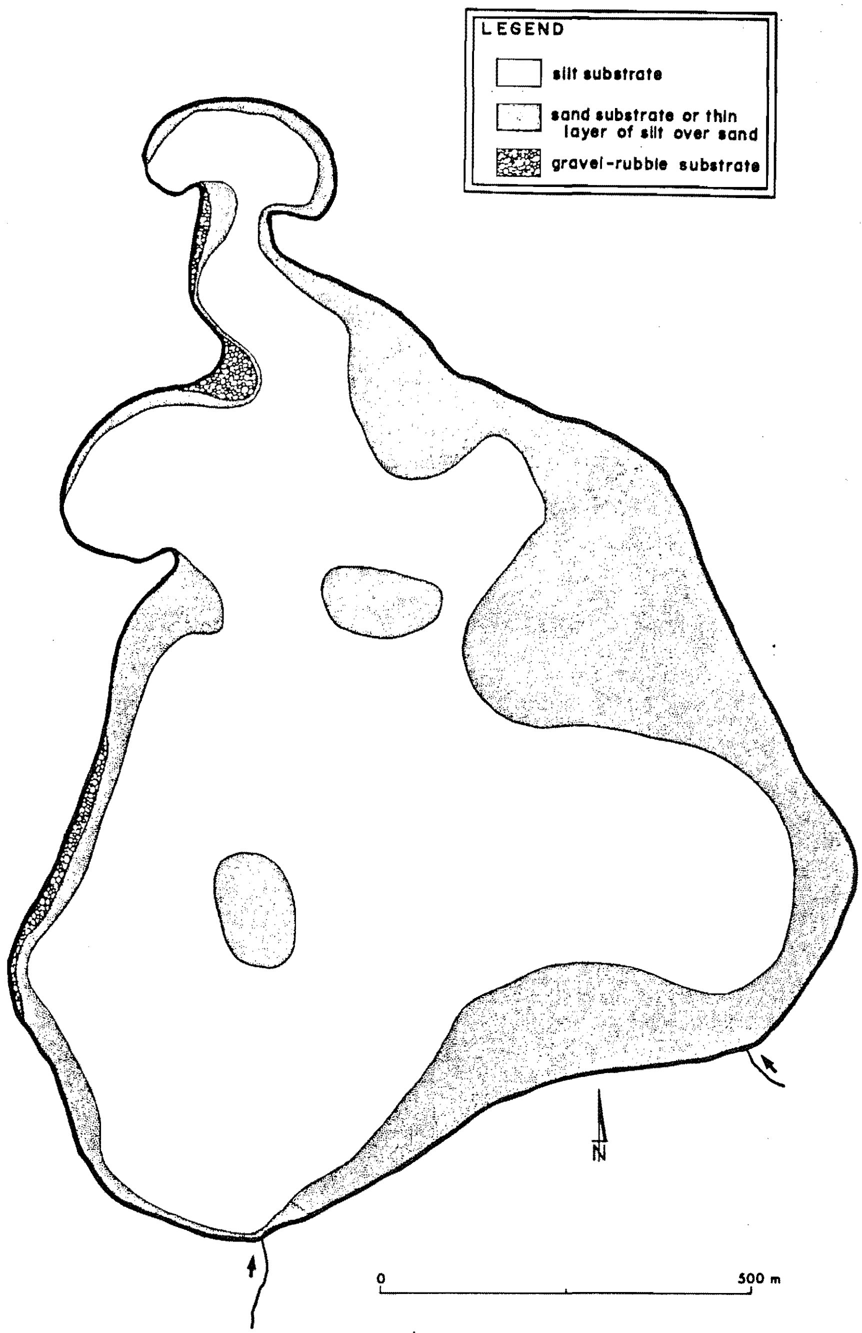

Figure 28. Approximate distribution of surficial lake sediment types in Unnamed Lake #4.

4.4.5 Aquatic Vegetation

Most of the shoreline of the lake was vegetated with a narrow (2 to 5 m wide) band of *Carex* (Figure 29). Stands of *Scirpus* were common around most of the lake but were largest along the south shore and in the bay at the north end of the lake. *Typha* (along the west shore) and *Phragmites* (along the northwest shore) were the other abundant emergents. Localized patches of *Potamogeton* and *Sparganium* were also noted. *Nuphar* which was observed in most study lakes, was not observed in this lake during the survey.

4.4.6 Fish

Five species of fish were captured in one overnight gillnet set (Table 14). The 3.8 cm mesh gillnet was reset for 2.5 h on 13 September and captured additional northern pike. The gillnet catch consisted of lake whitefish (72%), walleye (18%), northern pike (9%), yellow perch (<1%), and spottail shiner (<1%). In three seine hauls taken around the lake, approximately 150 spottail shiner were captured. The presence of ninespine stickleback in four of the walleye stomachs examined indicated that this species was present in fair numbers.

4.4.6.1 Lake Whitefish. Of the 137 lake whitefish captured in gillnets, 54 were sampled for life history information. Length ranged from 177 to 526 mm and weight from 57 to 2290 g. Age varied from 1 to 9 years, with age 7 fish being predominant (Figure 30). A good growth rate was apparent, with the fish reaching a mean length of 352 mm by age 4.

The mean condition factor of the sampled whitefish was 1.44 ± 0.02 (SE), indicating that they were in excellent physical condition. The regression equation relating weight (g) to length (mm) was:

$$W = 2.588 \times 10^{-6} L^{3.288} \text{ where } r^2 = 0.99, N = 54.$$

All of the 5-year-old fish (males and females) were mature. Younger females were all immature; no males 3 or 4 years of age were captured.

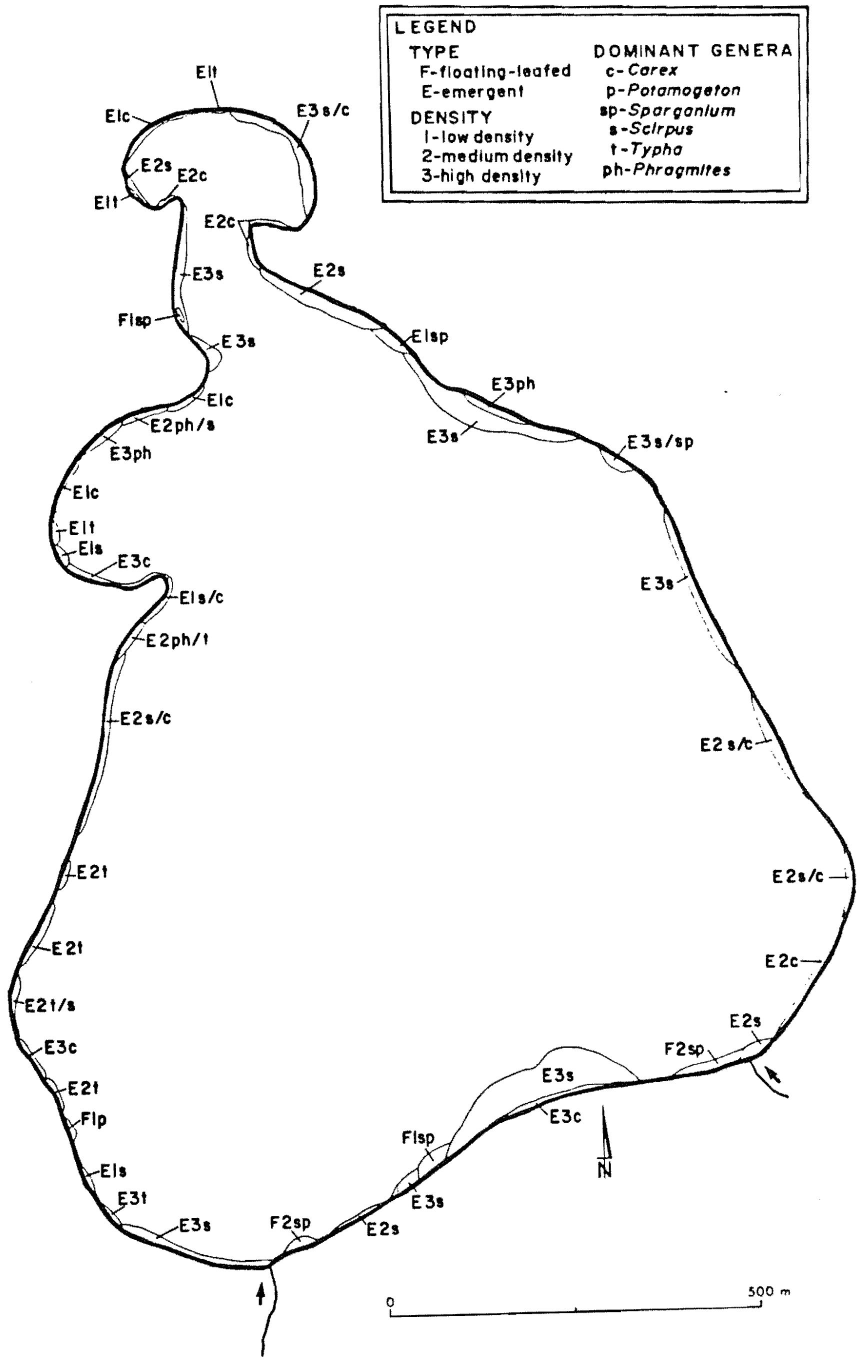

Figure 29. Approximate distribution of aquatic vegetation in Unnamed Lake #4.

Table 14. Test net results for Unnamed Lake #4.

Date Set	Duration of Set (h)	Water Depth (m)	Mesh Size (cm)	Species and Number: Lake Whitefish	Northern Pike	Yellow Walleye	Yellow Perch	Spottail Shiner	Total
11 September 1979	13.0	6.0	3.8	19	0	4	0	0	23
			5.1	17	0	3	1	1	22
			6.4	17	4	8	0	0	29
		1.0	7.6	13	4	7	0	0	24
		7.0	8.9	23	1	9	0	0	33
		7.5	10.2	20	2	1	0	0	23
		7.5	11.4	23	1	2	0	0	26
		7.0	14.0	5	0	0	0	0	5
13 September 1979	2.5	2.0	3.8	0	6	0	0	0	6
Total				137	18	34	1	1	191

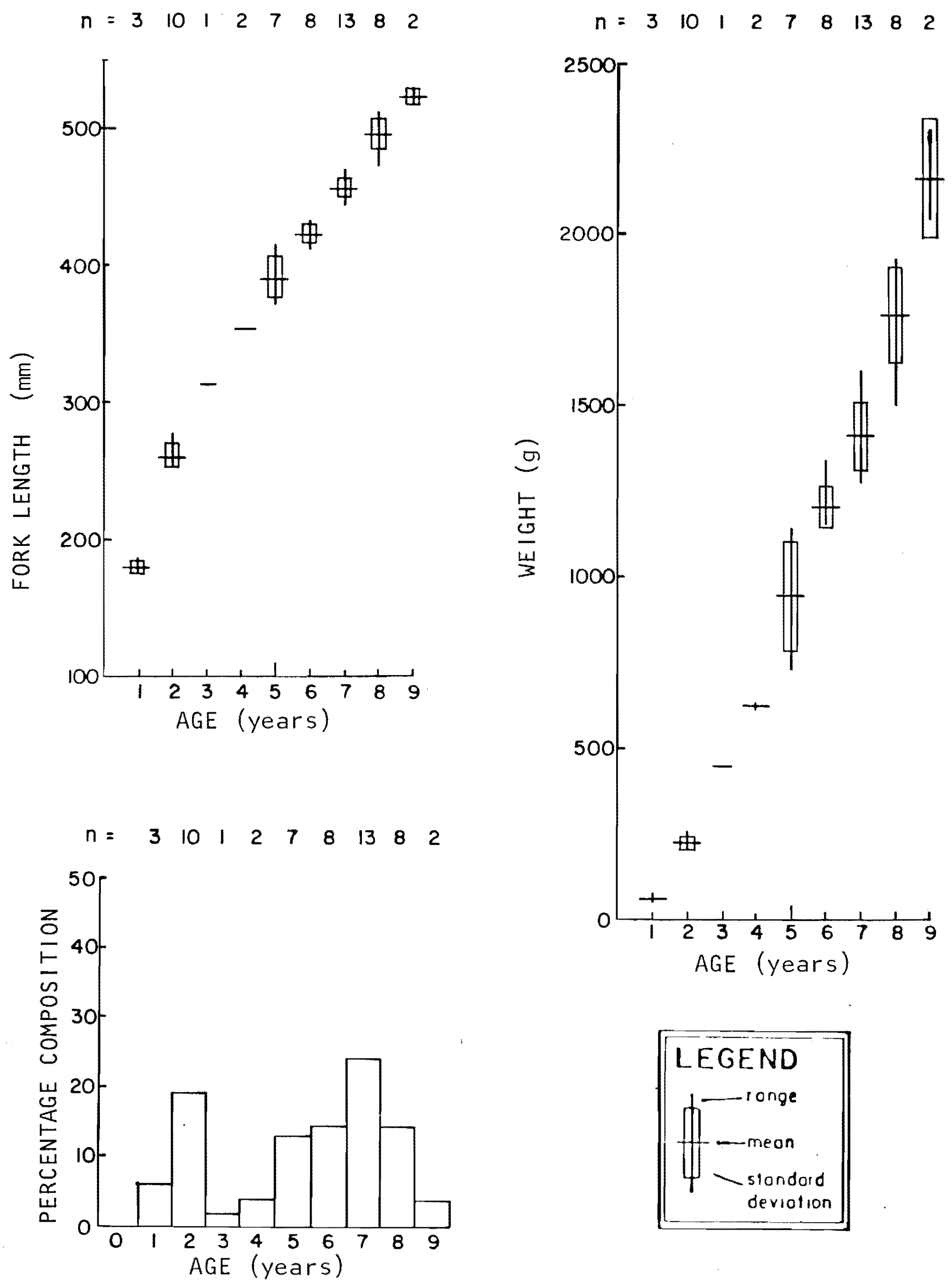

Figure 30. Age composition and age-growth relationships for lake whitefish in Unnamed Lake #4, September 1979.

Fifty-three lake whitefish stomachs were examined for food contents. The primary food items were Chironomidae larvae (13 stomachs), Gastropoda (eight stomachs), *Nostoc* (six stomachs), and Pelecypoda (five stomachs). Corixidae, Trichoptera larvae, unidentifiable fish remains, and a Nematomorpha also were present. Twenty stomachs were empty.

Twenty-six lake whitefish were examined to determine the infestation rate of *Triaenophorus crassus*. Twenty-three (88%) of the fish examined were infected with a total of 202 cysts, giving an infestation rate of 276 cysts/45.4 kg of fish. Due to the high infestation rate, these fish would not be marketable for human consumption.

4.4.6.2 Northern Pike. All 18 northern pike captured in gillnets were sampled for life history information. The pike ranged from 330 to 885 mm in length and from 210 to 4750 g in weight. Age of the sampled fish varied from 3 to 12 years, with fish aged 6, 8, and 11 years being absent from the catch (Figure 31). Four-year-old fish were most abundant, making up 39% of the sample.

The mean condition factor of the sampled fish was 0.65 ± 0.01 (SE), and the length(mm)-weight(g) relationship was:

$$W = 2.580 \times 10^{-6} L^{3.150} \text{ where } r^2 = 0.99, N = 18.$$

All of the sampled fish were mature at age 5. Two of the four age 4 males, and one of the three age 4 females were mature. A total of 18 northern pike stomachs were examined for food contents. The primary food item present was fish remains; yellow perch were the only identifiable fish eaten. One stomach contained Amphipoda. Fourteen stomachs were empty.

4.4.6.3 Walleye. Of the 34 walleye captured, 33 were sampled for life history information. Length of the fish ranged from 104 to 562 mm and weight from 9 to 2260 g. Age varied from 0 to 11 years, but no 1-, 2-, or 3-year-old individuals were present (Figure 32). Thirty-three percent of the sample was comprised of 7-year-old fish.

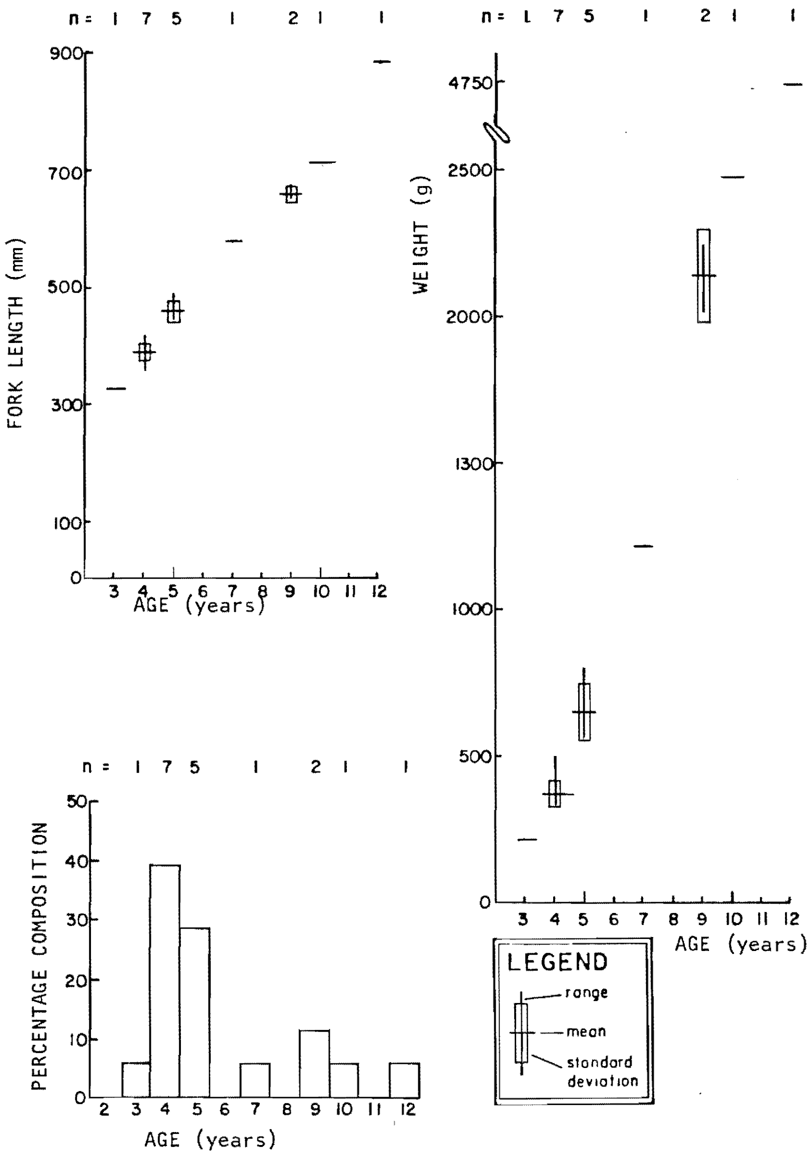

Figure 31. Age composition and age-growth relationships for northern pike from Unnamed Lake #4, September 1979.

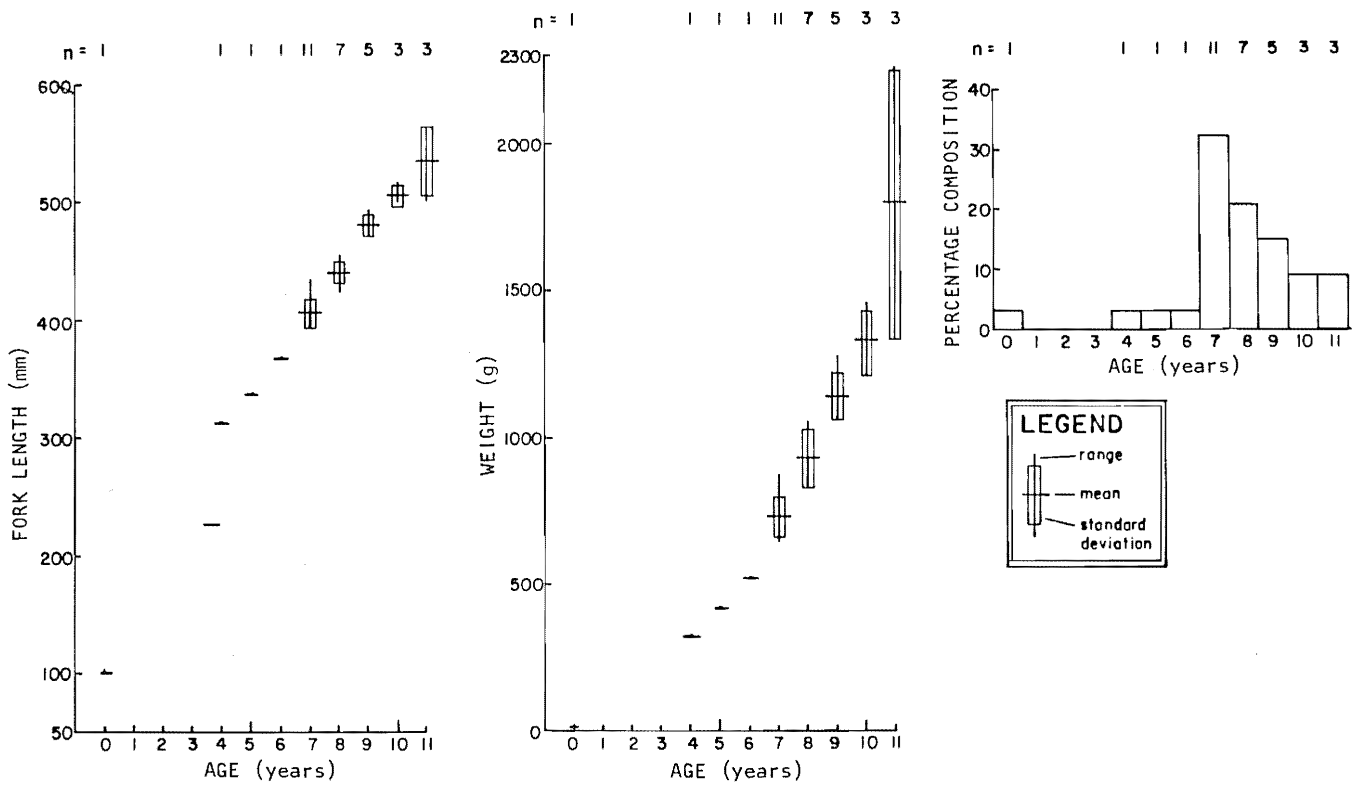

Figure 32. Age composition and age-growth relationships for walleye from Unnamed Lake #4, September 1979.

The growth rate displayed by walleye in this system was fair; fish reached an average length of 409 mm and a weight of 736 g by age 7. The mean condition factor of the sampled fish was 1.06 ± 0.01 (SE), indicating that they were in fair physical condition. The length(mm)-weight(g) regression was:

$$W = 3.981 \times 10^{-6} L^{3.162} \text{ where } r^2 = 0.99, N = 33.$$

All fish 5 years of age and older were mature. Of the 37 walleye stomachs examined, 17 were empty, eight contained yellow perch (some up to 80 mm long), eight contained unidentifiable fish remains, and four contained ninespine stickleback.

4.4.6.4 Yellow Perch. Only one yellow perch was collected from this lake during the study. It was a 3-year-old mature female 123 mm in length and 19 g in weight. Due to the apparent small population size and slow growth displayed by yellow perch in this lake, the species is not likely to contribute significantly to a sport fishery.

4.4.6.5 Spottail Shiner. Spottail shiner appeared to be abundant in this lake, as indicated by the seine haul catches. One spottail shiner was captured in the 5.1 cm mesh gillnet. This individual was 73 mm long and weighed 4 g.

4.4.6.6 Potential Production. Applying the regression equations developed by Ryder (1965) and Allan (1975), it was estimated that Lake #4 could sustain an annual fish harvest between 5.8 and 7.8 kg/ha. This represents a total annual harvestable production of between 600 and 810 kg/yr for the lake. Based on the percentage (by weight) of sportfish in the gillnet catch (26%), the harvestable sportfish production would be in the order of 160 to 210 kg/yr. The sportfish catch would be composed primarily of walleye and northern pike. Lake whitefish, although heavily infested with *Triaenophorus crassus,* were abundant in the lake and could contribute to the catch during the winter. Since whitefish are generally not classed as a sportfish, they were not included in the estimate of sportfish production.

4.4.7 Discussion

Due to the presence of both walleye and northern pike, the lake is attractive from the sport fishery point of view. However, due to its small size, it would support only a limited fishery. Northern pike did not appear to be very abundant in the lake, as was indicated by their relatively low numbers in the catch. Northern pike spawning habitat did not appear to be limiting. Aquatic vegetation was abundant around much of the lake, especially in the bay at the north end of the lake. It is possible that the large walleye population may be controlling the northern pike population either by predation on the young pike or on the forage species that pike depend on. Although the amount of gravel-rubble substrate, the prime spawning habitat for walleye and lake whitefish, was limited, these species appeared to be reproducing successfully in the lake.

4.5 UNNAMED LAKE #5 (EAST HERB LAKE)

4.5.1 Introduction

This lake, locally called East Herb Lake, is situated in Township 103, Range 7, West of the Fourth Meridian (57°55'N; 111°00'W). The surface elevation is approximately 275 m above m.s.l. A small creek enters the lake from the east; the lake drains west into adjacent Unnamed Lake #6. A beaver dam situated on the outlet maintains high water levels and has eliminated all beach areas. The shoreline profile generally featured a rapid dropoff to between 0.5 and 0.7 m immediately off shore. Numerous islands exist in the lake; the larger ones support stands of white spruce (*Picea glauca*) or jack pine. The terrain surrounding this lake is largely forested with medium to dense growths of jack pine. Birch and willow are common along the shoreline of the lake. Exposed sand hills are located to the northwest of the lake.

In the summer, the lake is accessible only by aircraft, but it is located within 2 km of the Fort McMurray-Fort Chipewyan winter road. It is also approximately 3 km north of the Richardson Tower aircraft landing strip.

Sampling on the lake was conducted during the period 17 to 21 September 1979. The locations of the sampling sites are shown in Figure 33.

4.5.2 Morphometry

Lake #5 has a surface area of 157.2 ha and an estimated volume of 6.1×10^6 m^3, giving it a mean depth of 3.9 m (Table 15). The maximum depth noted on a total of 23 sounding transects (8.5 m) was recorded in the northwestern portion of the lake (Figure 34). The southern end of the lake was shallow, being less than 4 m in depth. Only 45% of the surface area of the lake had a depth greater than 4 m. The lake bottom profile was very irregular due to the presence of numerous islands throughout the lake.

The maximum length of the lake was 2.2 km with the maximum effective length being 1.7 km. The maximum width was 1.2 km. The lake had a total of 9.7 km of shoreline, giving a shoreline development factor of 2.2 (not including islands). This indicated that the lake had a moderately irregular shoreline.

4.5.3 Water Quality

When sampled, the lake was isothermal and there was only a slight decline in oxygen in the lowest metre of water (Figure 35). Lake water was fairly clear and uncoloured. The principal ions were calcium and bicarbonate with a total filterable residue of slightly more than 100 mg/L (Table 16). Total alkalinity as $CaCO_3$ was 83 mg/L.

4.5.4 Substrate

Approximately 77% of the surface area of the lake had a substrate of silt or a thick layer of silt over sand (Figure 36). Sixteen percent of the lake had a substrate of sand or a thin layer of silt over hard sand. Gravel or rubble substrate was abundant around much of the lake, underlying 7% of the surface area. Major concentrations of rubble were noted along the western shore, along the mideastern shore, and around the islands in the northern half of the lake.

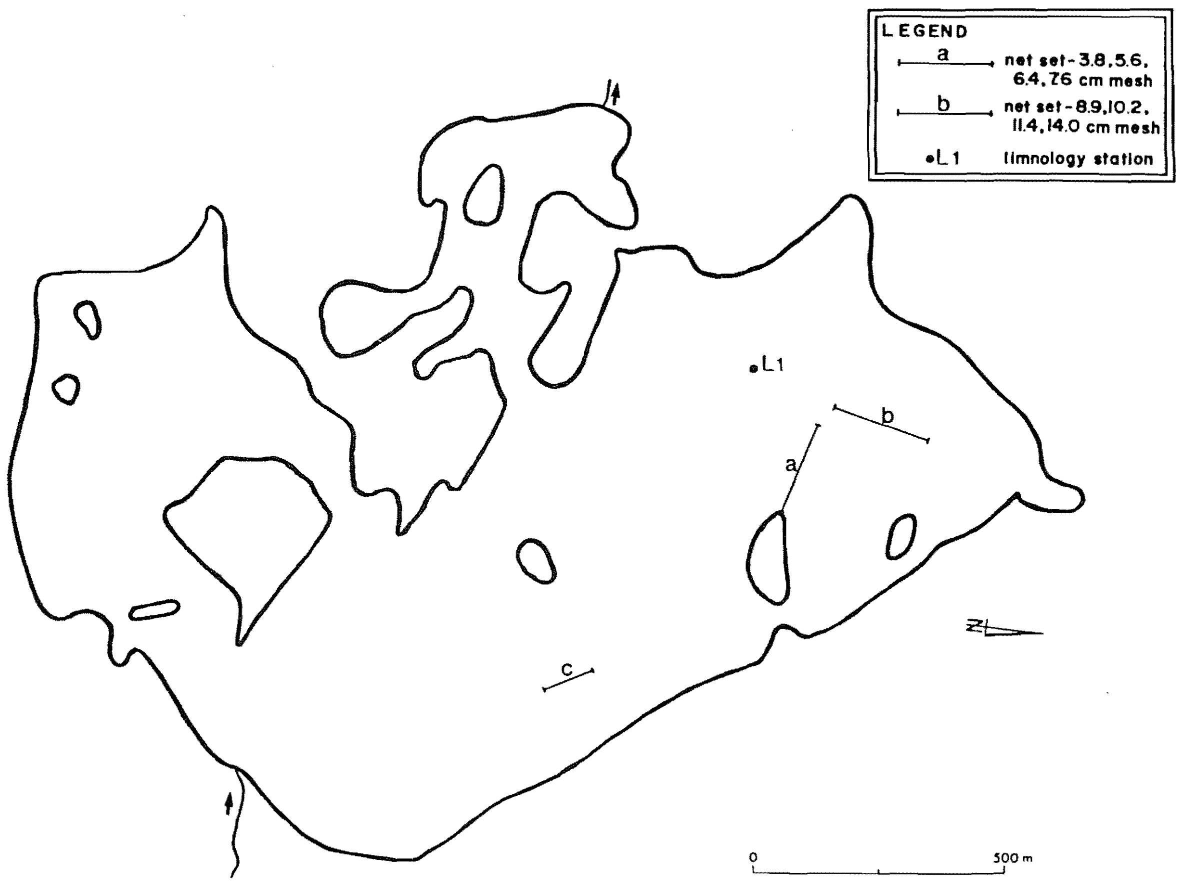

Figure 33. Sampling site locations in Unnamed Lake #5, September 1979.

Table 15. Morphometry of Unnamed Lake #5.

Location		Tp. 103, Rg. 7, W4
Surface area		157.2 ha
Volume		6.1×10^6 m^3
Shoreline length (excluding islands)		9.7 km
Shoreline development factor		2.2
Maximum length		2.2 km
Maximum effective length		1.7 km
Maximum width		1.2 km
Maximum effective width		1.2 km
Mean width		0.8 km
Maximum depth		8.5 m
Mean depth		3.9 m
Depth Distribution:		
	ha	% Surface Area
Surface area	157.2	100
2 m+	118.9	76
4 m+	70.1	44
6 m+	39.5	25
8 m+	4.3	3

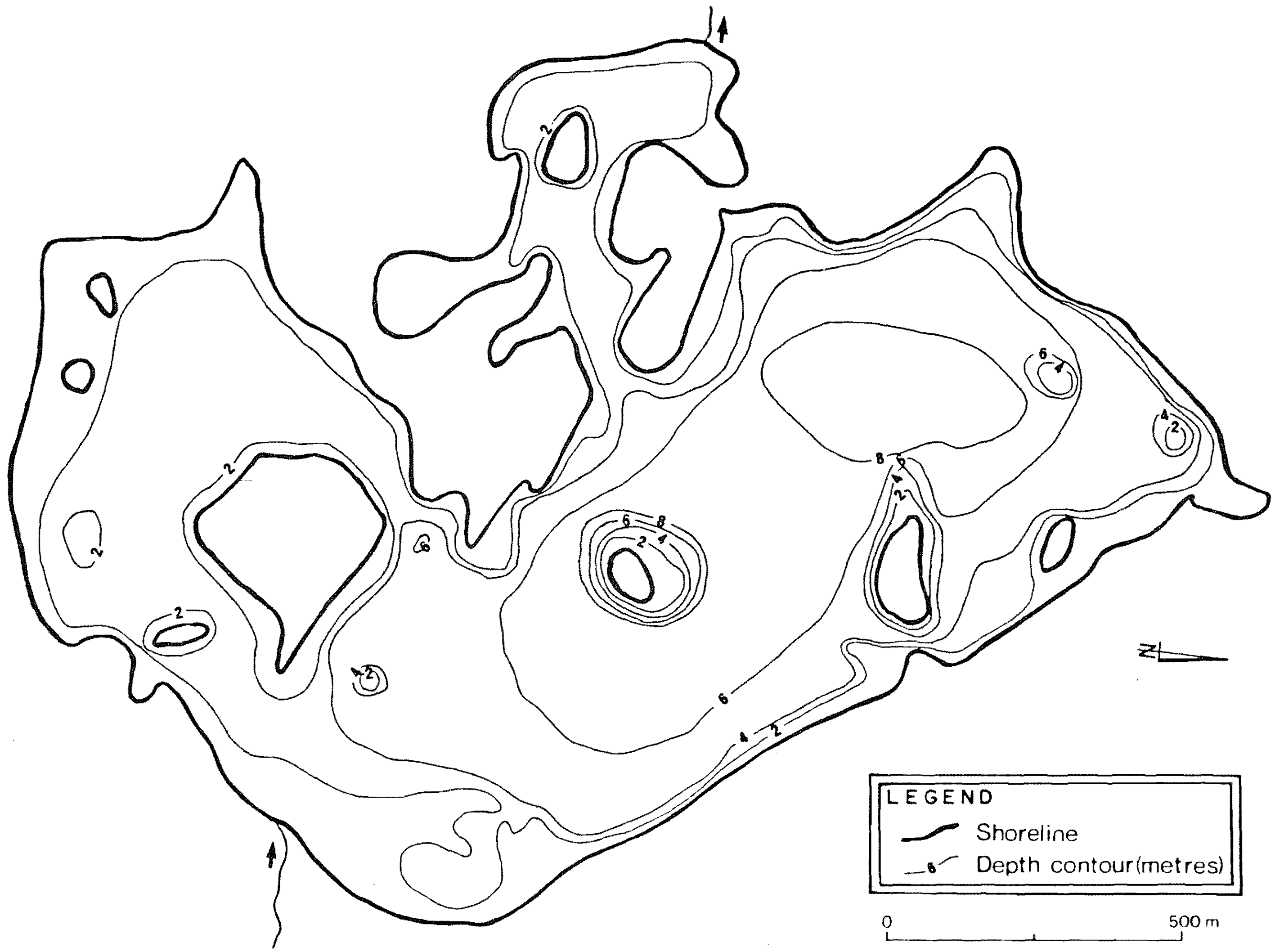

Figure 34. Bathymetric map of Unnamed Lake #5.

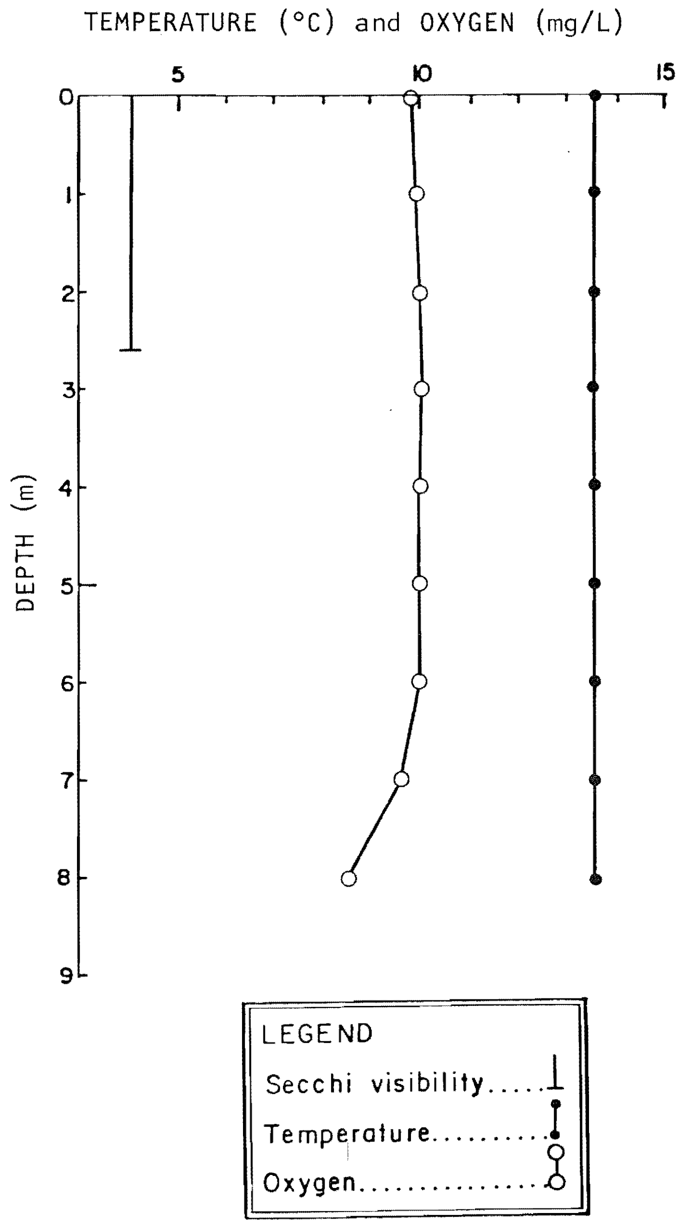

Figure 35. Temperature, dissolved oxygen, and Secchi visibility in Unnamed Lake #5, Site L1, 21 September 1979.

Table 16. Water quality analyses for Unnamed Lake #5.

21 September 1979	Site L1			
Na	3.6	mg/L	0.16	meq/L
K	0.7	mg/L	0.02	meq/L
Ca	24.1	mg/L	1.20	meq/L
Mg	7.4	mg/L	0.61	meq/L
SO_4	2.1	mg/L	0.044	meq/L
Cl	0.3	mg/L	0.008	meq/L
CO_3	0	mg/L	0	meq/L
HCO_3	101	mg/L	1.66	meq/L
Alkalinity				
Total	83	mg/L (as $CaCO_3$)	1.66	meq/L
P'thalein	0			
pH (pH units)	8.2			
Hardness, total (as $CaCO_3$)	90.7	mg/L		
Total filterable residue				
Evap. @ 105°C	118	mg/L		
Ignit. @ 550°C	68	mg/L		
Conductivity	170	µS/cm		
Turbidity	1.8	NTU		
Total P	<0.016	mg/L		
Ammonia-N	<0.05	mg/L		
Reactive silica	8.8	mg/L		
Total organic carbon	8.8	mg/L		
Fe (total)	0.15	mg/L		

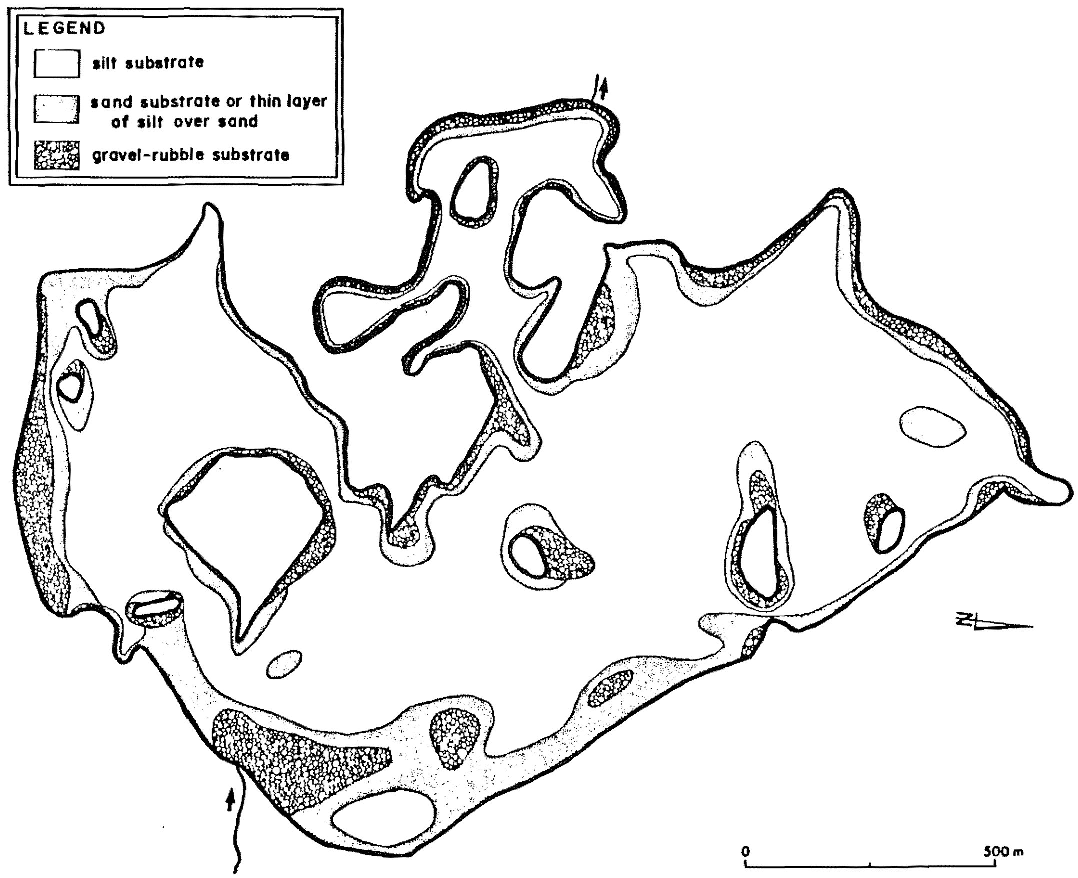

Figure 36. Approximate distribution of surficial lake sediment types in Unnamed Lake #5.

4.5.5 Aquatic Vegetation

Substantial growths of emergent and floating-leafed aquatic vegetation occurred around most of the lake. Extensive stands of *Scirpus,* often extending 200 to 300 m off shore, were noted along the east and southeast edge of the lake (Figure 37). *Phragmites* was especially prevalent along the western and northeastern shores. Other abundant emergents were *Carex, Equisetum,* and *Typha*. Dominant floating-leafed vegetation consisted of *Nuphar, Sparganium,* and *Potamogeton*. The banks around most of the lake supported thick growths of shrubs extending to the water's edge.

4.5.6 Fish

Six species of fish were captured in gillnets set in Lake #5; of these, walleye was the most abundant (Table 17). Walleye constituted 65% of the total catch (N = 124). Northern pike was the next most abundant species (26%), followed by lake whitefish (5%). Only one cisco, one yellow perch, and three white sucker were collected. No seine hauls were conducted in this lake due to unsuitable shoreline conditions. The presence of large numbers of ninespine stickleback in the stomachs of walleye and northern pike, and a burbot in a northern pike stomach, confirmed the presence of these species in the lake. In addition, a school of spottail shiner was observed in shallow water in a bay at the west end of the lake.

4.5.6.1 Lake Whitefish. Lake whitefish appeared to be present only in small numbers in the lake. Of the six specimens captured, all were large individuals caught in 10.2 cm mesh or larger. Length ranged from 422 to 523 mm and weight from 1400 to 2700 g. Age varied from 5 to 8 years. The excellent growth rate shown by these fish was likely a reflection of their low population size in the lake and therefore limited competition for food resources. All fish were mature with the exception of one 5-year-old fish that appeared to have spawned previously but would not spawn during the coming season. The mean

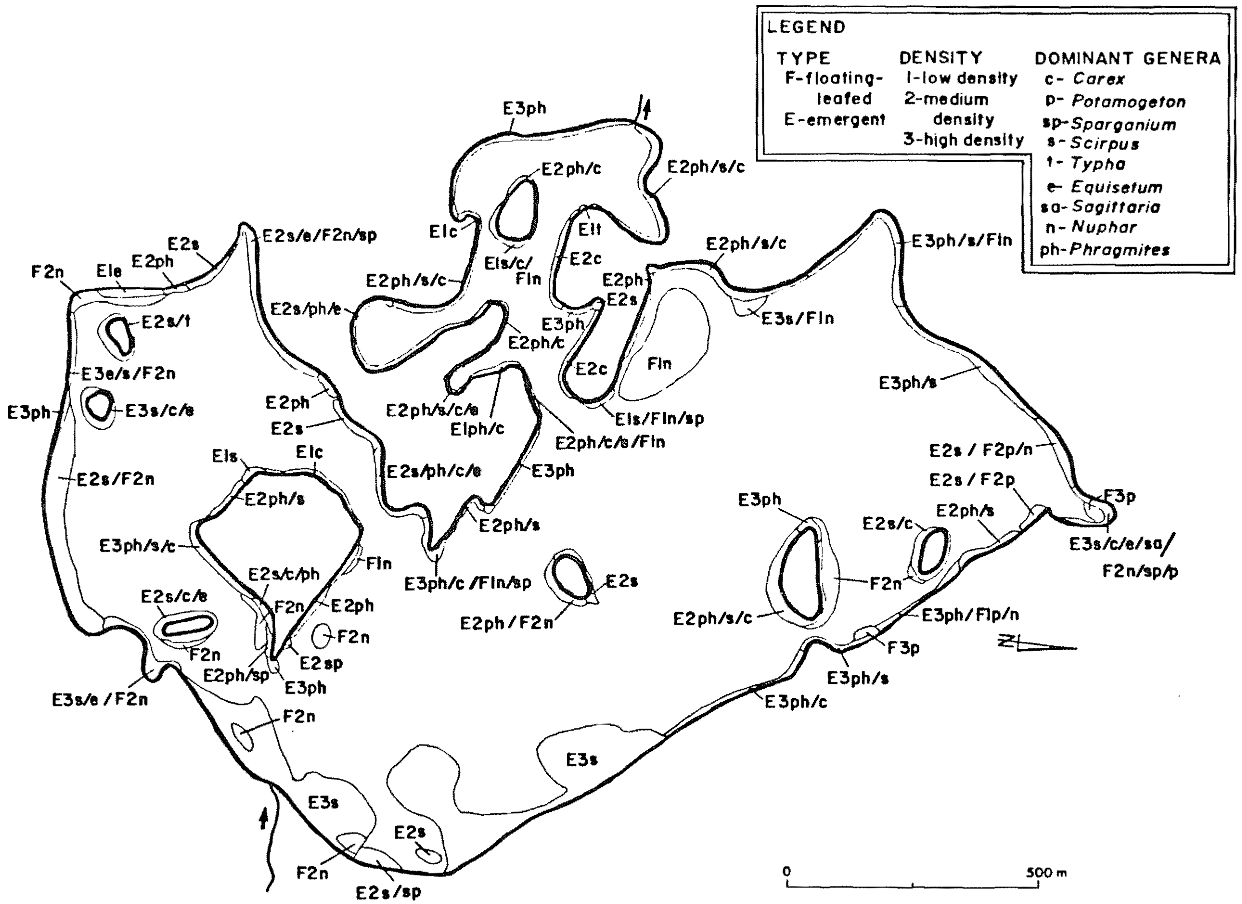

Figure 37. Approximate distribution of aquatic vegetation in Unnamed Lake #5.

Table 17. Test net results for Unnamed Lake #5.

Date Set	Duration of Set (h)	Water Depth (m)	Mesh Size (cm)	Species and Number: Lake Whitefish	Cisco	Northern Pike	Yellow Walleye	Yellow Perch	White Sucker	Total
17 September 1979	12.5	1.0	3.8	0	0	3	8	1	0	12
			5.1	0	0	10	8	0	2	20
			6.4	0	0	6	8	0	1	15
		7.5	7.6	0	0	9	35	0	0	44
		8.5	8.9	0	0	1	12	0	0	13
			10.2	1	0	1	7	0	0	9
			11.4	1	0	1	3	0	0	5
		7.0	14.0	2	1	0	0	0	0	3
20 September 1979	20.0	7.0	11.4	0	0	1	0	0	0	1
		7.0	14.0	2	0	0	0	0	0	2
Total				6	1	32	81	1	3	124

condition factor of the six fish was 1.86 ± 0.04, indicating that the fish were in excellent physical condition. No length-weight regression was calculated due to the small sample size.

Stomach content analysis of the six specimens indicated that Chironomidae larvae (three stomachs), Pelecypoda (one stomach), and unidentified fish (one stomach) were the major food items consumed.

No plerocercoids of *Triaenophorus crassus* were found in the six fish examined.

4.5.6.2 Cisco. Only one cisco, a large mature male measuring 401 mm and weighing 1260 g, was captured in Lake #5. Attaining this size by age 8 indicates a good rate of growth. Its condition factor was 1.95, which indicated that the fish was in excellent condition. This fish contained no plerocercoids of *T. crassus*. Since only one cisco was captured in one overnight set of the standard gillnet meshes and an additional 20 h set of 11.4 and 14.0 cm mesh nets (the smaller mesh nets were not reset due to high catches of walleye in the previous set), it appears that cisco were not abundant in the lake. However, additional sampling effort at different depths in the water column may yield more cisco since they are known to select specific strata at certain times of the year (Colby and Brooke 1969).

4.5.6.3 Northern Pike. Of the 32 northern pike captured in gillnets in this lake, 31 were sampled for life history information. Length ranged from 310 to 554 mm and weight from 225 to 1090 g. Age varied from 3 to 8 years, with 7-year-old fish being predominant (42%) (Figure 38). No age 4 fish were present in the sample. The mean condition factor was 0.65 ± 0.01 (SE) and the length(mm)-weight(g) relationship was:

$$W = 6.185 \times 10^{-5} L^{2.634} \text{ where } r^2 = 0.94, N = 31.$$

The condition factor of the pike from this lake was similar to that of the other nine lakes studied.

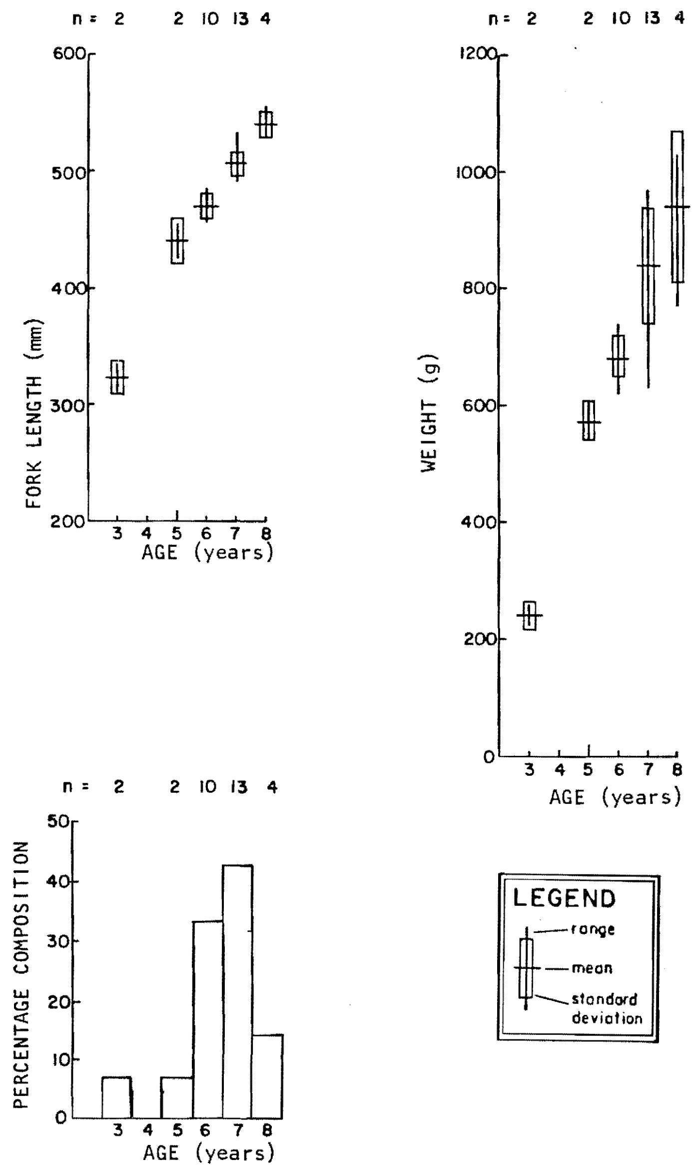

Figure 38. Age composition and age-growth relationships for northern pike from Unnamed Lake #5, September 1979.

All of the pike 5 years and older were mature. The primary food items eaten were ninespine stickleback (present in four of the 30 stomachs examined), yellow perch (two stomachs), white sucker (one stomach), and burbot (one stomach). Twenty of the stomachs were empty and three contained unidentifiable fish remains.

4.5.6.4 Walleye. As indicated by the gillnet catch, walleye were the most abundant sportfish in the lake, making up 65% of the catch. Of the 81 specimens captured, 42 were sampled for life history information. Length ranged from 184 to 525 mm and weight from 54 to 1410 g. Age of the fish ranged from 1 to 10 years, although no 2-year-olds were present in the sample (Figure 39). Age 7 fish were predominant (33% of the sample). The condition factor of the sampled fish was 1.08 ± 0.02 (SE), indicating that they were in fair physical condition. The length(mm)-weight(g) regression equation was:

$$W = 3.576 \times 10^{-6} L^{3.184} \text{ where } r^2 = 0.98,\ N = 42.$$

All of the fish 5 years and older were mature. The one age 4 female sampled and two of the three age 4 males, were immature. The primary food items present in the 33 stomachs examined were yellow perch (three stomachs), ninespine stickleback (two stomachs), and unidentifiable fish remains (11 stomachs). The remainder of the stomachs (48%) were empty. Three of the walleye captured had large growths of what appeared to be fungus on their caudal fin, dorsal fin, or head. In one of the cases, the growths appeared large enough to affect swimming performance and also block vision from one eye.

4.5.6.5 Other Species. One 4-year-old mature female yellow perch, measuring 154 mm and weighing 39 g, was captured in the 3.8 cm mesh gillnet. Three white sucker, captured in the 5.1 and 6.4 cm mesh sizes, were also sampled. Their length ranged from 225 to 410 mm and weight from 230 to 940 g. The 3-year-old sucker was immature while both 4-year-olds were mature.

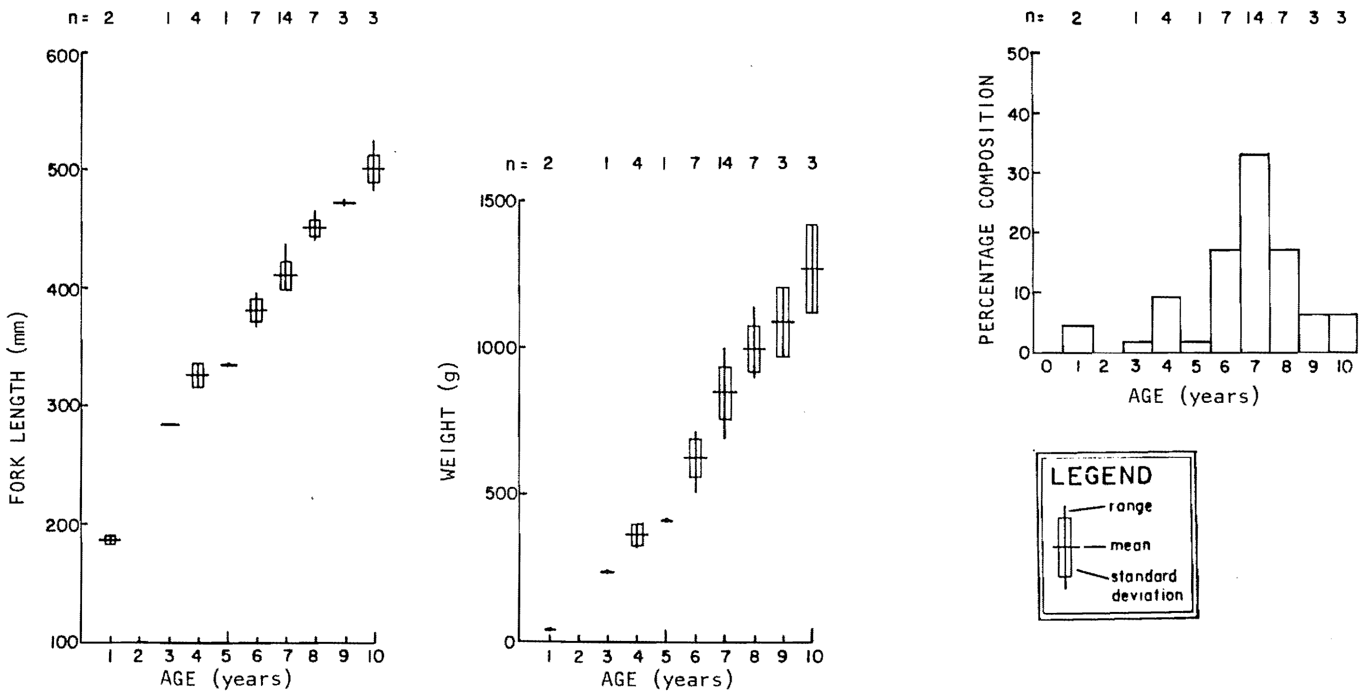

Figure 39. Age composition and age-growth relationships for walleye from Unnamed Lake #5, September 1979.

4.5.6.6 Potential Production. Applying the regression equations developed by Ryder (1965) and Allan (1975), an estimate of harvestable fish production in Lake #5 was 6.3 to 8.5 kg/ha/yr or a total harvestable production of 990 to 1340 kg/yr. Based on the percentage (by weight) of sportfish in the gillnet catch (85%), the harvestable sportfish production would be in the order of 840 to 1140 kg/yr. The sportfish catch would be primarily walleye and northern pike. Due to the apparent low abundance, small size, and slow growth rate of yellow perch in this lake, they likely would not contribute substantially to a sport fishery.

4.5.7 Discussion

Due to the presence of large populations of walleye and northern pike, the lake has a good potential for sport fishing. There appeared to be an adequate amount of spawning and rearing habitat for northern pike, especially in the shallow bays in the western portion of the lake. Gravel-rubble substrates in the lake likely provide ample spawning habitat for walleye, lake whitefish, and cisco. The apparent low population size of the latter two species may be due to heavy predation on the young of these species by the abundant walleye and pike populations.

At the present time, the lake is receiving some sport fishing pressure by tourists who are flown into the lake from Fort McMurray. Angling success is reported to be fair (J. Bergeron, Contact Airways Ltd., Fort McMurray, pers. comm., 21 September 1979).

4.6 UNNAMED LAKE #6 (WEST HERB LAKE)

4.6.1 Introduction

Lake #6, locally known as West Herb Lake, is located in Township 103, Range 7, West of the Fourth Meridian (57°55'N; 111°02'W). The surface elevation is approximately 274.6 m above m.s.l. The major inflow to the lake is from Unnamed Lake #5 (East Herb Lake). An outlet stream, Grayling Creek, leaves the west end of the lake and flows to the Athabasca River. The level of the lake was controlled by a large beaver dam at the outlet. As a result of the high water level in the lake, the shoreline generally dropped off immediately to between 0.5 and 0.7 m. The surrounding terrain is primarily forested with a moderate to dense cover of jackpine. Exposed sand hills are present in some locations around the lake.

During the summer, the lake is accessible only by aircraft; however, the lake is located within 1 km of the Fort McMurray-Fort Chipewyan winter road and within 2 km of the Richardson Tower aircraft landing strip.

Sampling on the lake was conducted during the period 17 to 21 September 1979. The locations of sampling sites are shown in Figure 40.

4.6.2 Morphometry

Lake #6 has a surface area of 116.5 ha and an estimated volume of 4.9×10^6 m^3, giving it a mean depth of 4.2 m (Table 18). The maximum depth noted during a total of 29 sounding transects was 9.0 m; it was recorded in the middle of the large basin in the northern part of the lake (Figure 41). The southern part of the lake was generally shallow, with the depth rarely exceeding 4 m. Approximately 52% of the surface area of the lake was greater than 4 m deep. The lake bottom profile was quite irregular due to the presence of numerous islands in the lake.

The maximum length of the lake was 2.4 km while the maximum effective length was 2.1 km. The maximum effective width was 1.1 km. The lake had a total of 8.3 km of shoreline (not including islands). A shoreline development factor of 2.1 was calculated, indicating the presence of a moderately irregular shoreline.

4.6.3 Water Quality

Lake #6 was essentially isothermal and nearly saturated with oxygen when sampled in September (Figure 42). The water was unstained

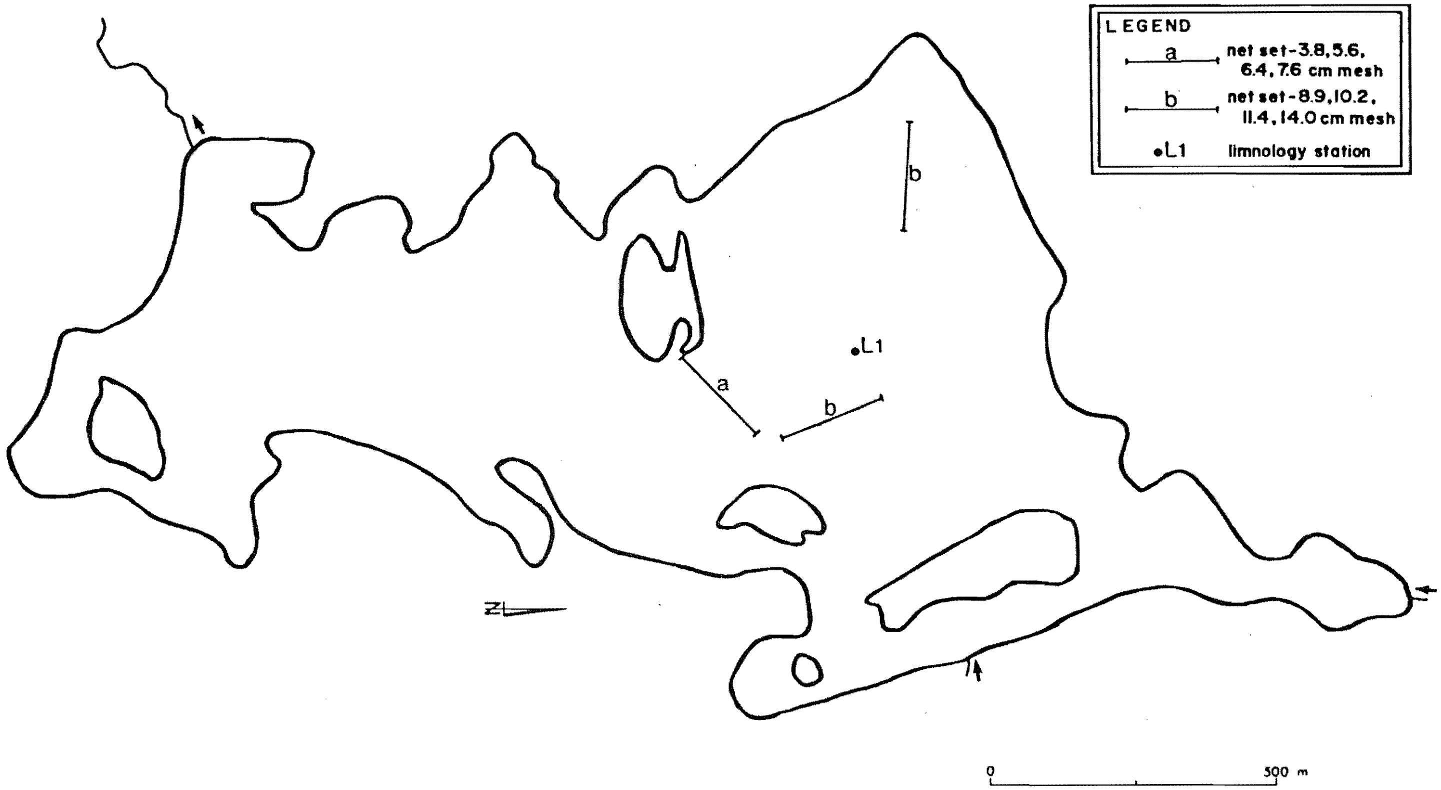

Figure 40. Sampling site locations in Unnamed Lake #6, September 1979.

Table 18. Morphometry of Unnamed Lake #6.

Location	Tp. 103, Rg. 7, W4
Surface area	116.5 ha
Volume	4.9×10^6 m^3
Shoreline length (excluding islands)	8.3 km
Shoreline development factor	2.1
Maximum length	2.4 km
Maximum effective length	2.1 km
Maximum width	1.2 km
Maximum effective width	1.1 km
Mean width	0.5 km
Maximum depth	9.0 m
Mean depth	4.2 m

Depth Distribution:

	ha	% Surface Area
Surface area	116.5	100
2 m+	92.4	79
4 m+	66.0	52
6 m+	26.6	23
8 m+	12.0	10

Figure 41. Bathymetric map of Unnamed Lake #6.

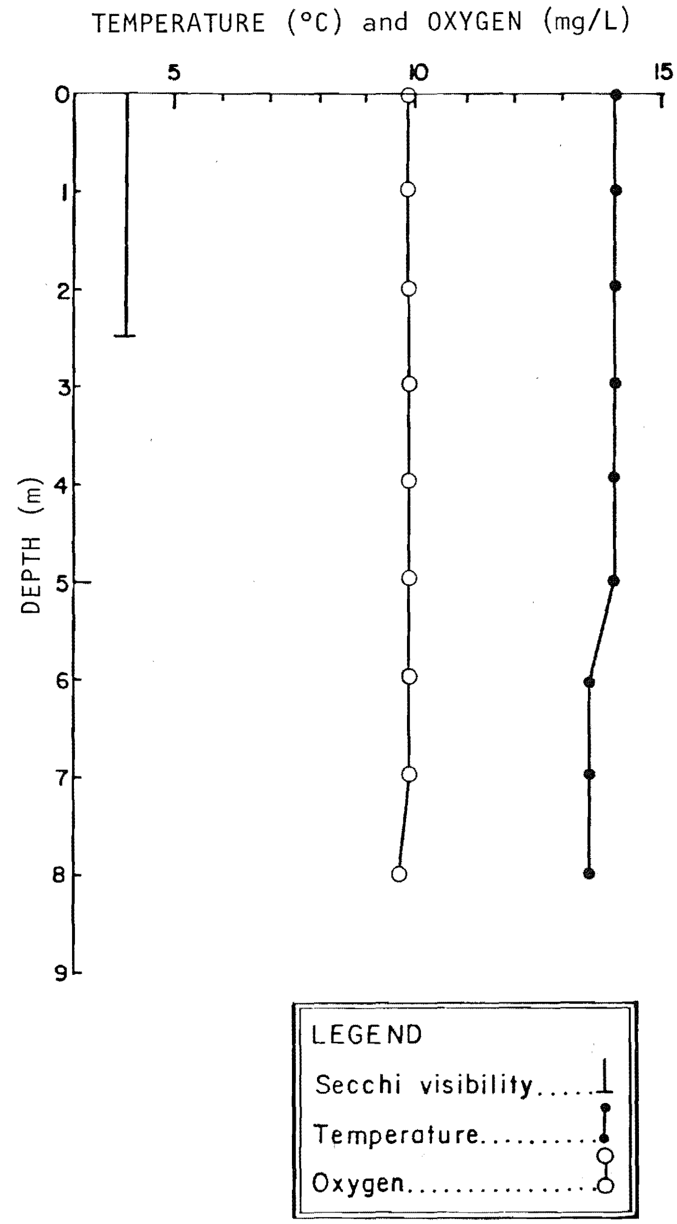

Figure 42. Temperature, dissolved oxygen, and Secchi visibility in Unnamed Lake #6, Site L1, 21 September 1979.

and low in turbidity. Principal ions were calcium and bicarbonate, and total filterable residue was 120 mg/L. Total alkalinity was 84 mg/L (Table 19).

4.6.4 Substrate

Approximately 76% of the lake had a substrate of silt or a thick layer of silt over sand, while 16% had a sand substrate (or thin layer of silt over sand) (Figure 43). Eight percent of the lake had a gravel or rubble bottom.

4.6.5 Aquatic Vegetation

Most of the shoreline of the lake was vegetated with shrubs. Extensive growths of emergents (primarily *Carex, Phragmites, Scirpus,* and *Equisetum*) were present around much of the shoreline (Figure 44). Floating-leafed vegetation was also abundant in the lake; major growths of *Nuphar* occurred around the majority of the shoreline. Other prominent floating-leafed plants were *Potamogeton* and *Sparganium*.

4.6.6 Fish

Five species of fish were captured in two overnight gillnet sets in Lake #6 (Table 20). The most abundant fish in the catch were walleye, which composed 65% of the 142 fish captured. White sucker were next in abundance (14%), followed by northern pike (13%). Only seven cisco and four lake whitefish were captured. No seining was conducted in this lake due to unsuitable shoreline conditions. However, yellow perch, ninespine stickleback, and spottail shiner were identified in the stomach contents of northern pike and walleye, confirming the presence of these species in the lake.

4.6.6.1 Lake Whitefish. Four lake whitefish were captured; they ranged in length from 241 to 461 mm and in weight from 178 to 1480 g. Age varied from 2 to 5 years, and the age-length relationship

Table 19. Water quality analyses for Unnamed Lake #6.

21 September 1979	Site L1			
Na	3.6	mg/L	0.16	meq/L
K	0.7	mg/L	0.02	meq/L
Ca	24.5	mg/L	1.22	meq/L
Mg	7.5	mg/L	0.62	meq/L
SO_4	2.1	mg/L	0.044	meq/L
Cl	0.3	mg/L	0.008	meq/L
CO_3	0	mg/L	0	meq/L
HCO_3	103	mg/L	1.68	meq/L
Alkalinity				
Total	84	mg/L ($CaCO_3$)	1.68	meq/L
P'thalein	0	mg/L ($CaCO_3$)		
pH (pH units)	8.2			
Hardness, total (as $CaCO_3$)	92.1	mg/L		
Total filterable residue				
Evap. @ 105°C	120	mg/L		
Ignit. @ 550°C	76	mg/L		
Conductivity	178	µS/cm		
Turbidity	1.9	NTU		
Total P	<0.016	mg/L		
Ammonia-N	<0.05	mg/L		
Reactive silica	7.8	mg/L		
Total organic carbon	7.3	mg/L		
Fe (total)	0.12	mg/L		

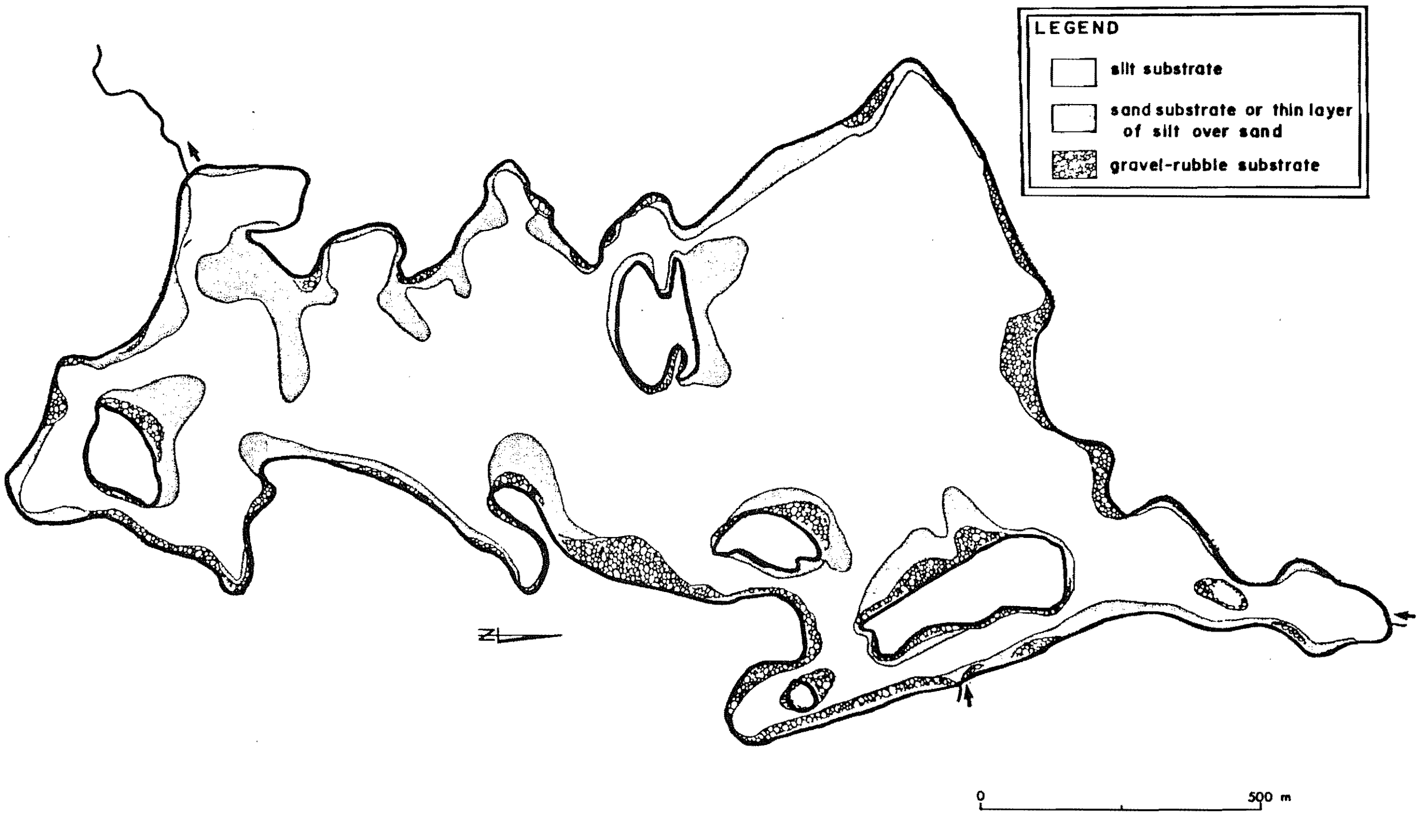

Figure 43. Approximate distribution of surficial lake sediment types in Unnamed Lake #6.

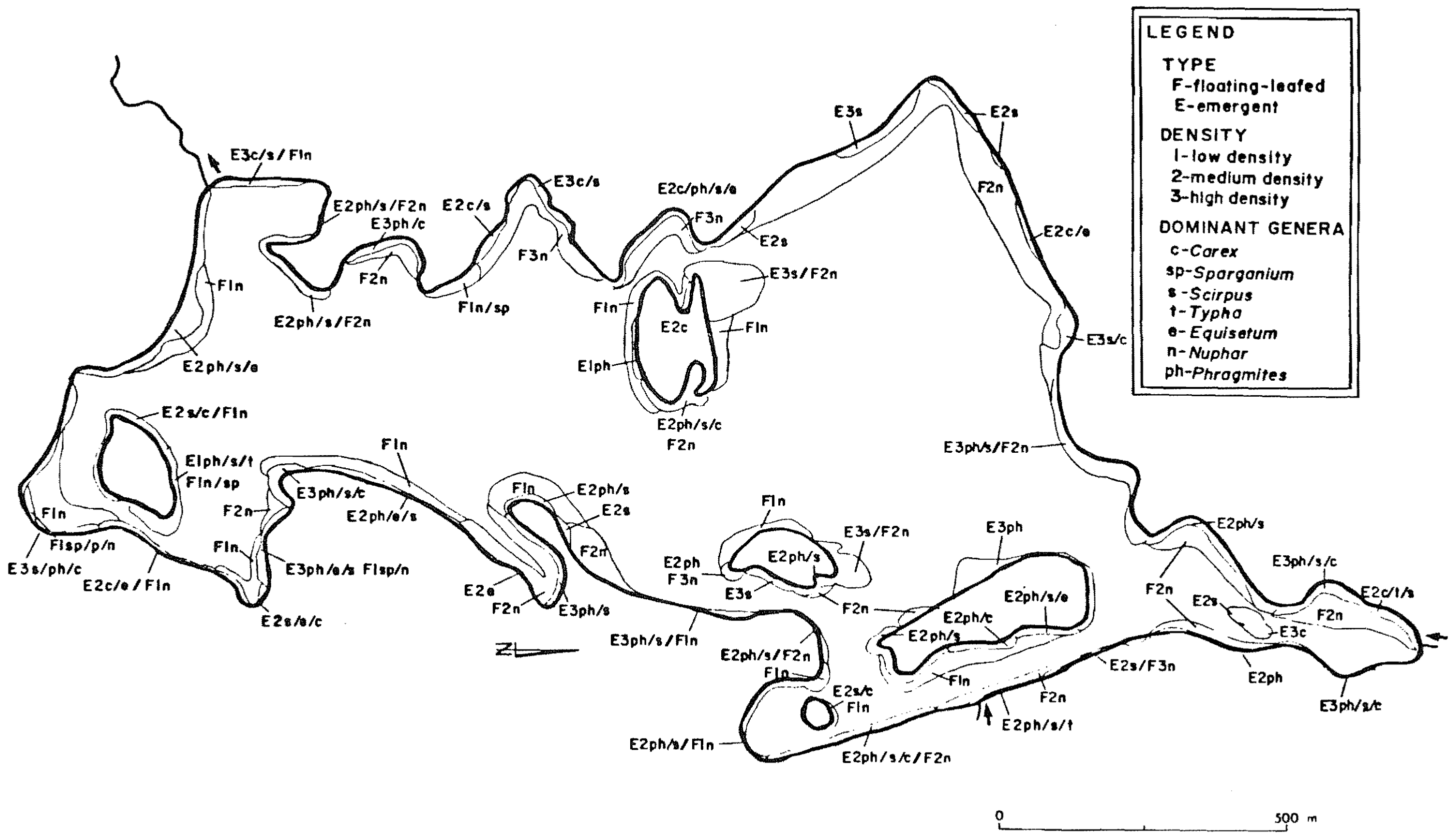

Figure 44. Approximate distribution of aquatic vegetation in Unnamed Lake #6.

Table 20. Test net results for Unnamed Lake #6.

Date Set	Duration of Set (h)	Water Depth (m)	Mesh Size (cm)	Species and Number					Total
				Lake Whitefish	Cisco	Northern Pike	Yellow Walleye	White Sucker	
18 September 1979	16	1.5	3.8	1	0	7	23	1	32
			5.1	1	0	6	7	1	15
			6.4	0	2	4	8	2	16
		7.0	7.6	0	0	1	15	3	19
		8.0	8.9	0	1	0	9	0	10
			10.2	0	0	0	1	0	1
			11.4	1	0	0	0	0	1
		8.0	14.0	0	0	0	0	0	0
19 September 1979	14	5.5	8.9	0	3	0	27	7	37
			10.2	0	1	0	2	3	6
			11.4	0	0	0	1	3	4
		6.5	14.0	1	0	0	0	0	1
Total				4	7	18	93	20	142

indicated an excellent growth rate (i.e., fish reaching 461 mm by age 5). The mean condition factor of the grouped sample was 1.54 ± 0.103 (SE), indicating that the fish were in good physical condition. None of the whitefish examined contained plerocercoids of *Triaenophorus crassus*.

4.6.6.2 Cisco. Length of the seven cisco captured in gillnets varied from 323 to 350 mm, while weight ranged from 430 to 550 g. Five of the fish were age 4 (mean length 334 mm); the remaining two were age 5 (mean length 343 mm). The mean condition factor was 1.27 ± 0.038 (SE). One of the 4-year-old females was mature, as was one of the 4 year old and one of the 5-year-old males. No plerocercoids of *T. crassus* were noted in the seven cisco.

4.6.6.3 Northern Pike. Eighteen northern pike were captured in gillnets. Length ranged from 231 to 488 mm and weight from 68 to 750 g. Age varied from 2 to 6 years, with age 5 fish being predominant (50%) (Figure 45). The mean condition factor of the sample was 0.62 ± 0.01 (SE) and the length(mm)-weight(g) regression was:

$$W = 7.817 \times 10^{-6} L^{2.963} \text{ where } r^2 = 0.99,\ N = 18.$$

All of the pike 4 years of age or older were mature. The stomach contents of all 18 fish were examined. The food items present were ninespine stickleback in one stomach, and yellow perch and spottail shiner in another. Sixteen of the stomachs examined were empty.

4.6.6.4 Walleye. Forty-four of the 93 walleye captured were sampled for life history information. Length ranged from 180 to 475 mm and weight from 50 to 1010 g. All age-classes between 1 and 9 were represented in the sample, but age 6 fish were predominant (27%) (Figure 46). The mean condition factor was 0.99 ± 0.02 (SE) and the length(mm)-weight(g) relationship was:

$$W = 5.331 \times 10^{-6} L^{3.105} \text{ where } r^2 = 0.97,\ N = 44.$$

The majority of males were mature at age 4, although one 6-year-old

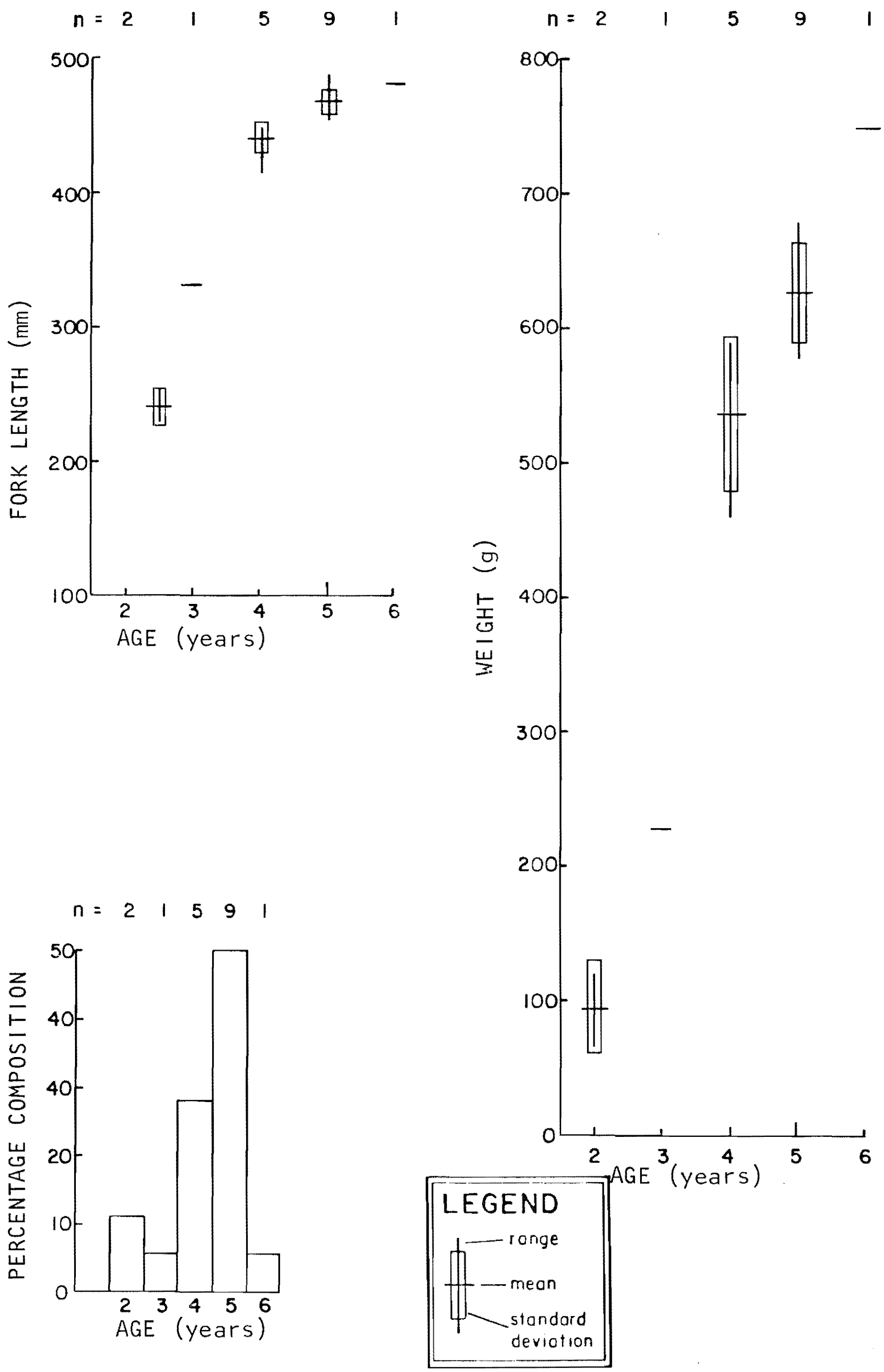

Figure 45. Age composition and age-growth relationships for northern pike from Unnamed Lake #6, September 1979.

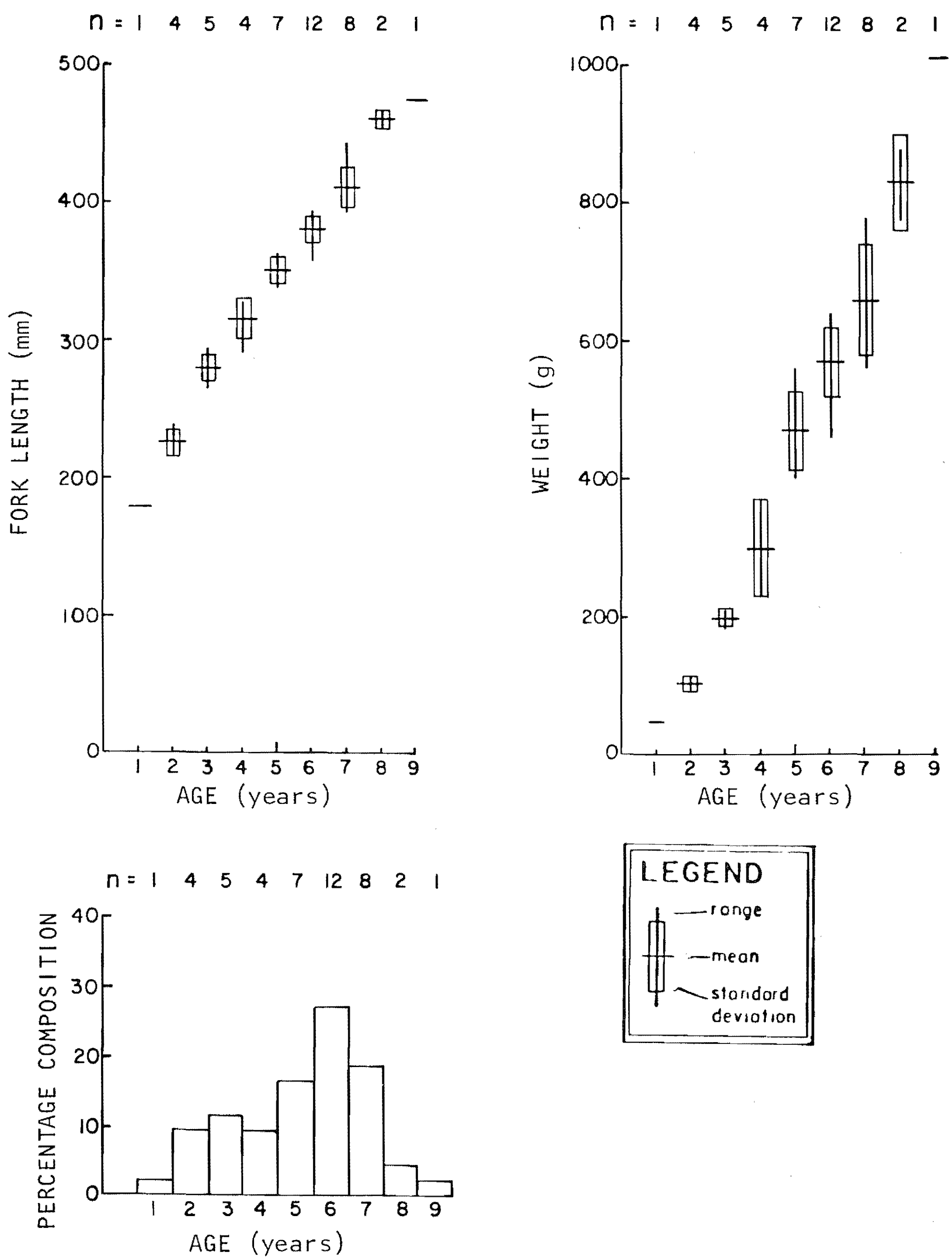

Figure 46. Age composition and age-growth relationships for walleye from Unnamed Lake #6, September 1979.

male was classed as immature. All females age 5 or older were mature, with the exception of two age 7 females that were classed as immature. It is possible that these may have been alternate year spawners. Forty-four walleye stomachs were examined for food contents. The major identifiable food items were ninespine stickleback and yellow perch (each present in one stomach). Ten stomachs contained unidentifiable fish remains and the remaining 32 were empty.

4.6.6.5 White Sucker. Seven of the 20 white sucker captured in gillnets were sampled for life history information. Length ranged from 265 to 340 mm and weight from 260 to 570 g. Five of the fish were 3 year olds (mean length of 279 mm) and the remaining two were 4 years of age (mean length of 327 mm).

4.6.6.6 Potential Production. Applying the regression equations developed by Ryder (1965) and Allan (1975), it was estimated that the harvestable fish production in Lake #6 was between 6.2 and 8.3 kg/ha/yr or between 720 and 970 kg/yr for the lake. Based on the percentage (by weight) of sportfish in the gillnet catch (78%), the harvestable sportfish production would be in the order of 560 to 760 kg/yr. Walleye and northern pike would make up the majority of the sportfish catch. Due to the apparent small size of yellow perch in the lake. this species likely would not contribute substantially to a sport fishery.

4.6.7 Discussion

The presence of large populations of walleye and northern pike in Lake #6 indicate a high potential for a sport fishery. Extensive development of aquatic vegetation around the periphery of the lake provides adequate spawning and rearing habitat for northern pike and many of the forage fish species. In addition, the presence of numerous gravel-rubble areas provides suitable spawning habitat for walleye, lake whitefish, and cisco. The apparent low numbers of cisco and whitefish in this lake may be due to heavy predation on the juveniles of these species by the abundant walleye and northern pike. It is doubtful that fish move from Lake #6 into Lake #5 due to the large beaver dam on the inlet channel; however, some fish may pass over the dam from Lake #5 into Lake #6. Any fish moving into Grayling Creek (the outlet stream from Lake #6) likely would not move back into the lake due to a large beaver dam at the outlet.

4.7 UNNAMED LAKE #7

4.7.1 Introduction

Lake #7 is located in Township 103, Range 7, West of the Fourth Meridian (57°55'N; 111°06'W). Its surface elevation is approximately 270.0 m above m.s.l. No significant inflow or outflow streams were noted during the survey. Extensive sand beaches are present around much of the lake, especially along the southeast shore. The surrounding terrain is covered with medium to dense growths of jack pine, although birch and other deciduous trees and shrubs are present in low-lying areas around the lake.

During the summer, the lake is accessible only by aircraft, but it is located within 1.5 km of the Fort McMurray-Fort Chipewyan winter road.

Sampling on the lake was conducted during the period 21 to 23 September 1979. The locations of sampling sites are shown in Figure 47.

4.7.2 Morphometry

Lake #7 has a surface area of 169.7 ha and an estimated volume of 3.6×10^6 m^3, giving it a mean depth of 2.1 m (Table 21). The maximum depth noted during 13 sounding transects was 6.0 m. It was recorded south of the island in the centre of the lake (Figure 48). The majority of the basin of the lake east of the island was less than 4 m deep. Only 5% of the surface area of the lake was greater than 4 m in depth. A shallow gravel and sand bar, generally

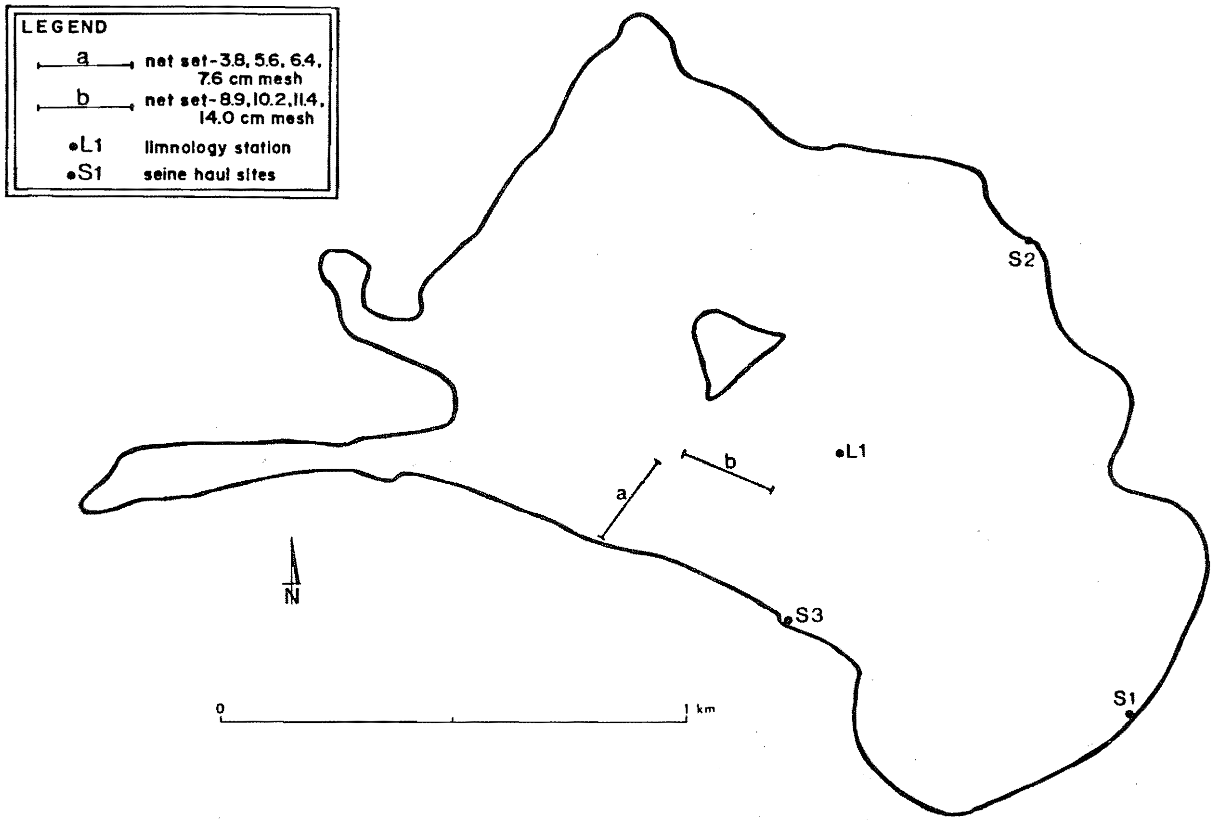

Figure 47. Sampling site locations in Unnamed Lake #7, September 1979.

Table 21. Morphometry of Unnamed Lake #7.

Location	Tp. 103, Rg. 7, W4
Surface area	169.7 ha
Volume	3.6×10^6 m^3
Shoreline length (excluding islands)	7.5 km
Shoreline development factor	1.6
Maximum length	2.3 km
Maximum effective length	2.3 km
Maximum width	1.4 km
Maximum effective width	1.4 km
Mean width	0.7 km
Maximum depth	6.0 m
Mean depth	2.1 m

Depth Distribution:

	ha	% Surface Area
Surface area	169.7	100
1 m+	145.4	86
2 m+	91.4	54
3 m+	35.6	21
4 m+	3.7	5
5 m+	1.7	1
6 m+	0.6	<1

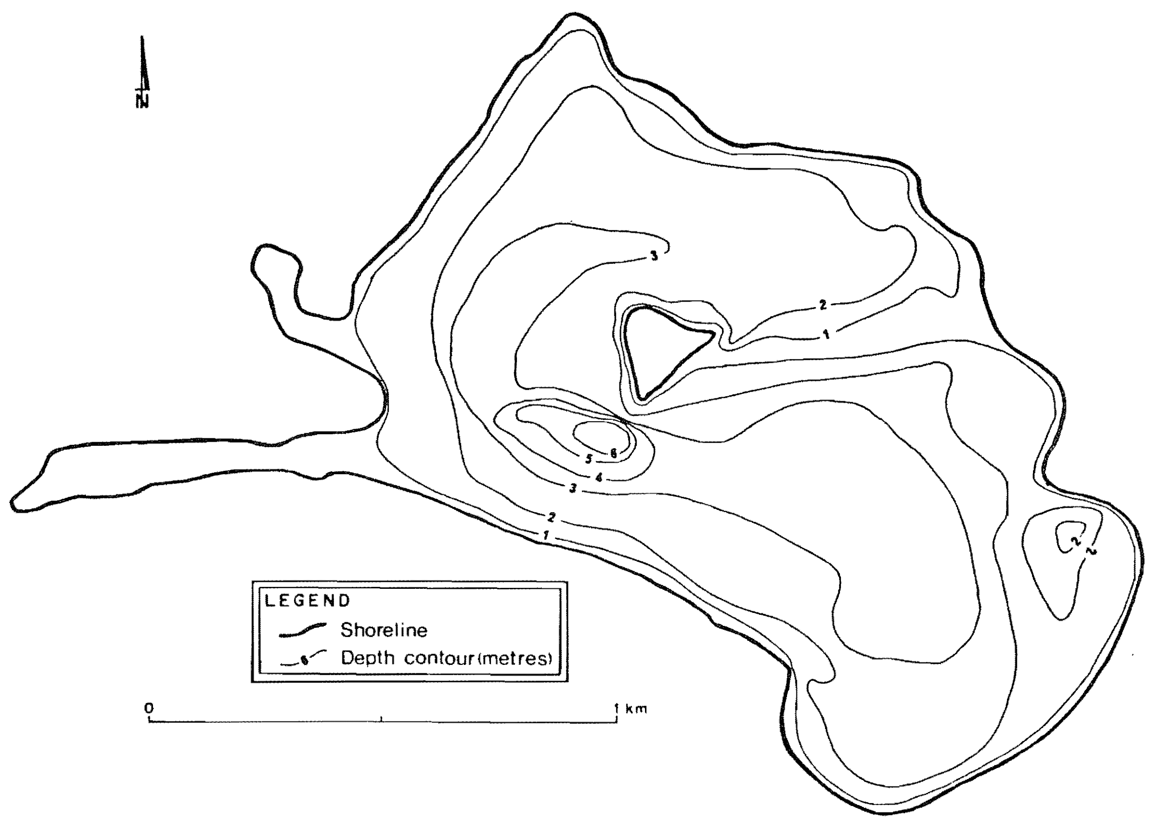

Figure 48. Bathymetric map of Unnamed Lake #7.

less than 1 m below the surface, extended from the island to the east shore of the lake. This area could be hazardous to boats on the lake, as it was too shallow in places for an outboard motor to pass over it.

The maximum length of the lake was 2.3 km, and the maximum width was 1.4 km. The total shoreline length was 7.5 km (excluding the island). A shoreline development factor of 1.6 was calculated; this indicates the presence of a highly regular shoreline.

4.7.3 Water Quality

The principal dissolved ions of Lake #7 were calcium and bicarbonate (Table 22), although the equivalent concentration of magnesium was only slightly lower than that of calcium. When sampled, total filterable residue was 114 mg/L, total alkalinity was 74 mg/L, and pH was 8.9. The lake was isothermal and well oxygenated (Figure 49), and the water was fairly clear and uncoloured.

4.7.4 Substrate

Approximately 69% of the lake area had an organic/silt substrate or a thick layer of silt or organic material over a sand bottom (Figure 50). This organic/silt bottom was orange to light brown in colour. In some areas, such as the bays at the west end of the lake, it was very flocculent and over 2.5 m in depth (i.e., a pole could be pushed easily into the bottom material). Sand substrate, or a thin layer of organic/silt over hard sand, accounted for approximately 18% of the bottom cover; gravel or rubble contributed 13%. A large area of sand and gravel-rubble extended from the island to the west shore. Other large gravel or rubble areas were present along the southwest and northwest shores of the lake.

4.7.5 Aquatic Vegetation

The sand and gravel-rubble beach areas along the east end of the lake were highly exposed to wave action and had very little aquatic vegetation (Figure 51). Aquatic vegetation was abundant along

Table 22. Water quality analyses for Unnamed Lake #7.

23 September 1979	Site L1			
Na	1.4	mg/L	0.061	meq/L
K	0.7	mg/L	0.02	meq/L
Ca	16.4	mg/L	0.818	meq/L
Mg	8.3	mg/L	0.68	meq/L
SO_4	4.9	mg/L	0.10	meq/L
Cl	2.4	mg/L	0.068	meq/L
CO_3	10	mg/L	0.32	meq/L
HCO_3	71	mg/L	1.2	meq/L
Alkalinity				
Total	74	mg/L ($CaCO_3$)	1.48	meq/L
P'thalein	8	mg/L ($CaCO_3$)		
pH (pH units)	8.9			
Hardness, total (as $CaCO_3$)	75.2	mg/L		
Total filterable residue				
Evap. @ 105°C	114	mg/L		
Ignit. @ 550°C	50	mg/L		
Conductivity	138	µS/cm		
Turbidity	2	NTU		
Total P	<0.016	mg/L		
Ammonia-N	0.2	mg/L		
Reactive silica	3.1	mg/L		
Total organic carbon	6.3	mg/L		
Fe (total)	0.08	mg/L		

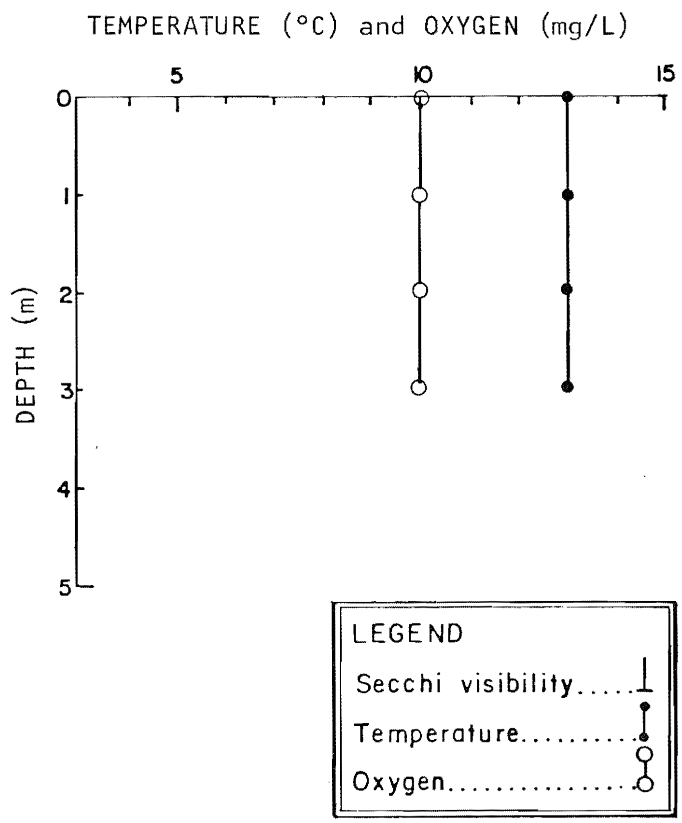

Figure 49. Temperature, dissolved oxygen, and Secchi visibility in Unnamed Lake #7, Site L1, 23 September 1979.

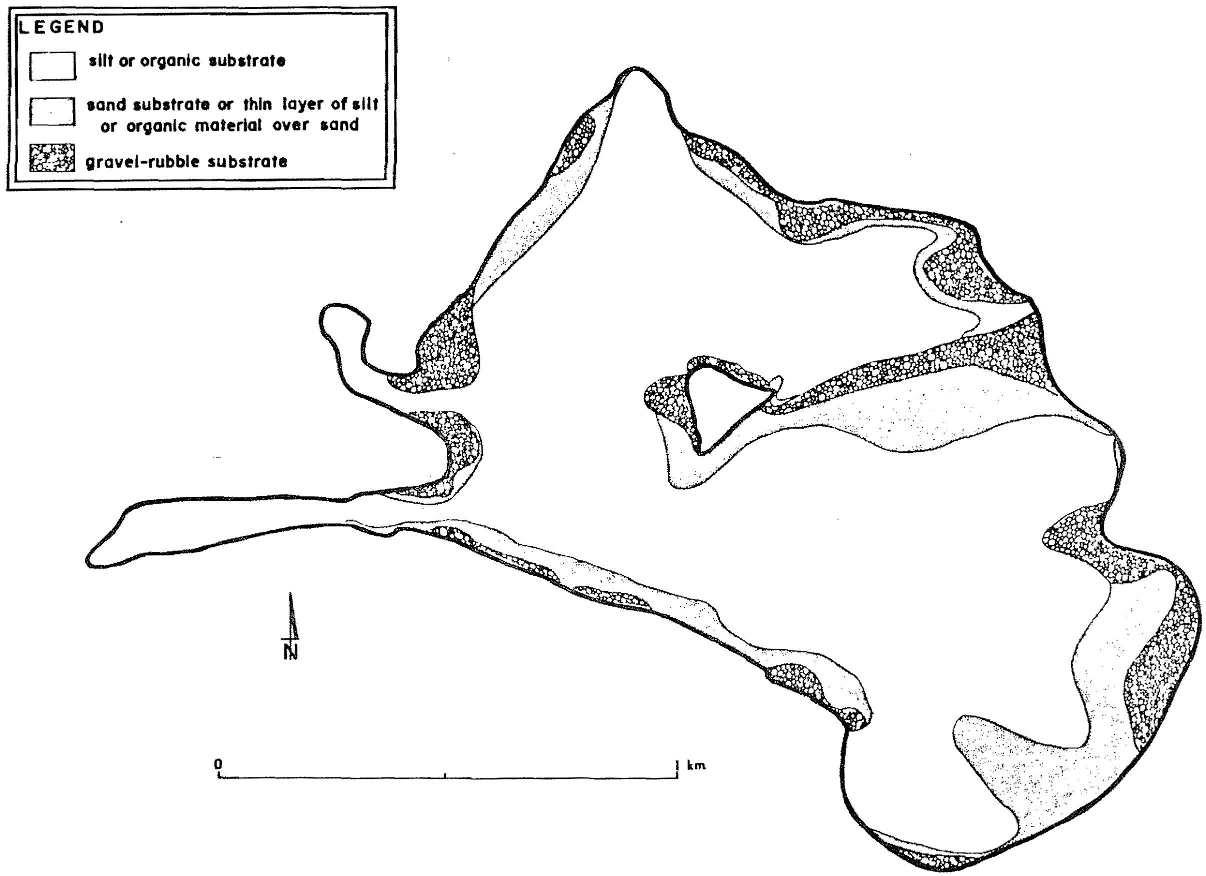

Figure 50. Approximate distribution of surficial lake sediment types in Unnamed Lake #7.

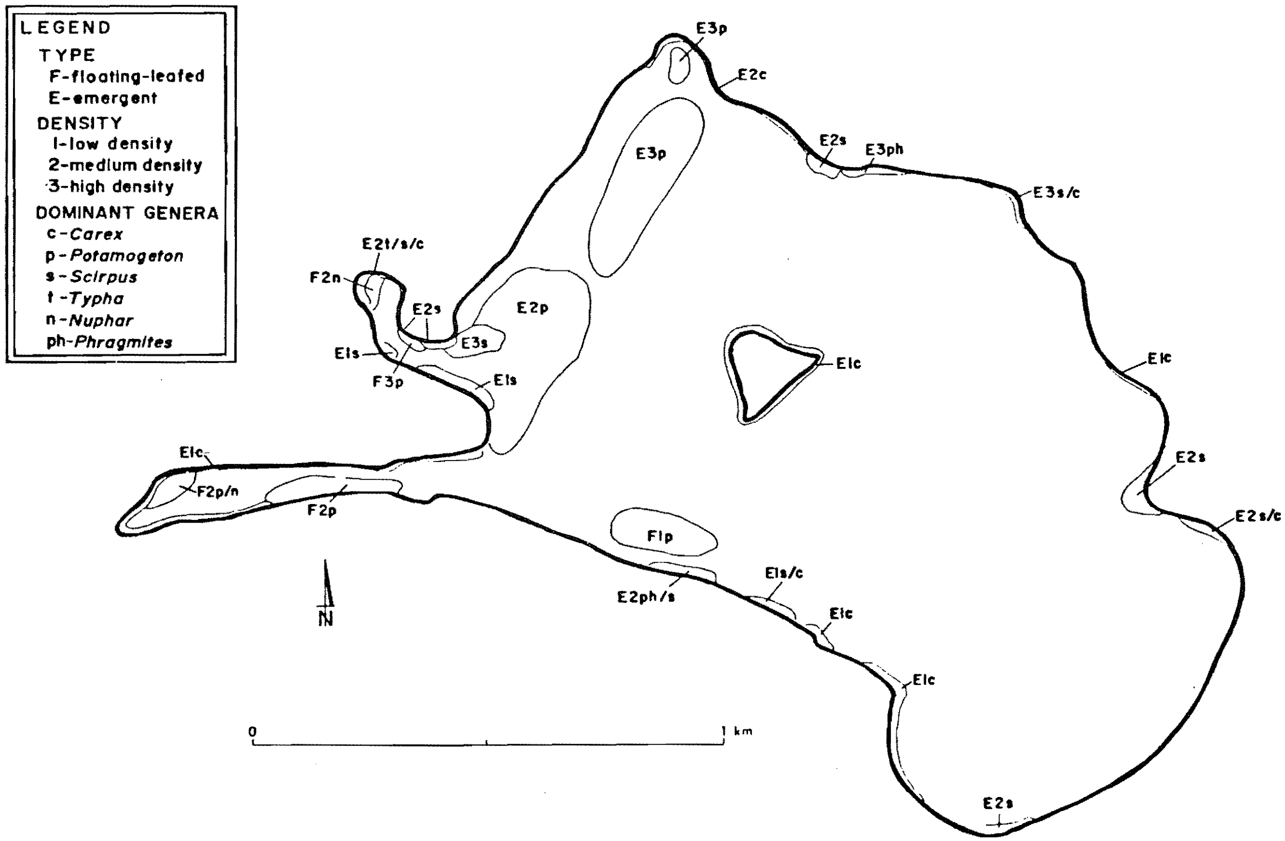

Figure 51. Approximate distribution of aquatic vegetation in Unnamed Lake #7.

the west and north shores of the lake, especially in the two protected bays on the west end. *Carex* and *Scirpus* were the predominant emergents, although *Typha* and *Phragmites* were also abundant in localized areas. *Nuphar* and *Potamogeton* were the predominant genera of floating-leafed plants and were most common in the west end of the lake.

4.7.6 Fish

Only two species of fish were captured in one overnight gillnet set (Table 23). Lake whitefish constituted 81% of the total catch of 130 fish; northern pike made up the remainder of the catch. In three seine hauls, only seven Iowa darter were captured; all were taken in one haul along the southwest shore. No other fish species were observed in the lake, or in the stomach contents of northern pike and lake whitefish.

4.7.6.1 Lake Whitefish. Of the 105 lake whitefish captured in the gillnets, 69 were sampled for life history information. Length ranged from 186 to 423 mm and weight from 75 to 1050 g. Age ranged from 2 to 9 years, with age 6 fish being predominant (22%) (Figure 52). The growth rate of lake whitefish was low [i.e., mean length of only 258.5 mm reached by age 4 (n = 12)].

The mean condition factor of sampled fish was 1.33 ± 0.02 (SE), indicating that they were in fair physical condition. The regression equation relating weight (g) to length (mm) was:

$$W = 3.194 \times 10^{-6} L^{3.249} \text{ where } r^2 = 0.97, N = 69.$$

Of the 31 males sampled, all were mature at age 4; of the 36 females sampled, only five out of eight of the 4-year-olds were mature. All age 5 females were mature. One of the 6-year-old fish collected was classed as being immature, but this individual may have been an alternate year spawner.

Sixty-eight lake whitefish stomachs were examined for food contents. The primary food items were Corixidae (31 stomachs),

Table 23. Test net results for Unnamed Lake #7.

Date Set	Duration of Set (h)	Water Depth (m)	Mesh Size (cm)	Species and Number		Total
				Lake Whitefish	Northern Pike	
21 September 1979	14.5	1.0	3.8	26	6	32
			5.1	25	7	32
			6.4	17	3	20
		4.0	7.6	14	3	17
		4.0	8.9	12	4	16
			10.2	6	2	8
			11.4	5	0	5
		4.0	14.0	0	0	0
Total				105	25	130

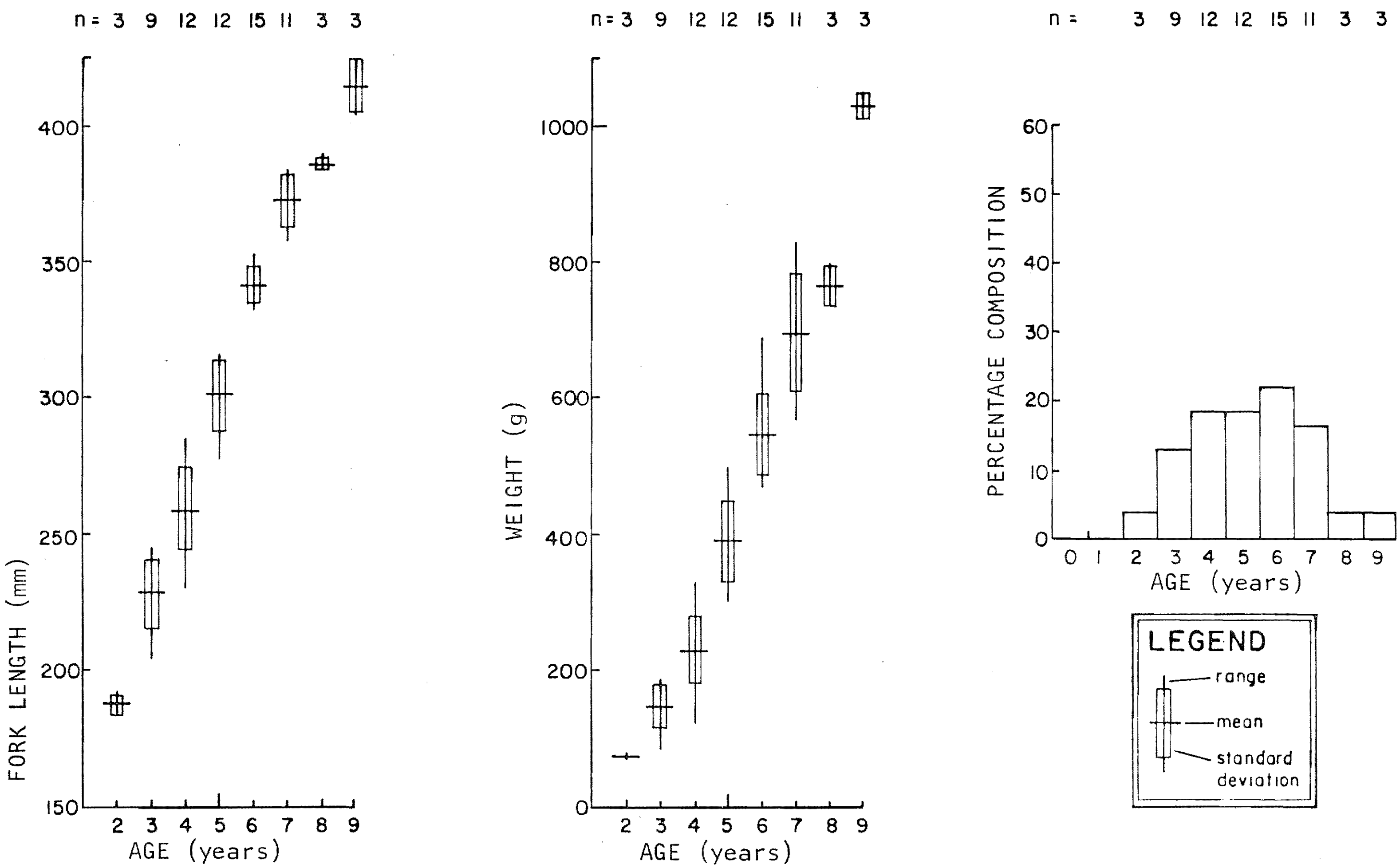

Figure 52. Age composition and age-growth relationships for lake whitefish from Unnamed Lake #7, September 1979.

Gastropoda (12 stomachs), Trichoptera larvae (10 stomachs), and unidentifiable fish remains (five stomachs). Other food items included Pelecypoda, Amphipoda, Chironomidae pupae, zooplankton, and one Hirudinea. Only 12 of the stomachs examined were empty and the majority of the stomachs were over half full. This suggests the presence of an abundant supply of food organisms in the lake at the time of sampling.

Twenty-six lake whitefish were sampled to determine the infestation rate of *Triaenophorus crassus*. Twenty-two of the fish (85%) were infected with a total of 154 plerocercoids, giving an infestation rate of 425 cysts/45.4 kg of fish. Due to the high infestation rate, the lake whitefish in this lake would have little commercial value.

4.7.6.2 Northern Pike. All 25 northern pike captured in the gillnet set were sampled for life history information. Length ranged from 405 to 836 mm and weight from 460 to 3290 g. Age varied from 4 to 12 years, although no age 5 fish were present (Figure 53). Thirty-six percent of the sample was composed of age 9 fish. All of the 12 females in the sample were 8 years of age or older. No males over 8 years of age were taken. The mean condition factor of the sample was 0.68 ± 0.01 (SE), and the length(mm)-weight(g) relationship was:

$$W = 3.318 \times 10^{-5} L^{2.753} \text{ where } r^2 = 0.97, N = 25.$$

All the northern pike captured were mature.

All 25 northern pike stomachs were examined for food contents. Food items identified included lake whitefish (two stomachs) and Iowa darter (four stomachs); one stomach contained one Hirudinea, along with unidentifiable fish remains. Eighteen of the 25 stomachs examined were empty. It appears, on the basis of these survey data, that only a limited number of forage species were available to northern pike.

Under normal conditions, lake whitefish are not heavily preyed upon by northern pike (Rawson 1951; Lawler 1965); however,

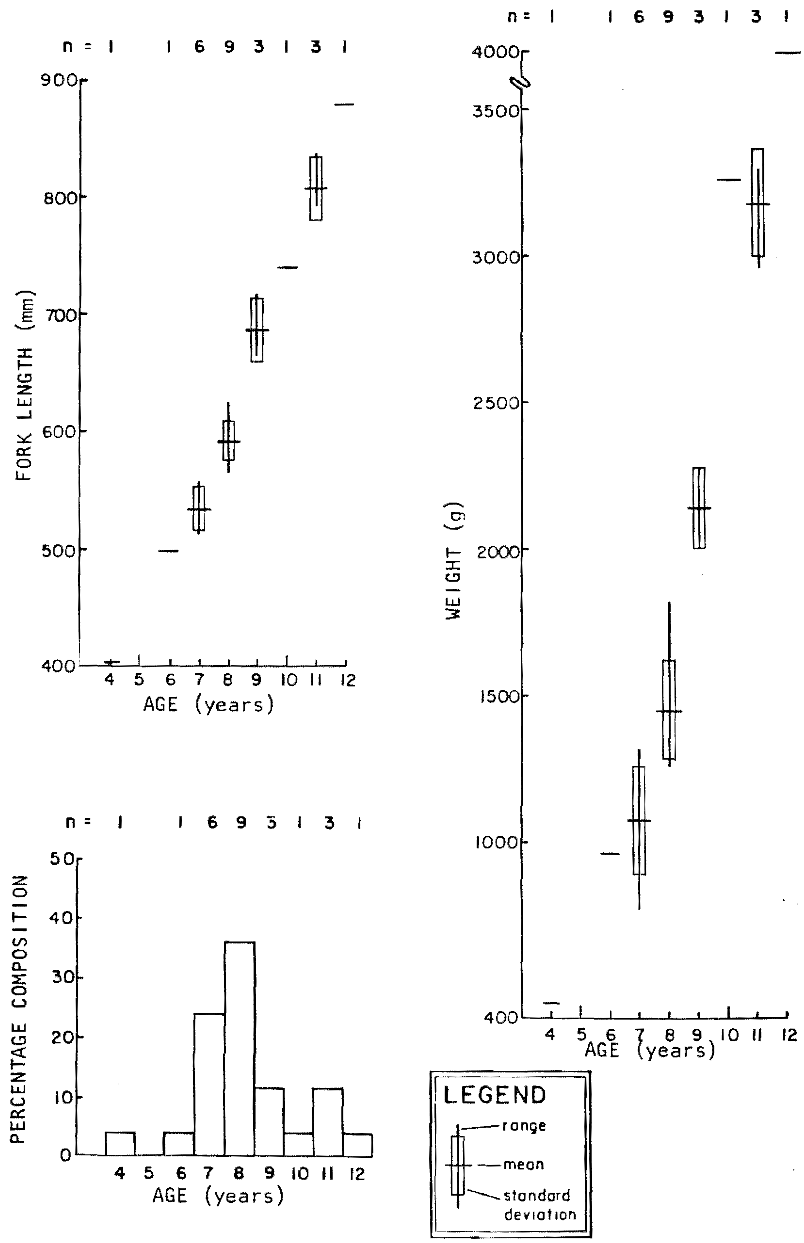

Figure 53. Age composition and age-growth relationships for northern pike from Unnamed Lake #7, September 1979.

because of the abundance of whitefish in the lake and due to the scarcity or absence of other preferred prey species (e.g., yellow perch or stickleback), lake whitefish are likely an important component of the pike diet.

4.7.6.3 Potential Production. Applying the regression equations developed by Ryder (1965) and Allan (1975), the harvestable fish production in Lake #7 was estimated to be between 8.2 and 10.9 kg/ha/yr. This represents an estimated total harvestable fish production of between 1390 and 1850 kg/yr. Based on the percentage of sportfish (by weight) in the gillnet catch (48%), it was estimated that the harvestable sportfish production would be in the order of 670 to 890 kg/yr for the lake.

4.7.7 Discussion

The presence of sand beaches, clear water, and surrounding jackpine forests make this lake attractive from a recreation viewpoint. However, due to the presence of only one sportfish species, northern pike, this lake has only a moderate sportfish potential. Adequate spawning and rearing habitat exists for northern pike, primarily in the west end of the lake; however, the presence of a high proportion of older fish in the lake, along with the small size and shallow nature of the lake, makes the pike population susceptible to overfishing. It also appeared that food supply for the pike may be limited. This may increase the vulnerability of the pike to angling. Some management options that exist for this lake include possible stocking with suitable forage species (after further investigation to be sure they are not already present) and stocking with walleye to provide alternative angling opportunities. Extensive gravel-rubble areas suitable for walleye spawning are present in the lake. If such introductions were successful, a more diverse sport fishery could be developed.

4.8 UNNAMED LAKE #8

4.8.1 Introduction

Lake #8 is located in Township 102, Range 7, West of the Fourth Meridian (57°50'N; 111°09'W). The surface elevation is approximately 289.9 m above m.s.l. The lake consists of two main basins connected by a narrow channel about 0.7 km long. A very large beaver dam was situated on this channel, near the eastern basin. It maintained a higher lake level in the eastern basin (i.e., approximately 0.7 m higher than the west basin). A small tributary enters the east basin along the southeast shore. Within the lower 75 m of this stream, the channel was 6 to 8 m wide and up to 1.5 m deep. There was no noticeable flow at the time of sampling. An outlet stream, flowing from the north end of the west basin, flows northward to Grayling Creek. This stream was 2.0 to 2.5 m in width and up to 1.5 m in depth; the bottom was composed of sand and rubble.

No beach areas were present around the lake; rather, the water depth increased almost immediately to 0.5 m. The banks were generally steep and vegetated with trees and shrubs to the edge of the water. Exceptions to this were the marshy areas located along the northern periphery of the east basin and along the connecting channel between the two basins. The surrounding terrain is forested with medium to low density growths of jack pine or white spruce (Intera Environmental Consultants Ltd. 1979). Birch and willow were common along the lake shore.

During the summer, the lake is accessible only by aircraft; however, it is location within 0.2 km of the Fort McMurray-Fort Chipewyan winter road.

Sampling in the lake was conducted during the period 23 to 25 September 1979. The locations of the sampling sites are shown in Figure 54.

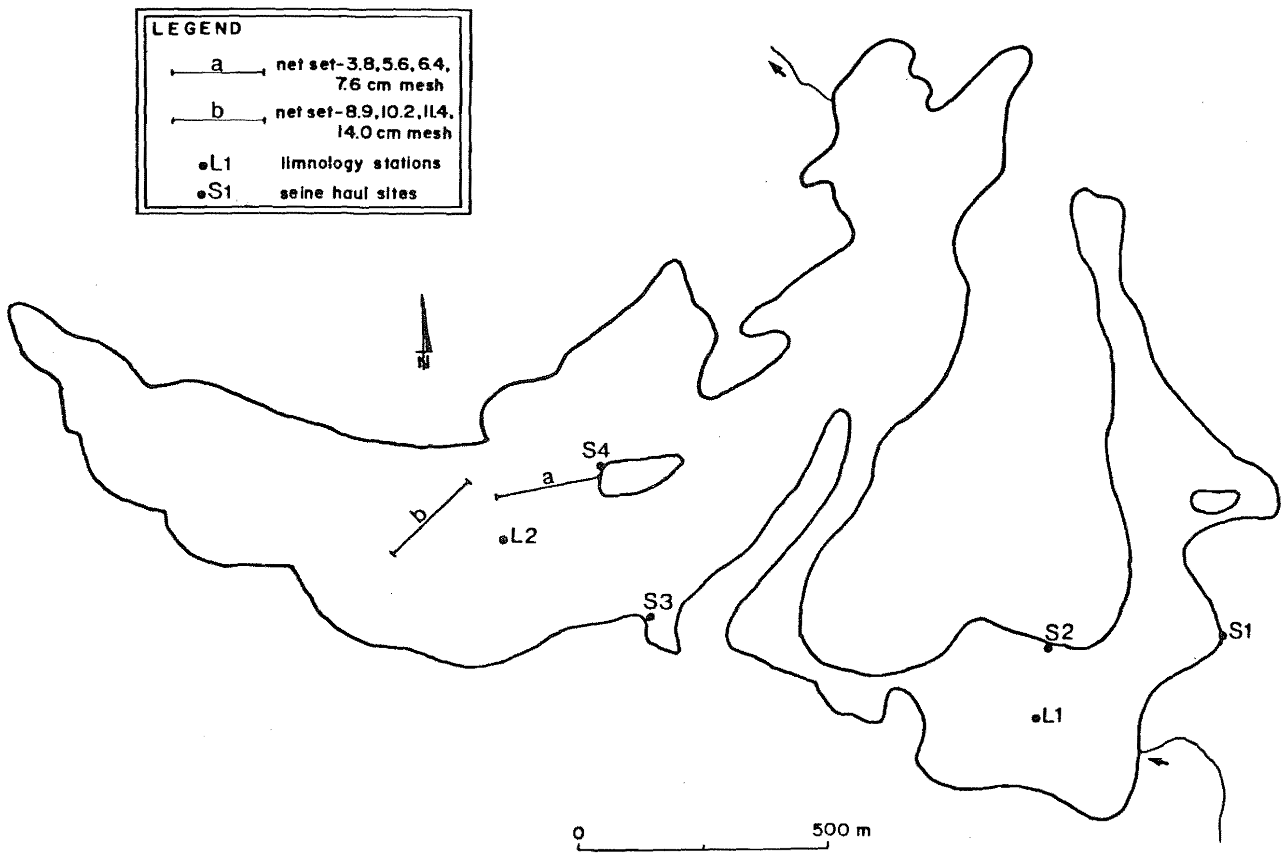

Figure 54. Sampling site locations in Unnamed Lake #8, September 1979.

4.8.2 Morphometry

Lake #8 has a surface area of 112.2 ha and an estimated volume of 4.3×10^6 m^3, giving it a mean depth of 3.8 m (Table 24). The maximum depth noted along 33 sounding transects was 8.3 m. This depth was recorded southwest of the island in the west basin (Figure 55). The maximum depth recorded in the east basin was 4.8 m. Approximately 53% of the surface area of the lake was deeper than 4 m.

The maximum length of the lake (using both basins) was calculated to be 4.0 km; however, the maximum effective length was only 1.4 km. The maximum width and the maximum effective width were 0.7 and 0.6 km, respectively. The total shoreline length (not including islands) was 12.2 km. A shoreline development factor of 3.2 was calculated; this indicates the presence of a highly irregular shoreline.

4.8.3 Water Quality

Water samples were collected in the two main basins of Lake #8. Both basins had vertically uniform oxygen and temperature distributions, although the east basin had a lower oxygen saturation (about 80%) than the west basin (about 90%) (Figure 56). Water was fairly clear in each basin. The solute content of each basin was also similar, with calcium and bicarbonate being the main ions (Table 25). This lake had a total alkalinity of about 80 mg/L and a total filterable residue of about 100 mg/L. Site L1, in the east basin, was the only site in the present study which had a concentration of total phosphorus (0.026 mg/L) greater than the analytical detection limit.

4.8.4 Substrate

Approximately 70% of the lake bottom consisted of silt, 21% sand (or thin layer of silt over sand), and 9% gravel or rubble (Figure 57). Sand or gravel-rubble was present near shore around most of the lake. An extensive gravel-rubble reef was noted in the northern part of the west basin.

Table 24. Morphometry of Unnamed Lake #8.

Location		Tp. 102, Rg. 7, W4
Surface area		112.2 ha
Volume		4.3×10^6 m^3
Shoreline length (excluding islands)		12.2 km
Shoreline development factor		3.2
Maximum length		4.0 km
Maximum effective length		1.4 km
Maximum width		0.7 km
Maximum effective width		0.6 km
Mean width		0.3 km
Maximum depth		8.3 m
Mean depth		3.8 m
Depth Distribution:		
	ha	% Surface Area
Surface area	112.2	100
2 m+	83.4	74
4 m+	59.7	53
6 m+	25.3	22
8 m+	6.7	6

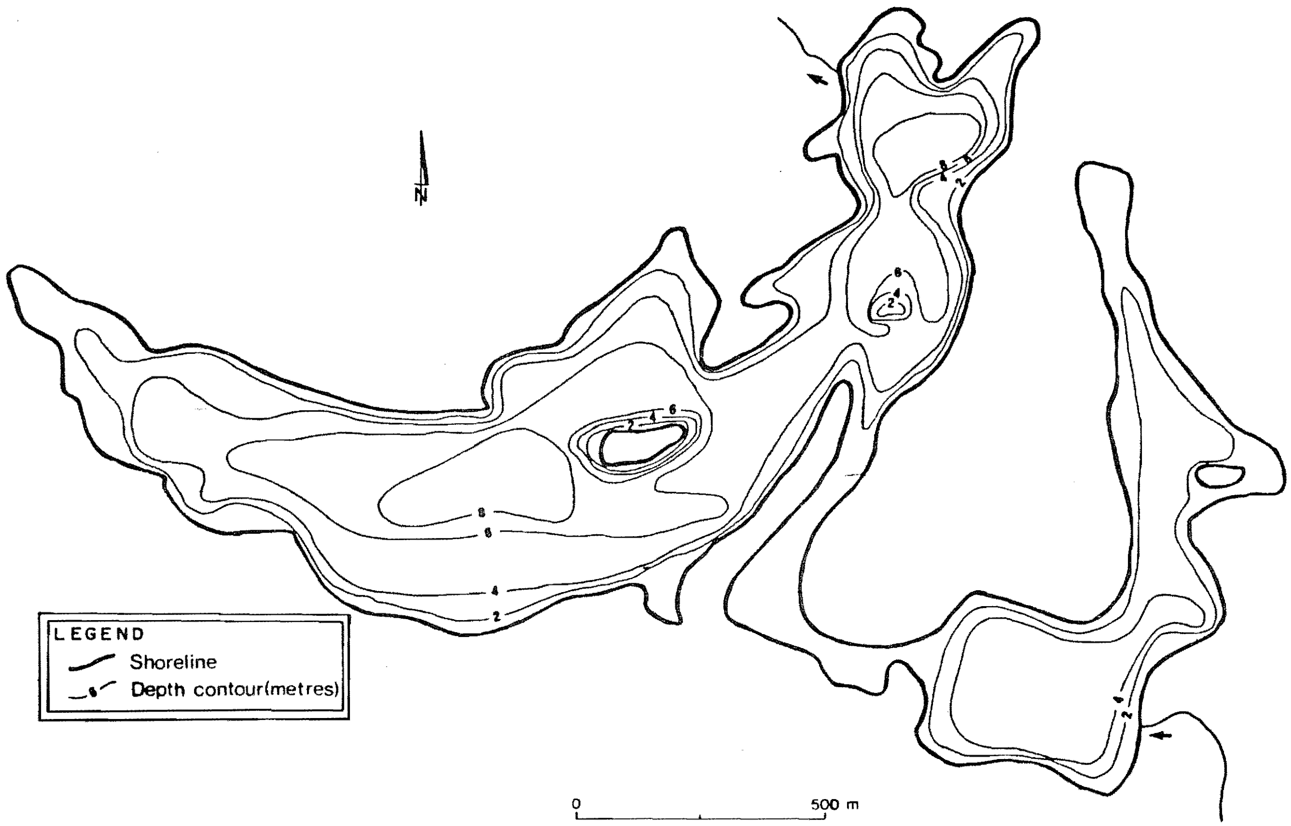

Figure 55. Bathymetric map of Unnamed Lake #8.

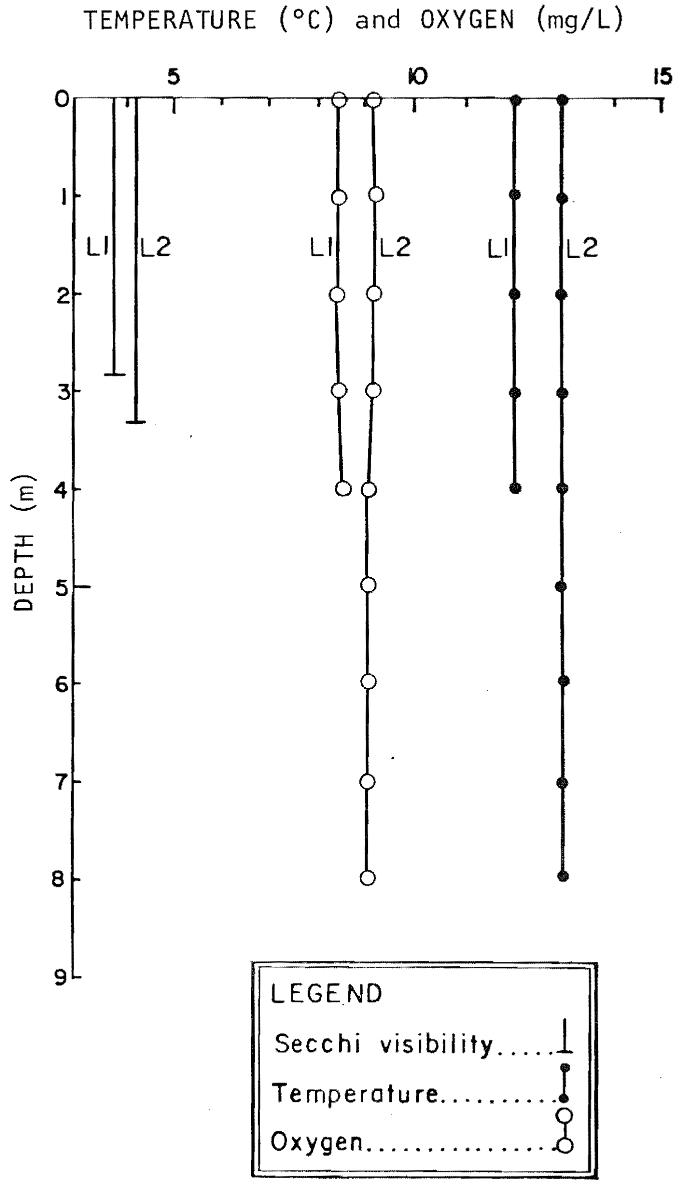

Figure 56. Temperature, dissolved oxygen, and Secchi visibility in Unnamed Lake #8, Site L1 and L2, 25 September 1979.

Table 25. Water quality analyses for Unnamed Lake #8.

	Site			
	L1		L2	
25 September 1979	mg/L[a]	meq/L	mg/L[a]	meq/L
Na	1.3	0.057	1.1	0.048
K	0.9	0.02	0.9	0.02
Ca	19.4	0.968	21.7	1.08
Mg	7.5	0.62	8.4	0.69
SO_4	7.4	0.15	9.9	0.21
Cl	2.2	0.062	2.2	0.062
CO_3	0	0	0	0
HCO_3	93	1.5	101	1.66
Alkalinity				
Total (mg/L $CaCO_3$)	76	1.52	83	1.66
P'thalein (mg/L $CaCO_3$)	0		0	
pH (pH units)	7.5		8.1	
Hardness, total (as $CaCO_3$)	79.3		88.8	
Total filterable residue				
Evap. @ 105°C	98		109	
Ignit. @ 550°C	44		49	
Conductivity	149 µS/cm		160 µS/cm	
Turbidity	2.5 NTU		2 NTU	
Total P	0.026		<0.016	
Ammonia-N	0.08		0.07	
Reactive silica	7.1		6.7	
Total organic carbon	6.4		10.3	
Fe (total)	0.26		0.11	

[a] Values expressed as milligrams per litre unless indicated otherwise.

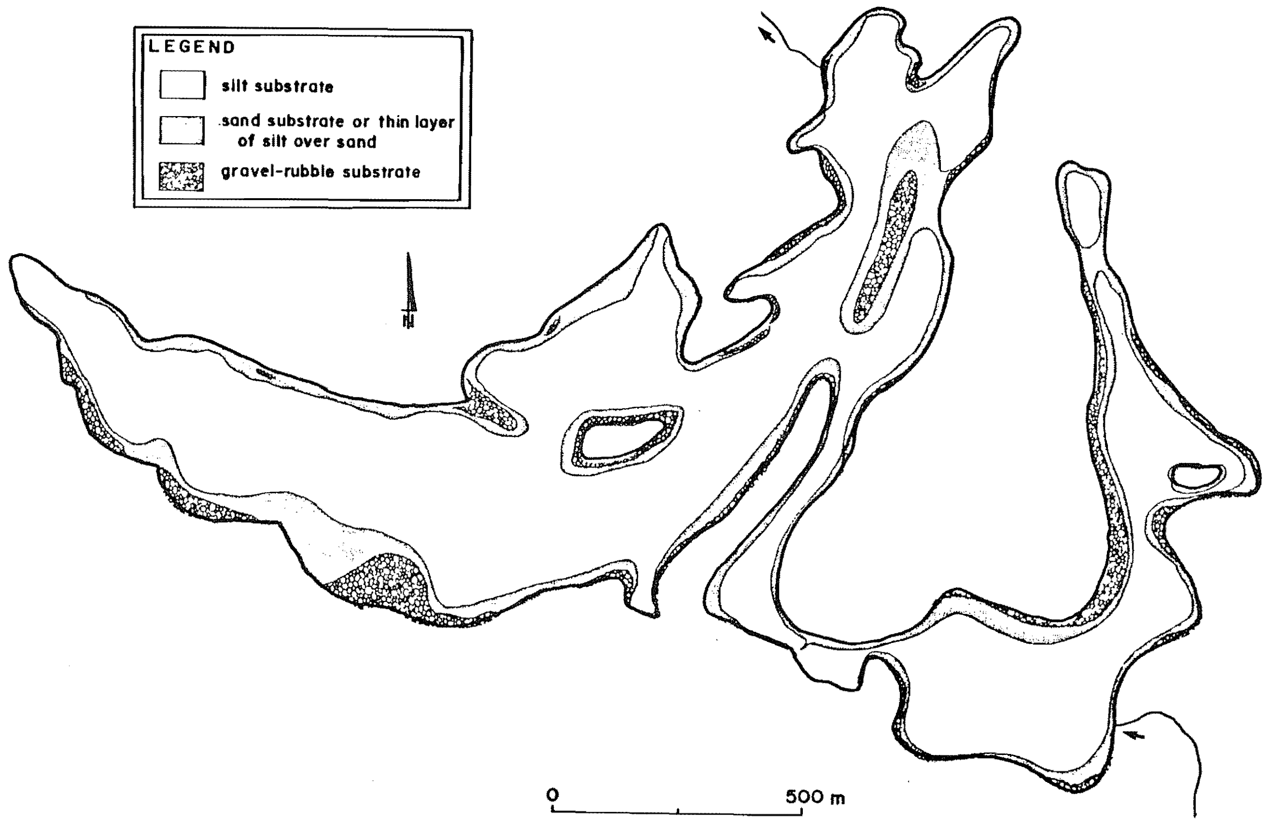

Figure 57. Approximate distribution of surficial lake sediment types in Unnamed Lake #8.

4.8.5 Aquatic Vegetation

Extensive growths of emergent and floating-leafed vegetation were present around most of the shoreline of the lake (Figure 58). Major genera of emergents included *Carex, Phragmites, Scirpus, Equisetum,* and *Typha*. *Nuphar* was very abundant in this waterbody and was the dominant floating-leafed plant. Two other floating-leafed plants, *Potamogeton* and *Sparganium,* were present in only a few areas.

4.8.6 Fish

Only one overnight gillnet set was conducted in Lake #8 and two species of fish were captured (Table 26). Northern pike made up 97% of the catch, with only two white sucker being taken. Two additional species were captured in the four seine hauls taken around the lake. Twenty-five yellow perch, six white sucker, and approximately 60 Iowa darter were captured in two hauls in the east basin; 13 yellow perch and one northern pike were taken in two hauls in the west basin. Spottail shiner were also present in the lake, as indicated by their occurrence in northern pike stomach contents.

4.8.6.1 Northern Pike. Of the 61 northern pike taken in the gillnet set, 49 were sampled for life history information. Length ranged from 157 to 573 mm and weight from 30 to 1330 g. The individual that weighed 1330 g had eaten a northern pike that measured 200 mm in length. The ages of the pike sampled varied between 1 and 8 years, with 46% of the fish being age 6 (Figure 59). Northern pike in this lake appeared to be slow growing, reaching a mean length of only 460.9 mm by age 6. This was likely a reflection of a large population size with only a limited abundance of forage fish available.

The mean condition factor of the grouped sample was 0.63 ± 0.01 (SE) and the length(mm)-weight(g) relationship was:

$$W = 2.894 \times 10^{-5} L^{2.749} \text{ where } r^2 = 0.97, N = 49.$$

All of the males age 5 or older were mature, while all of the females 4 years of age and older were mature.

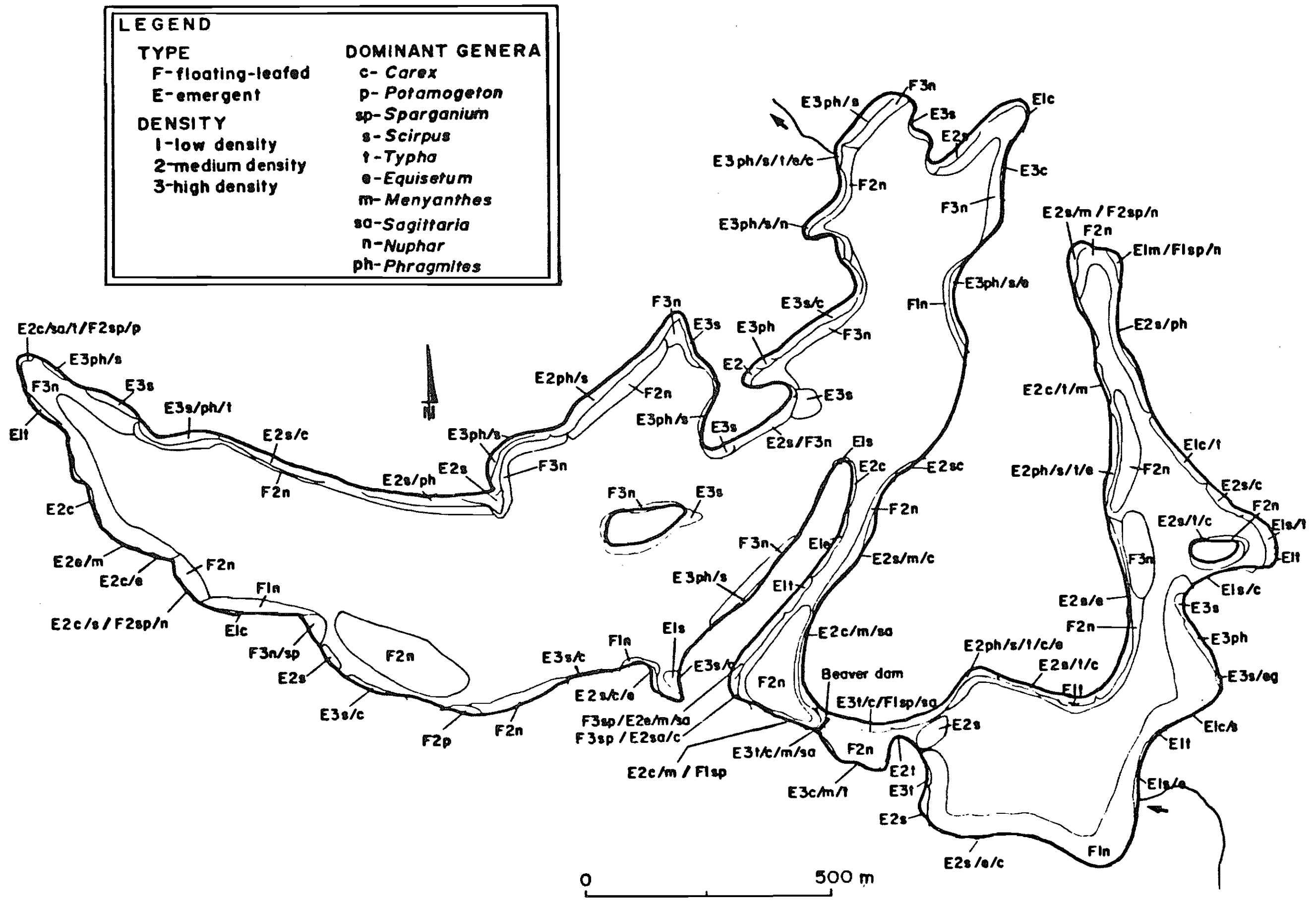

Figure 58. Approximate distribution of aquatic vegetation in Unnamed Lake #8.

Table 26. Test net results for Unnamed Lake #8.

Date Set	Duration of Set (h)	Water Depth (m)	Mesh Size (cm)	Species and Number		Total
				Northern Pike	White Sucker	
23 September 1979	13	1.0	3.8	12	1	13
			5.1	16	0	16
			6.4	20	0	20
		7.0	7.6	12	0	12
		8.0	8.9	1	1	2
			10.2	0	0	0
			11.4	0	0	0
		8.0	14.0	0	0	0
Total				61	2	63

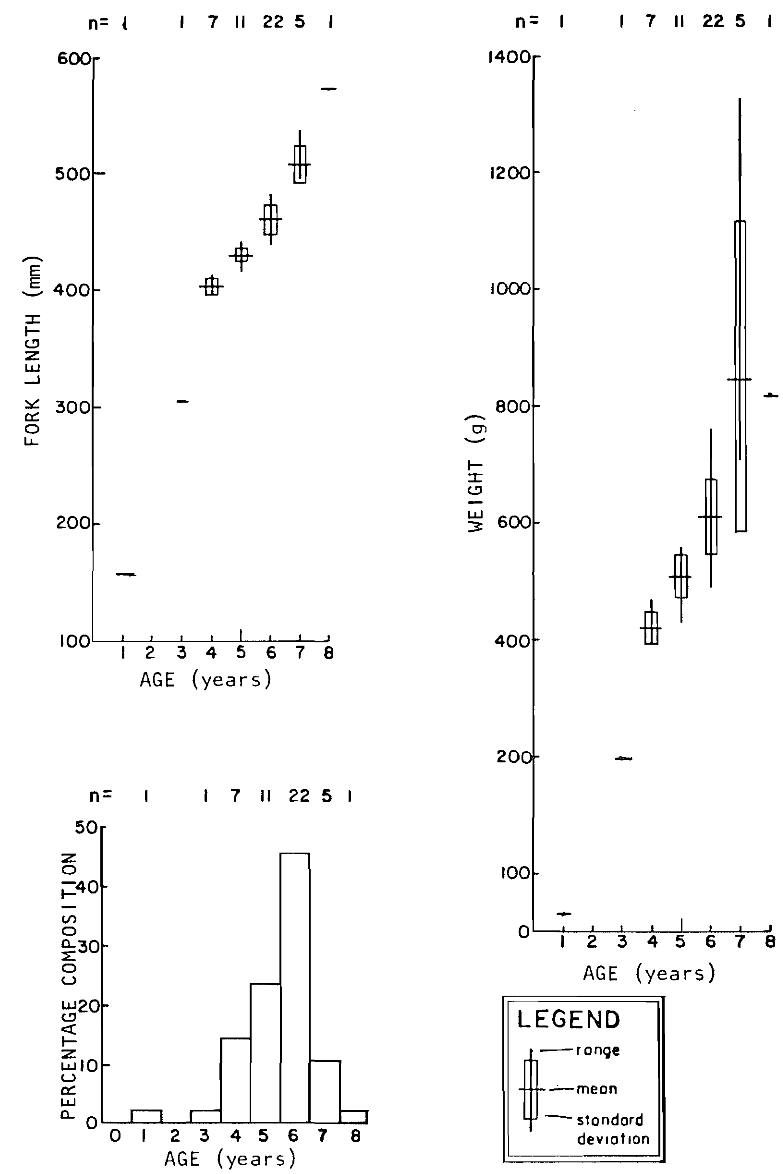

Figure 59. Age composition and age-growth relationships for northern pike from Unnamed Lake #8, September 1979.

4.8.6.2 Yellow Perch. Thirty-eight yellow perch captured by seining, and one taken from a northern pike stomach, were sampled for life history information. Length ranged from 56 to 125 mm and weight from 2 to 20 g. Age, as determined from scale samples, varied from 2 to 4 years, with age 2 fish being predominant (64% of the sample). The mean lengths for 2-, 3-, and 4-year-old fish were 62.5, 90.8, and 115.7 mm, respectively. Mean weights for these age-classes were 2.6, 8.6, and 17.0 g, respectively. The mean condition factor was 1.08 ± 0.02 (SE) and the length(mm)-weight(g) regression was:

$$W = 5.202 \times 10^{-6} L^{3.169} \text{ where } r^2 = 0.96; N = 39.$$

The majority of males were mature at age 3, whereas most of the females were not mature until age 4.

4.8.6.3 White Sucker. Only two white sucker were captured in gill-nets. A 2 year old immature individual measured 196 mm in length and weighed 77 g and a 5-year-old mature male measured 433 mm in length and weighed 1130 g. None of the six individuals captured by seining was measured, but all appeared to be juveniles.

4.8.6.4 Potential Production. Applying the regression equations developed by Ryder (1965) and Allan (1975), the harvestable fish production in Lake #8 was estimated to be between 6.0 and 8.1 kg/ha/yr or between 670 to 910 kg/yr for the lake. Based on the percentage (by weight) of sportfish in the gillnet catch (97%), the harvestable sportfish production would be in the order of 650 to 880 kg/yr. Northern pike would likely be the only species contributing to the sportfish catch.

4.8.7 Discussion

Despite the presence of a large population of northern pike, small individual sizes and slow growth rate would limit the sport fishery potential. Harvesting a portion of the pike population may reduce competition for food and thereby increase growth rate and size.

This would increase the desirability of the pike as a sportfish. Spawning habitat for northern pike and perch in this lake appears to be adequate.

4.9 UNNAMED LAKE #9 (DUROCHER LAKE)

4.9.1 Introduction

Lake #9, locally called Durocher Lake, is located in Township 103, Range 6, West of the Fourth Meridian (57°59'N; 110°56'W). An outlet located on the southeast end of the lake drains to a large slough situated to the east. This slough, in turn, flows into the Richardson River, a direct tributary to the Athabasca River. The lake outlet was controlled by a beaver dam; no flow was detected in the outlet channel at the time of sampling. The channel was approximately 3.5 m wide and had a depth of approximately 0.7 m. No significant inlet streams were located.

The surrounding terrain is covered with a medium density jackpine forest, although some deciduous trees were present. Birch is common along much of the immediate shoreline of the lake. Sparsely treed sand hills are present along the southwestern periphery of the lake.

During the summer, this waterbody is accessible only by aircraft; however, it is located within 6 km of the Fort McMurray-Fort Chipewyan winter road.

Sampling of the lake was conducted during the period 15 to 17 September 1979. The locations of sampling sites are shown in Figure 60.

4.9.2 Morphometry

Lake #9 has a surface area of 215.1 ha and an estimated volume of 1.1×10^7 m^3, giving it a mean depth of 5.1 m (Table 27). The maximum depth noted during a total of 15 sounding transects was 10.5 m. This depth was recorded in the eastern basin of the lake (Figure 61). Approximately 63% of the surface area was greater than 4 m in depth.

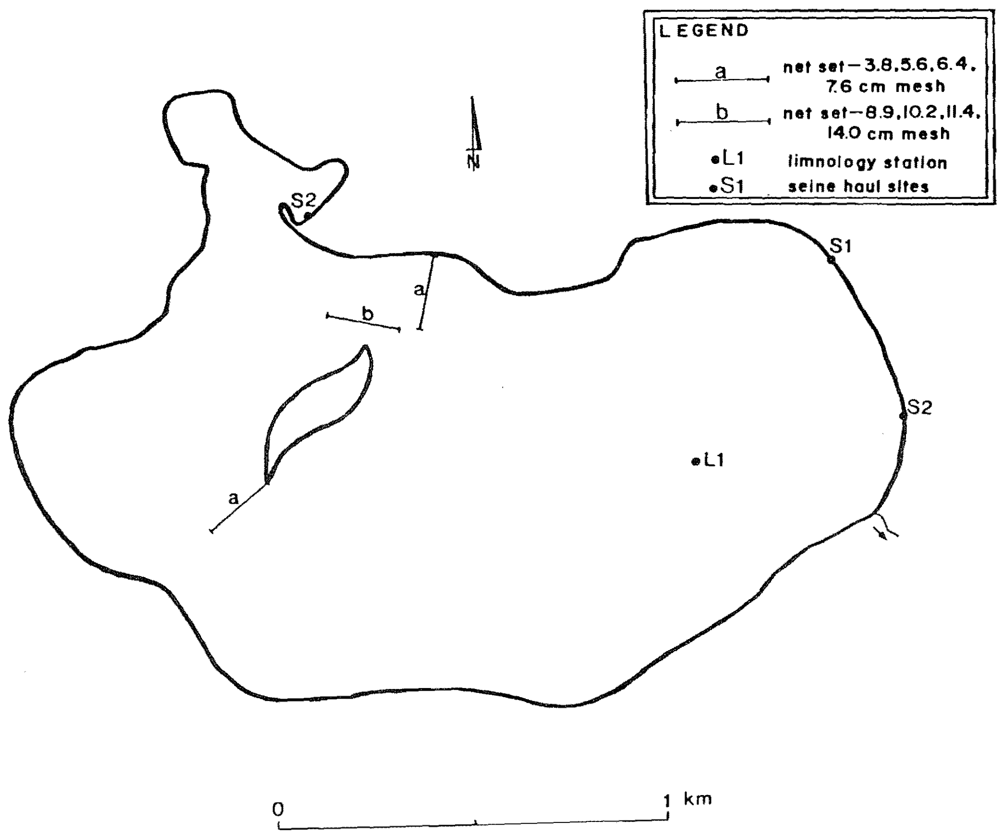

Figure 60. Sampling site locations in Unnamed Lake #9, September 1979.

Table 27. Morphometry of Unnamed Lake #9.

Location		Tp. 103, Rg. 6, W4
Area		215.1 ha
Volume		1.1 x 10^7 m^3
Shoreline length		7.0 km
Shoreline development factor		1.4
Maximum length		2.3 km
Maximum effective length		2.1 km
Maximum width		1.1 km
Maximum effective width		1.1 km
Mean width		0.9 km
Maximum depth		10.5 m
Mean depth		5.1 m
Depth Distribution:		
	ha	% Surface Area
Surface area	215.1	100
2 m+	175.0	81
4 m+	134.6	63
6 m+	89.7	42
8 m+	33.2	15
10 m+	6.2	3

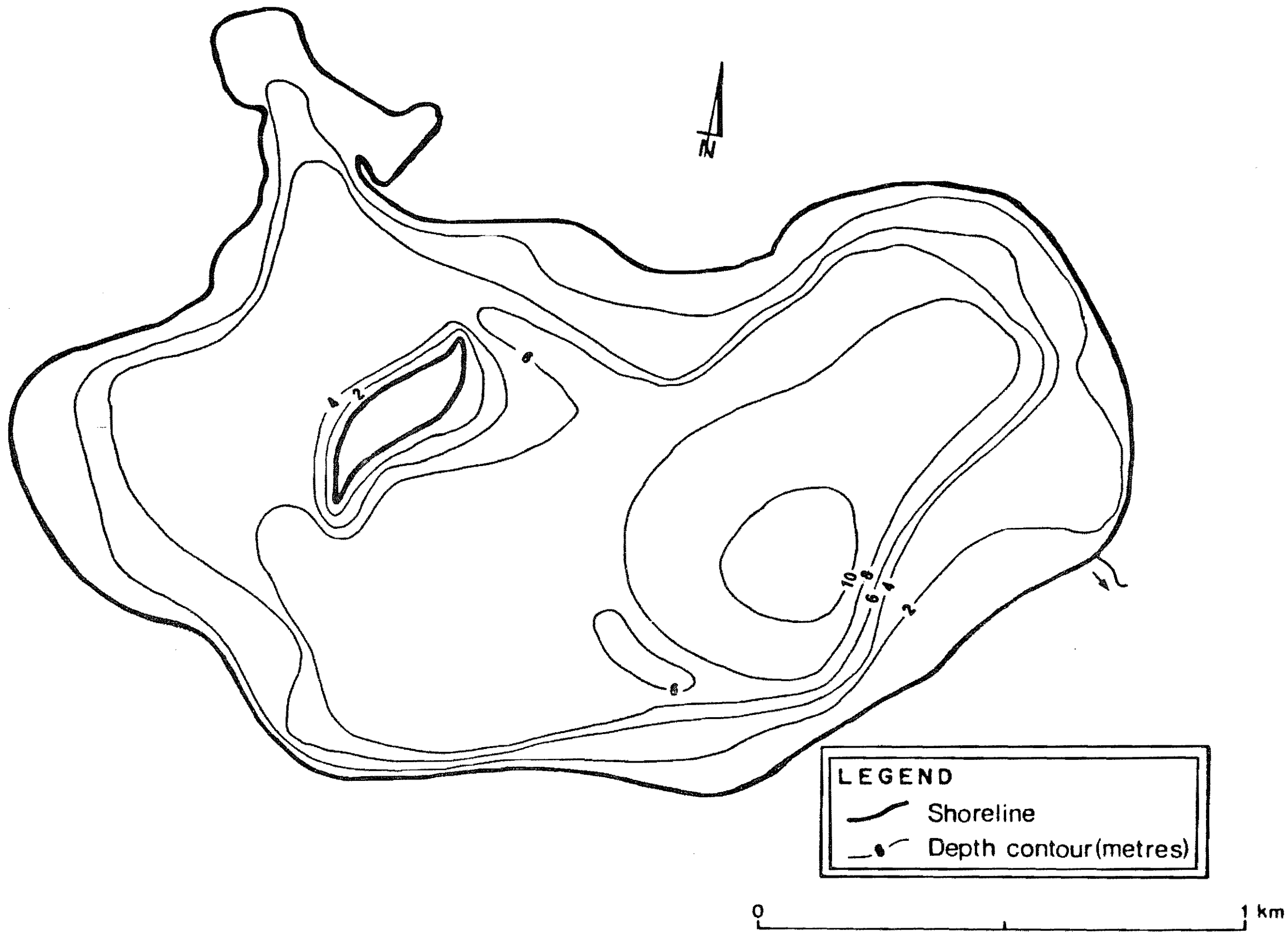

Figure 61. Bathymetric map for Unnamed Lake #9.

The maximum length of Lake #9 was 2.3 km, but the maximum effective length was only 2.1 km owing to a large island situated at the western end of the lake. The maximum width was 1.1 km. The total shoreline length (excluding the island) is 7.0 km. A shoreline development factor of 1.4 was calculated, indicating the presence of a highly regular shoreline. The regularity of the shoreline, in conjunction with the sizable effective length and width (relative to the surface area), likely results in regular mixing of the water column due to wind action.

4.9.3 Water Quality

As with the other lakes, this lake is of the calcium bicarbonate type (Table 28). Total filterable residue was 118 mg/L and total alkalinity was 65 mg/L. The water column was well oxygenated and isothermal when sampled (Figure 62) with little turbidity or colour to the water.

4.9.4 Substrate

The majority of the lake (73%) has a substrate consisting of silt or a thick layer of silt over sand (Figure 63). A substantial amount of sand substrate also was present (27% of the surface area), particularly on the southwest and east ends of the lake. No gravel or rubble areas were located.

4.9.5 Aquatic Vegetation

Growths of emergents such as *Scirpus*, *Phragmites*, *Equisetum*, and *Carex* occurred sporadically around the shoreline of the lake (Figure 64). *Sparganium*, *Nuphar*, and *Potamogeton* were the predominant floating-leafed plants. Most of the east and southeast shore was treed to the edge of the water or to a sand beach; no emergent or floating-leafed vegetation was present in these areas.

Table 28. Water quality analyses for Unnamed Lake #9.

17 September 1979	Site L1			
Na	1.7	mg/L	0.074	meq/L
K	0.9	mg/L	0.02	meq/L
Ca	18.0	mg/L	0.898	meq/L
Mg	4.9	mg/L	0.40	meq/L
SO_4	9.9	mg/L	0.21	meq/L
Cl	2.4	mg/L	0.068	meq/L
CO_3	0	mg/L	0	meq/L
HCO_3	79	mg/L	1.3	meq/L
Alkalinity				
Total	65	mg/L ($CaCO_3$)	1.30	meq/L
P'thalein	0	mg/L ($CaCO_3$)		
pH (pH units)	8.3			
Hardness, total (as $CaCO_3$)	65.1	mg/L		
Total filterable residue				
Evap. @ 105°C	118	mg/L		
Ignit. @ 550°C	50	mg/L		
Conductivity	130	µS/cm		
Turbidity	2.2	NTU		
Total P	<0.016	mg/L		
Ammonia-N	0.06	mg/L		
Reactive silica	10.3	mg/L		
Total organic carbon	12.2	mg/L		
Fe (total)	0.08	mg/L		

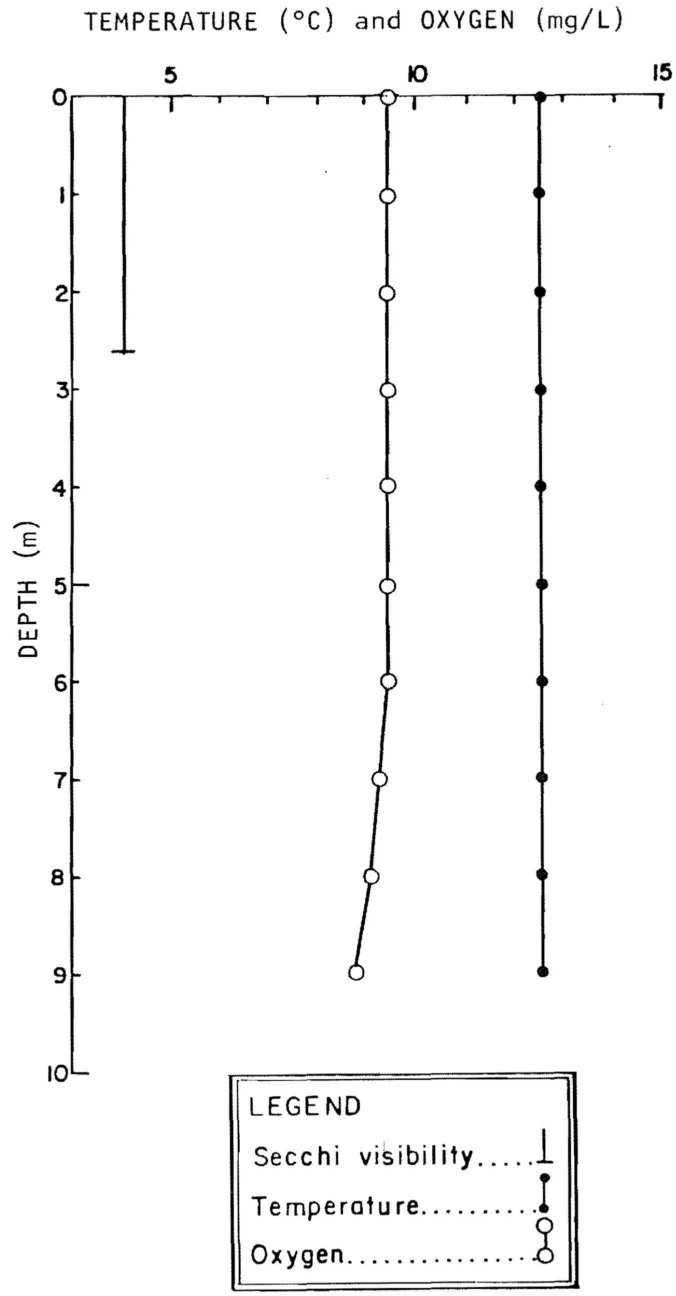

Figure 62. Temperature, dissolved oxygen, and Secchi visibility in Unnamed Lake #9, Site L1, 17 September 1979.

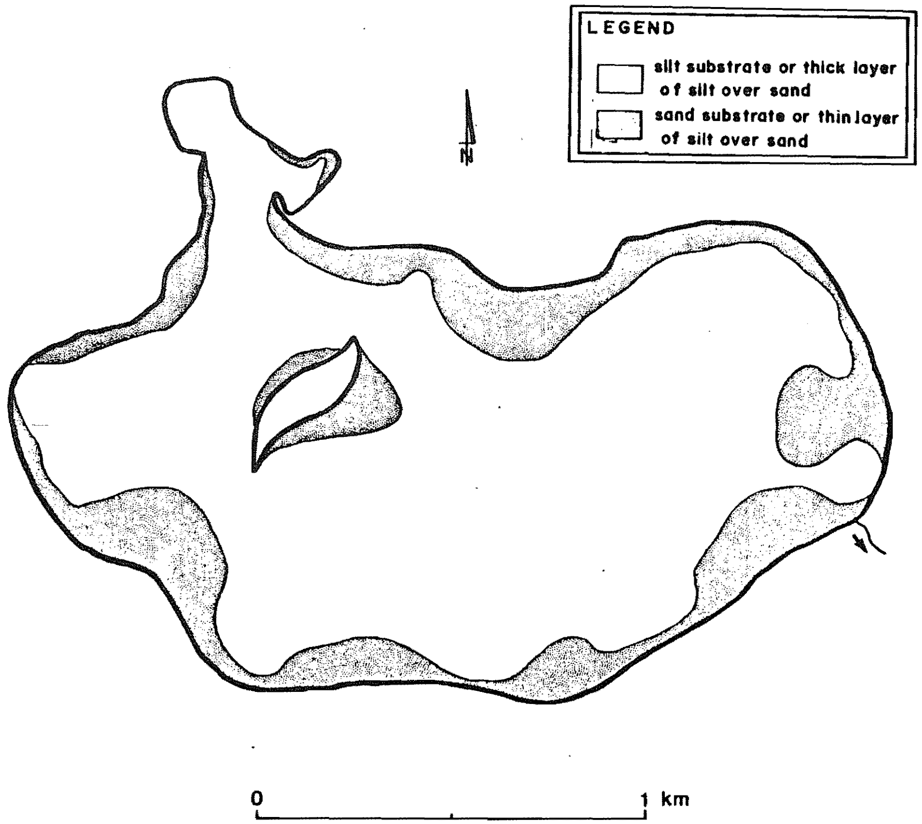

Figure 63. Approximate distribution of surficial lake sediment types in Unnamed Lake #9.

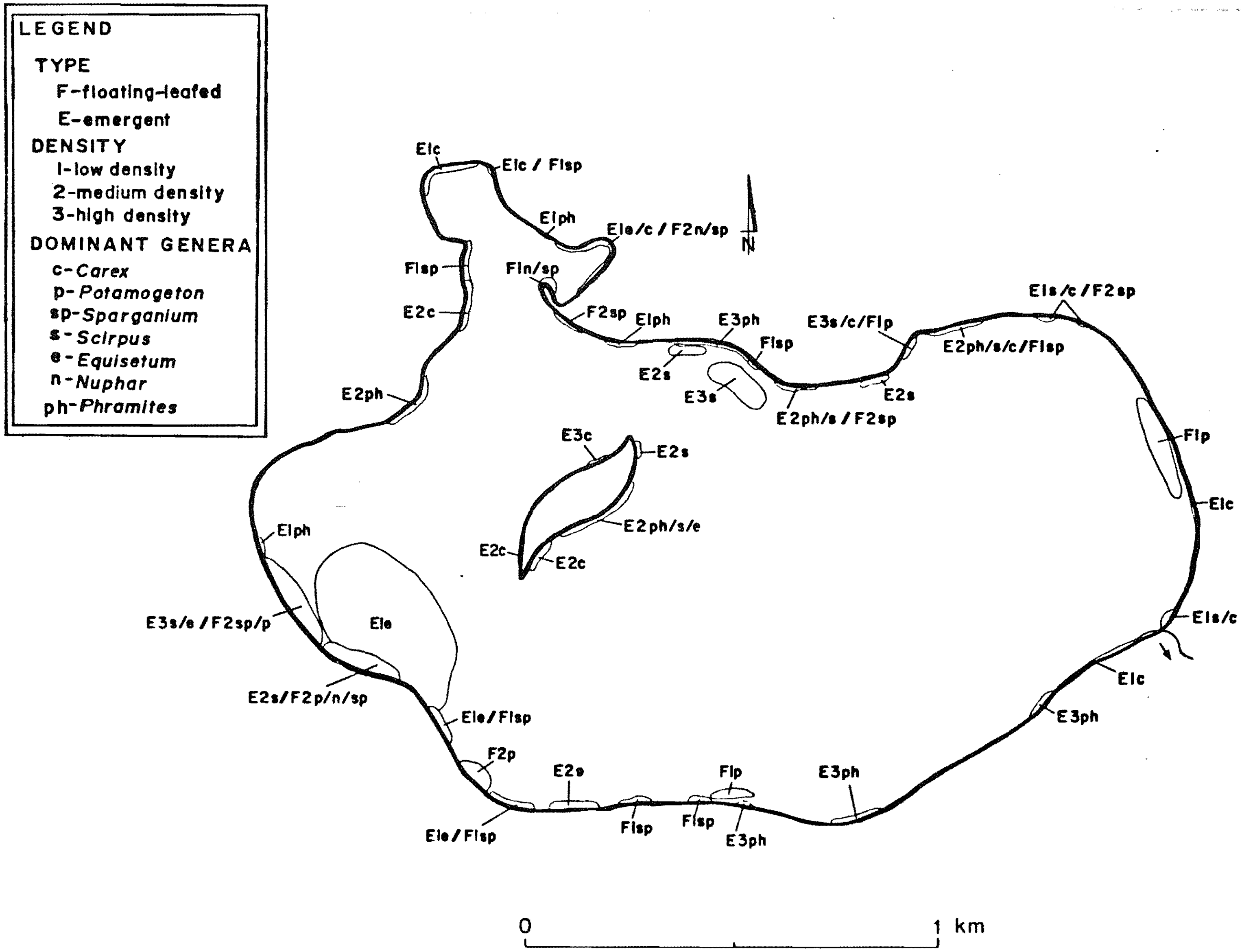

Figure 64. Approximate distribution of aquatic vegetation in Unnamed Lake #9.

4.9.6 Fish

Four species of fish were captured in gillnets set in Lake #9 (Table 29). The total catch of 169 fish consisted of 66% lake whitefish, 27% northern pike, 6% white sucker, and less than 1% yellow perch. In three seine hauls, an additional three species were captured, these being spottail shiner (54% of the seine haul catch), Iowa darter (0.2%), and ninespine stickleback (5%). Yellow perch contributed 40% of the seine haul catch.

4.9.6.1 Lake Whitefish. Of the 111 lake whitefish captured in the gillnets, 48 were sampled for life history information. Length ranged from 192 to 480 mm and weight from 83 to 1440 g. Age varied from 2 to 8 years, with age 6 fish being predominant (40% of the sample) (Figure 65). The growth rate appeared to be moderate, with the fish reaching a mean length of 315 mm and a mean weight of 435 g by age 4.

The mean condition factor of the sampled lake whitefish was 1.35 ± 0.02 (SE), indicating they were in fair physical condition. The length(mm)-weight(g) regression was:

$$W = 7.313 \times 10^{-6} L^{3.102} \text{ where } r^2 = 0.98,\ N = 48.$$

Two of the four age 4 male fish were mature; all older males were mature. All 5-year-old females were immature, as were one out of nine of the 6-year-olds and two out of four of the 7-year-olds.

Forty-six lake whitefish stomachs were examined for food contents. The major food items were fish (primarily ninespine stickleback in 24 stomachs). *Nostoc* was present in 13 stomachs and Trichoptera larvae were present in four stomachs. Minor food items included Gastropoda (two stomachs), Pelecypoda (one stomach), and Chironomidae larvae (one stomach). Nine of the lake whitefish stomachs examined were empty.

Twenty-four lake whitefish were dissected to determine the presence of plerocercoids of *Triaenophorus crassus*. Seven fish (29%) were infected with a total of 32 cysts, giving an infestation rate of 64 cysts/45.4 kg of fish. Due to the infestation rate, these whitefish would have little commercial value.

Table 29. Test net results for Unnamed Lake #9.

Date Set	Duration of Set (h)	Water Depth (m)	Mesh Size (cm)	Species and Number: Lake Whitefish	Northern Pike	White Sucker	Yellow Perch	Total
15 September 1979	12	1.0	3.8	5	13	0	0	18
			5.1	5	16	2	0	23
			6.4	18	4	2	0	24
		4.0	7.6	20	3	2	0	25
		5.0	8.9	14	2	2	0	18
			10.2	12	2	1	0	15
			11.4	8	0	0	0	8
		5.5	14.0	0	0	0	0	0
16 September 1979	1	1.5	3.8	11	1	0	1	13
			5.1	7	3	2	0	12
			6.4	3	1	0	0	4
		3.0	7.6	8	1	0	0	9
Total				111	46	11	1	169

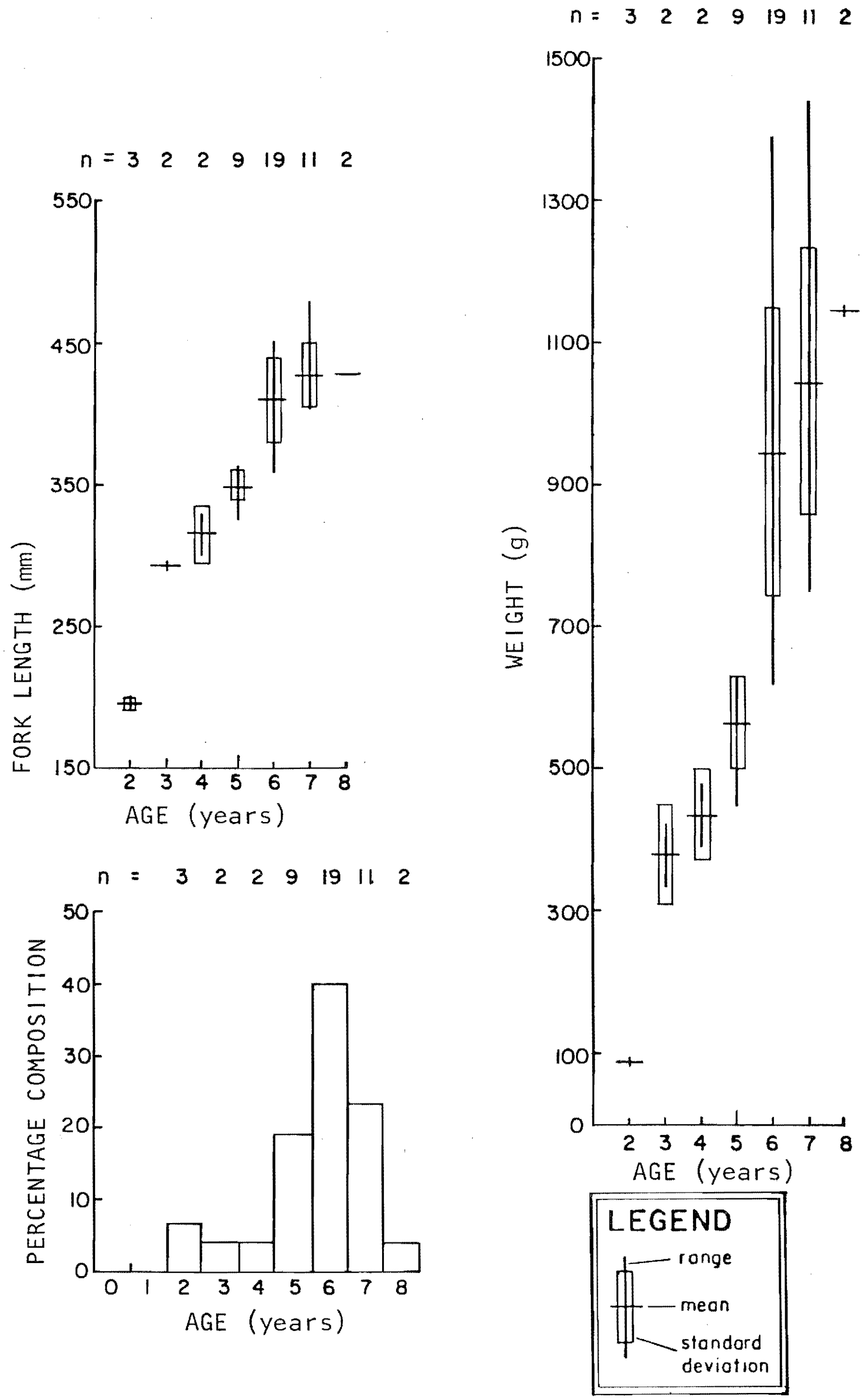

Figure 65. Age composition and age-growth relationships for lake whitefish from Unnamed Lake #9, September 1979.

4.9.6.2 Northern Pike. Of the 46 northern pike captured in gillnets, 31 were sampled to collect life history information. Length of the pike ranged from 201 to 760 mm and weight from 203 to 3210 g. Age varied from 1 to 10 years, with age 3 fish being predominant (32% of the sample) (Figure 66). No 4-, 5-, or 6-year-old fish were present in the sample. It is assumed that these age-classes were absent due to limited sampling.

The mean condition factor of the sample was 0.67 ± 0.01 (SE) and the length(mm)-weight(g) relationship was:

$$W = 3.787 \times 10^{-6} L^{3.093} \text{ where } r^2 = 0.99, N = 31.$$

All fish 3 years of age and younger were immature. Since all pike age 7 or older were mature, it is likely that pike in this lake mature at ages 4 to 6; however, no fish in these age-classes were present in the sample.

Thirty-two northern pike stomachs were examined for food contents. The primary food items present were ninespine stickleback (four stomachs), lake whitefish (three stomachs), white sucker (two stomachs), and yellow perch (one stomach). Two other stomachs contained unidentifiable fish remains and 21 were empty.

4.9.6.3 White Sucker. Nine of the 11 white sucker captured in the gillnets were sampled to collect life history information. Length ranged from 253 to 478 mm and weight from 220 to 1680 g. Age varied from 3 to 6 years, with age 5 fish being predominant (65%). The mean length of the 6 year olds was 443.2 mm, and the mean weight was 1326.7 g (N = 6). All of the fish age 4 or older were mature.

4.9.6.4 Yellow Perch. Only one yellow perch was sampled; it was a 5 year old mature female that measured only 163 mm in length and weighed 47 g. This indicated a very poor growth rate.

4.9.6.5 Potential Production. Applying the regression equations developed by Ryder (1965) and Allan (1975), the harvestable fish

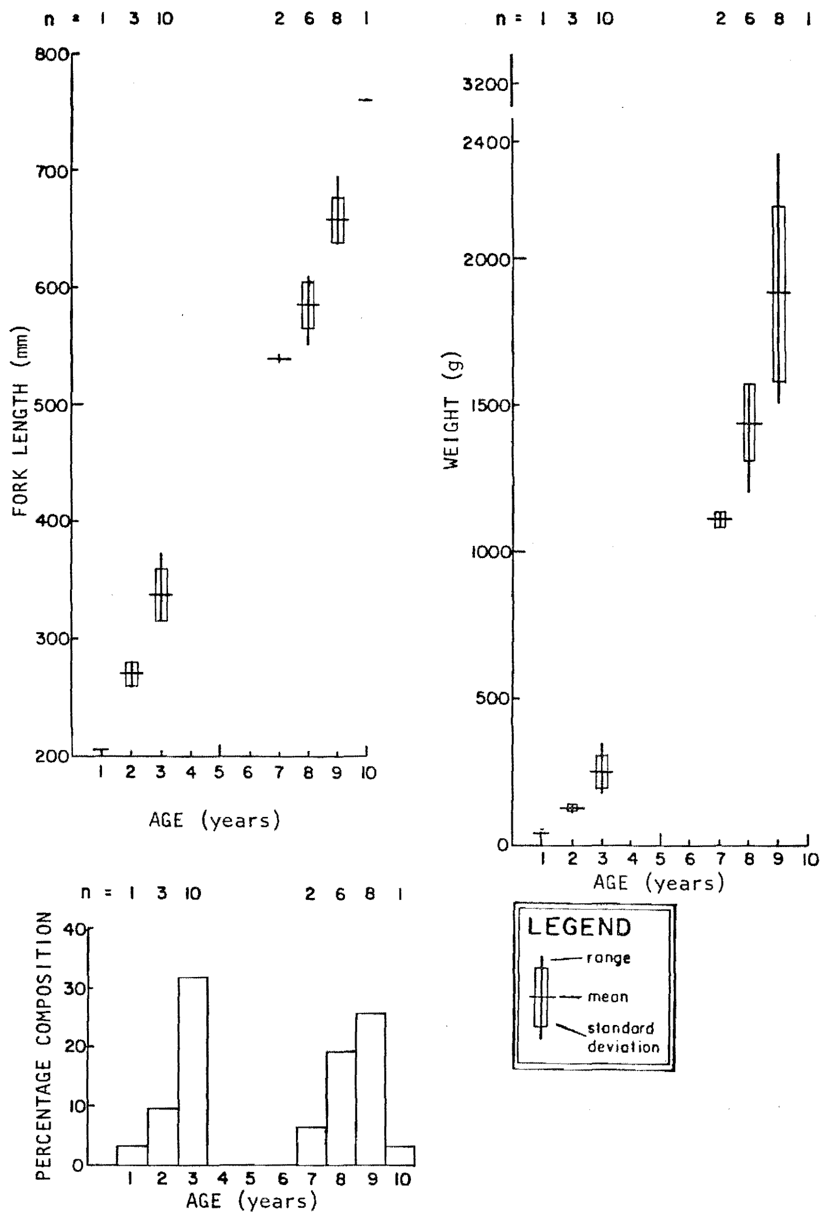

Figure 66. Age composition and age-growth relationships for northern pike from Unnamed Lake #9, September 1979.

production in Lake #9 was estimated as 5.6 to 7.6 kg/ha/yr. This represents a total harvestable production of 1200 to 1640 kg/yr. Using the percentage (by weight) of sportfish present in the gillnet catch (32%), the harvestable sportfish production in the lake was estimated to be in the order of 380 to 520 kg/yr. Northern pike would be the primary sportfish taken.

4.9.7 Discussion

Lake #9 has only a moderate potential to support a sport fishery. This is predicated upon the presence of only one catchable-sized sportfish species and the relatively low production estimate. The extent of aquatic vegetation in the lake was not great. As a result, suitable spawning and rearing habitat for northern pike may be limited. While no gravel-rubble substrate was observed, it is apparent that the lake whitefish were reproducing successfully. They may have been spawning on hard sand substrate which was widely available. Forage fish appeared to be abundant since lake whitefish, which normally feed on zoobenthos, contained large numbers of them in their stomachs.

Although this lake could support only limited angling pressure, its proximity to Unnamed Lake #10 (locally called Keith Lake), may make Lake #9 attractive from a recreational point of view. Angling pressure would have to be controlled to ensure that overfishing of the northern pike population did not occur.

4.10 UNNAMED LAKE #10 (KEITH LAKE)

4.10.1 Introduction

Lake #10, locally called Keith Lake, is located in Township 103, Range 6, West of the Fourth Meridian (57°57'N; 110°56'W). Lake drainage is restricted to a small outlet creek which flows northward and eventually enters the Richardson River. At the time of investigation, this creek was controlled at the outlet by a beaver dam. Below the dam, the channel was less than 1 m wide. Flow was negligible and water depth in the creek was generally less than 20 cm. For the above reasons, the stream had little fishery potential, at least during the fall. A small inlet stream enters the lake along the southeast shore, but this creek was not examined during this study. The stream originates from a lake situated to the southeast.

The surrounding terrain is generally forested with sparse to medium growth of jackpine; birch is common along the shoreline of the lake.

During the summer, the lake is accessible only by aircraft; however, it is located within 6 km of the Fort McMurray-Fort Chipewyan winter road.

Sampling on the lake was conducted during the period 13 to 15 September 1979. The locations of the sampling sites are shown in Figure 67.

4.10.2 Morphometry

Lake #10 has a surface area of 338.9 ha, making it the largest of the 10 lakes studied. It has an estimated volume of 2.7×10^7 m^3 and a mean depth of 7.9 m (Table 30). The maximum depth noted during a total of 14 sounding transects was 16.0 m which was recorded in the eastern portion of the lake (Figure 68). Approximately 61% of the surface area of the lake was deeper than 6 m. Lake #10 was the deepest of the 10 lakes surveyed.

The maximum length of the lake was 2.9 km, and the maximum width was 1.7 km. The total shoreline length was 9.7 km and the shoreline development factor was 1.5. The latter is indicative of a highly regular shoreline. The positioning of the lake (i.e., long axis in an east-west direction and sizeable effective length) likely results in regular mixing of the lake throughout most of the open-water period.

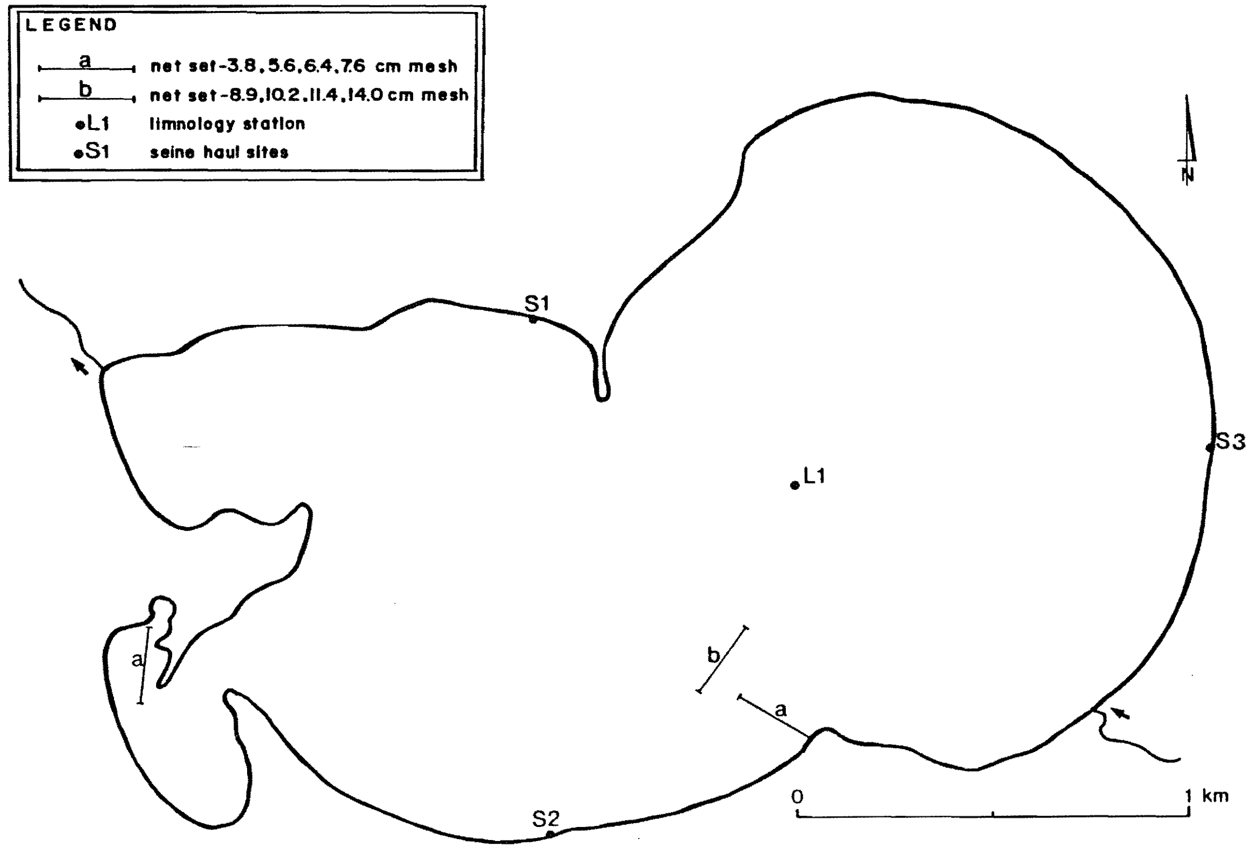

Figure 67. Sampling site locations in Unnamed Lake #10, September 1979.

Table 30. Morphometry of Unnamed Lake #10.

Location		Tp. 103, Rg. 6, W4
Area		338.9 ha
Volume		2.7×10^7 m^3
Shoreline length		9.7 km
Shoreline development factor		1.5
Maximum length		2.9 km
Maximum effective length		2.9 km
Maximum width		1.7 km
Maximum effective width		1.7 km
Mean width		1.2 km
Maximum depth		16.0 m
Mean depth		8.0 m
Depth Distribution:		
	ha	% Surface Area
Surface area	338.9	100
3 m+	252.1	74
6 m+	206.5	61
9 m+	160.8	47
12 m+	120.3	35
15 m+	9.3	3

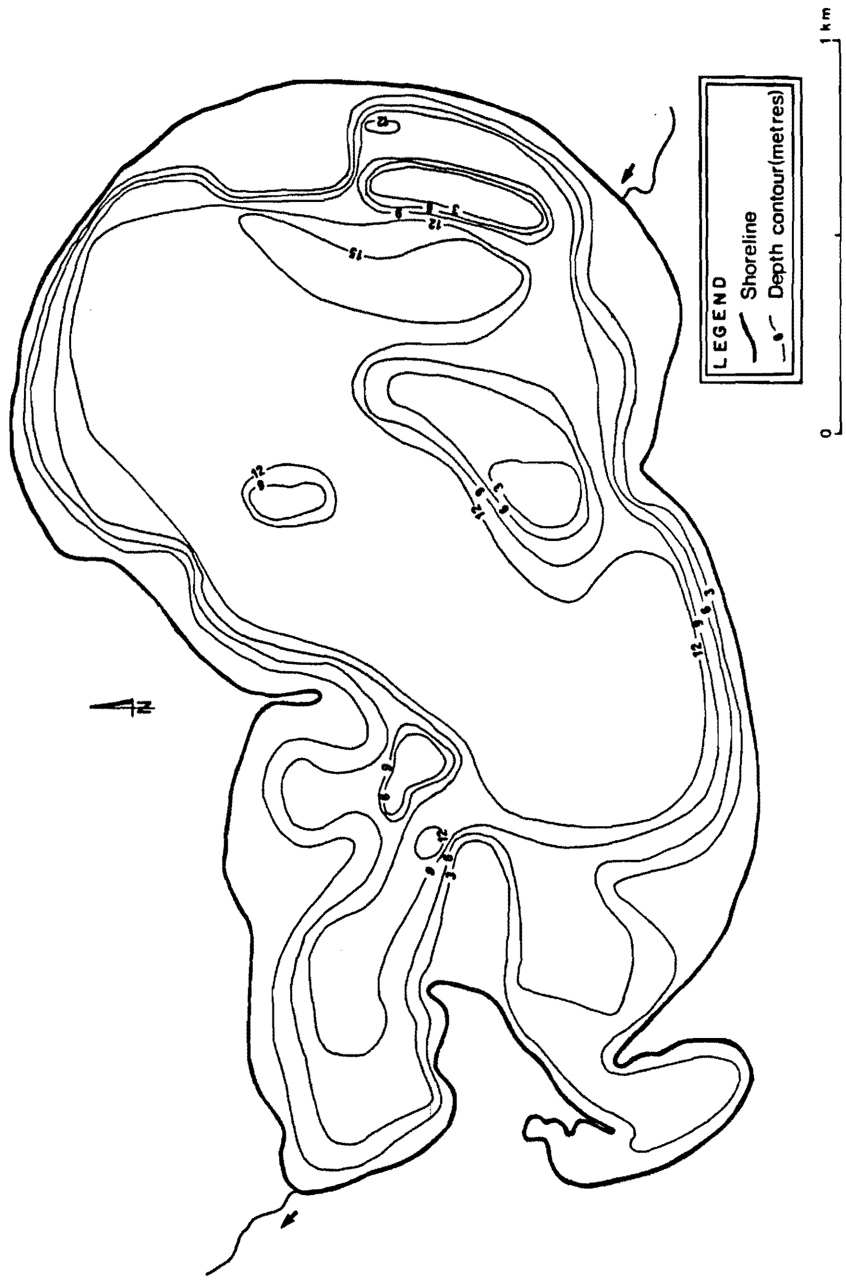

Figure 68. Bathymetric map for Unnamed Lake #10.

4.10.3 Water Quality

The lower depths of Lake #10 were slightly deficient in oxygen and slightly cooler than overlying strata (Figure 69). The water was uncoloured, fairly clear, and contained 99 mg/L total alkalinity and 142 mg/L total filterable residue (Table 31). Calcium and bicarbonate were the principal dissolved ions.

4.10.4 Substrate

Approximately 76% of the lake has a substrate of silt or a thick layer of silt over sand (Figure 70). Large areas of sand substrate occurred along the northwest and south shores. Sand composed approximately 22% of the lake substrate. Gravel-rubble material made up only about 2% of the substrate. The largest areas of gravel-rubble were located along the point on the north shore, at the east end of the lake, and on the small point in the middle of the south shore. The bays at the west end of the lake had predominantly silt substrates, although sand was found along shore in many places.

4.10.5 Aquatic Vegetation

The majority of the shoreline of the lake had either a sand beach or was treed to the shore, with very little emergent vegetation present. *Carex* occurred in sporadic patches along shore but was often above the water line (Figure 71). Small beds of *Potamogeton, Sparganium,* and *Scirpus* were located in the west end of the lake. *Nuphar,* which was present in most other study lakes, was not observed in Lake #10 during this survey. Submergent vegetation was seen at numerous locations around the lake, but dominant genera were not identified.

4.10.6 Fish

Four species of fish were captured in gillnets in Lake #10 (Table 32). Of the total catch of 221 fish, lake whitefish contributed 51%, walleye 39%, northern pike 4%, and white sucker 5%. Catch results from three seine hauls indicated the presence of spottail

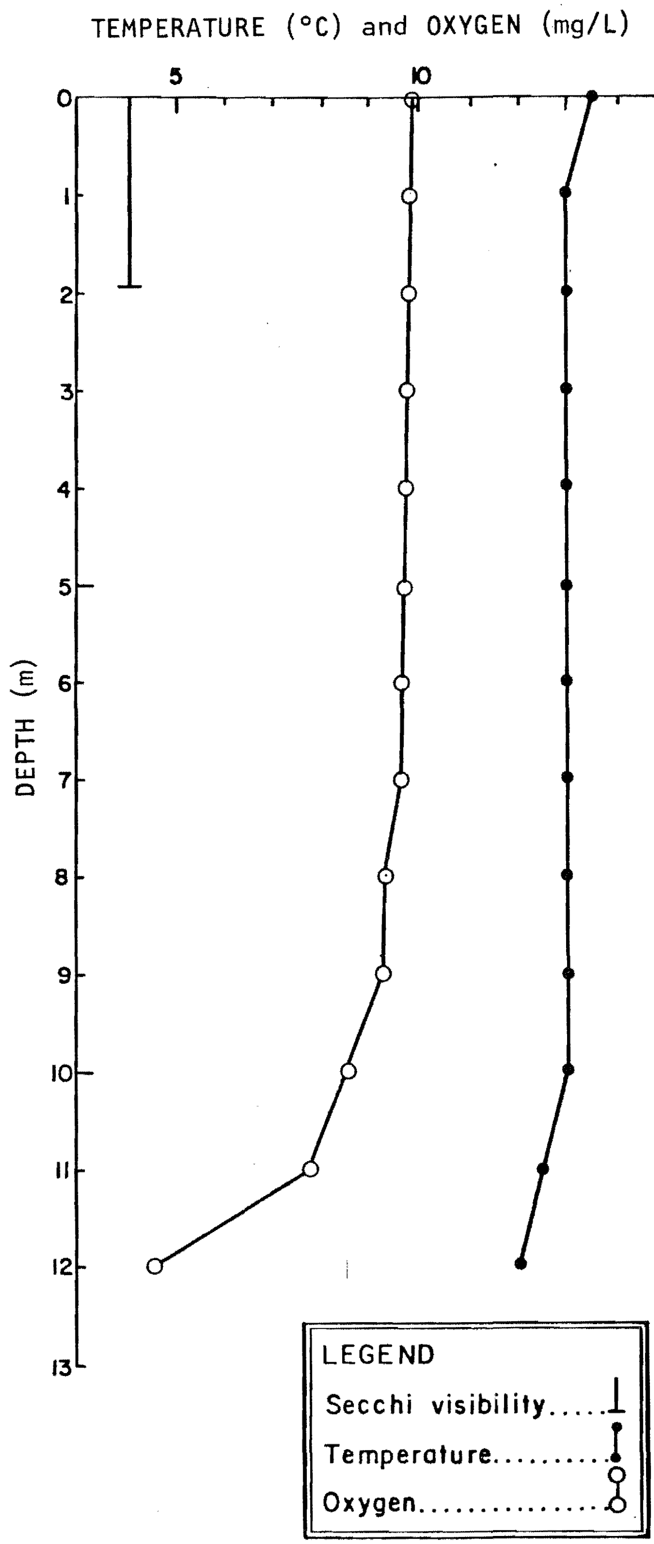

Figure 69. Temperature, dissolved oxygen, and Secchi visibility in Unnamed Lake #10, Site L1, 15 September 1979.

Table 31. Water quality analyses for Unnamed Lake #10.

15 September 1979	Site L1			
Na	1.9	mg/L	0.083	meq/L
K	0.8	mg/L	0.02	meq/L
Ca	26.1	mg/L	1.30	meq/L
Mg	9.1	mg/L	0.75	meq/L
SO_4	8.2	mg/L	0.17	meq/L
Cl	1.6	mg/L	0.045	meq/L
CO_3	1	mg/L	0.04	meq/L
HCO_3	118	mg/L	1.94	meq/L
Alkalinity				
Total	99	mg/L ($CaCO_3$)	1.98	meq/L
P'thalein	1	mg/L ($CaCO_3$)		
pH (pH units)	8.4			
Hardness, total (as $CaCO_3$)	102.7	mg/L		
Total filterable residue				
Evap. @ 105°C	142	mg/L		
Ignit. @ 550°C	88	mg/L		
Conductivity	185	µS/cm		
Turbidity	1.7	NTU		
Total P	<0.016	mg/L		
Ammonia-N	<0.05	mg/L		
Reactive silica	4.5	mg/L		
Total organic carbon	16.8	mg/L		
Fe (total)	0.08	mg/L		

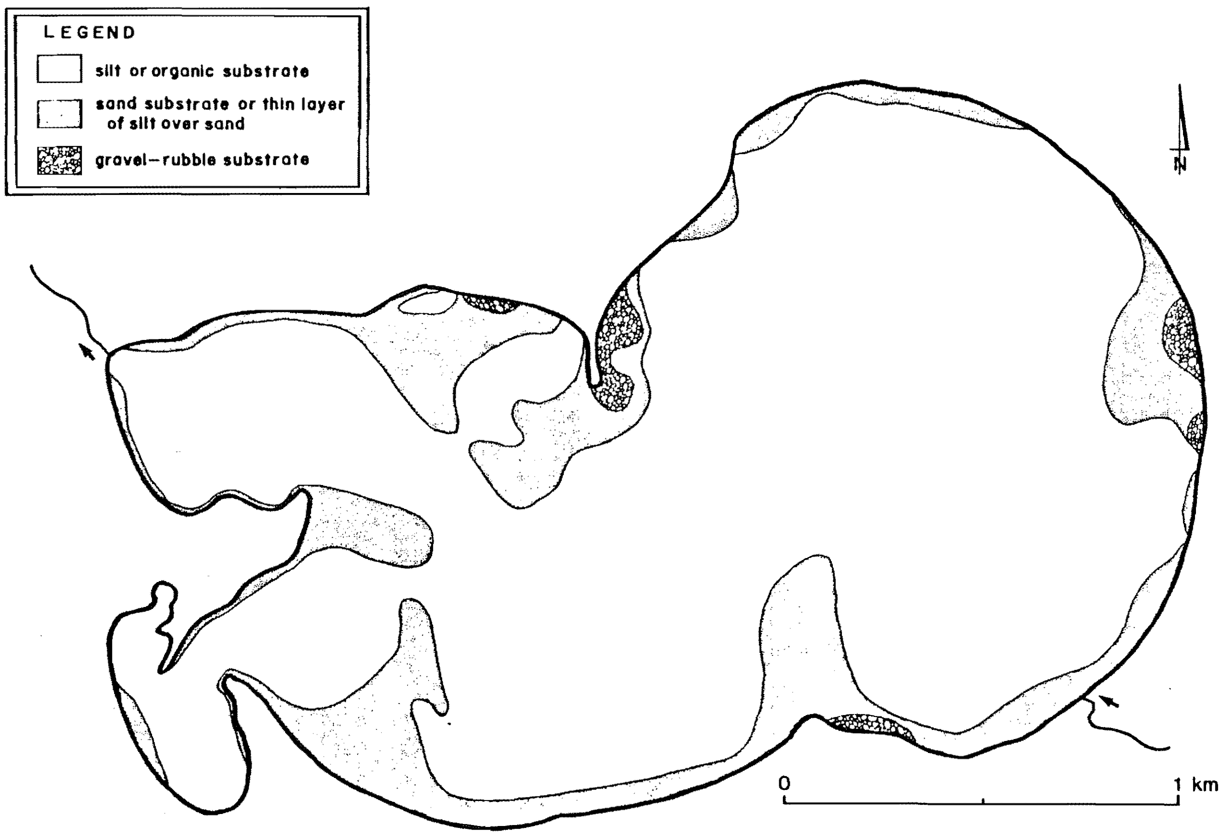

Figure 70. Approximate distribution of surficial lake sediment types in Unnamed Lake #10.

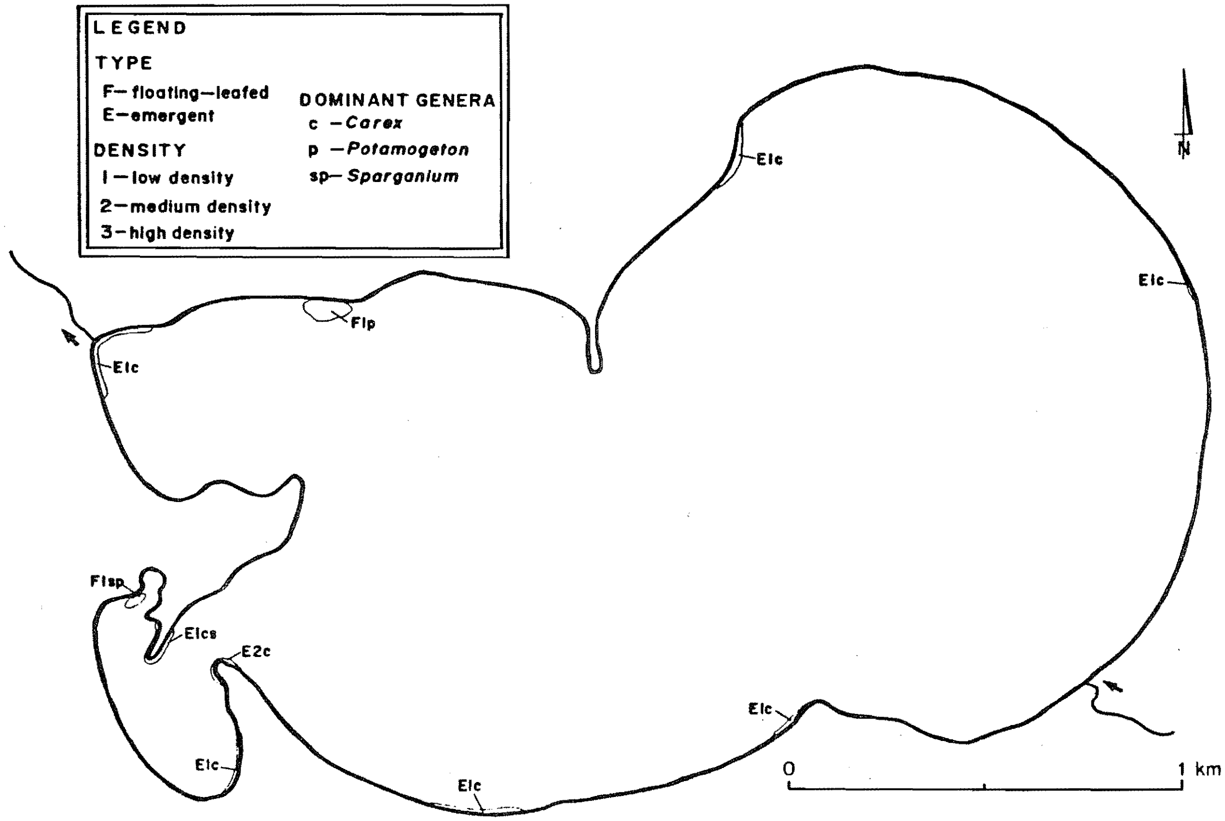

Figure 71. Approximate distribution of aquatic vegetation in Unnamed Lake #10.

Table 32. Test net results for Unnamed Lake #10.

Date Set	Duration of Set (h)	Water Depth (m)	Mesh Size (cm)	Species and Number: Lake Whitefish	Northern Pike	Yellow Walleye	White Sucker	Total
13 September 1979	13.0	1.0	3.8	29	4	17	0	50
			5.1	14	0	22	5	41
			6.4	25	0	25	3	53
		7.5	7.6	13	1	15	3	32
		7.5	8.9	14	0	0	0	14
			10.2	6	2	2	0	10
			11.4	7	0	5	0	12
		5.0	14.0	0	1	1	0	2
15 September 1979	3.5	1.0	3.8	1	1	0	0	2
			5.1	0	0	0	0	0
			6.4	1	0	0	0	1
		3.0	7.6	3	0	0	0	3
Total				113	9	87	11	221

shiner and yellow perch. Spottail shiner made up 81% of the estimated 677 fish collected in seine hauls. Yellow perch contributed 11%, lake whitefish juveniles contributed 7%, and white sucker made up less than 1%. Ninespine stickleback were also present in the lake, as indicated by their occurrence in the stomach contents of walleye.

4.10.6.1 Lake Whitefish. A total of 113 lake whitefish were taken in gillnets; an additional 50 were captured in a seine haul. Of this total, 69 were sampled to collect life history information. Length ranged from 68 to 499 mm and weight from 3 to 1730 g. Age varied from age 0 (young-of-the-year) to age 9, although no age 1 and no age 3 fish were present in the sample (Figure 72). The whitefish showed a good rate of growth, reaching a mean length of 321.3 mm and a mean weight of 419.1 by age 4.

The mean condition factor of the sampled lake whitefish was 1.12 ± 0.02 (SE), indicating that they were in only fair physical condition. The low condition factor of whitefish in this lake, in comparison to the other surveyed lakes, may be a response to the apparent large size of the whitefish population in this lake.

The length(mm)-weight(g) regression equation was:

$W = 4.250 \times 10^{-6} L^{3.1752}$ where $r^2 = 0.99$, N = 69.

All of the fish 5 years of age and older were mature, although two females and three males aged 7 or 8 were classed as alternate year spawners. Two out of three female fish 4 years of age were immature, but only one out of eight of the 4-year-old males was immature.

Forty-two lake whitefish stomachs were examined for food contents. The primary food items were Trichoptera larvae, Pelecypoda, Chironomidae larvae, Amphipoda, and Gastropoda. Approximately 35 ninespine stickleback were present in one of the stomachs. Twenty-nine of the 42 stomachs examined were empty.

Eighteen lake whitefish were examined to determine the occurrence of plerocercoids of *Triaenophorus crassus;* all were infected. A total of 172 cysts were identified, giving an infestation

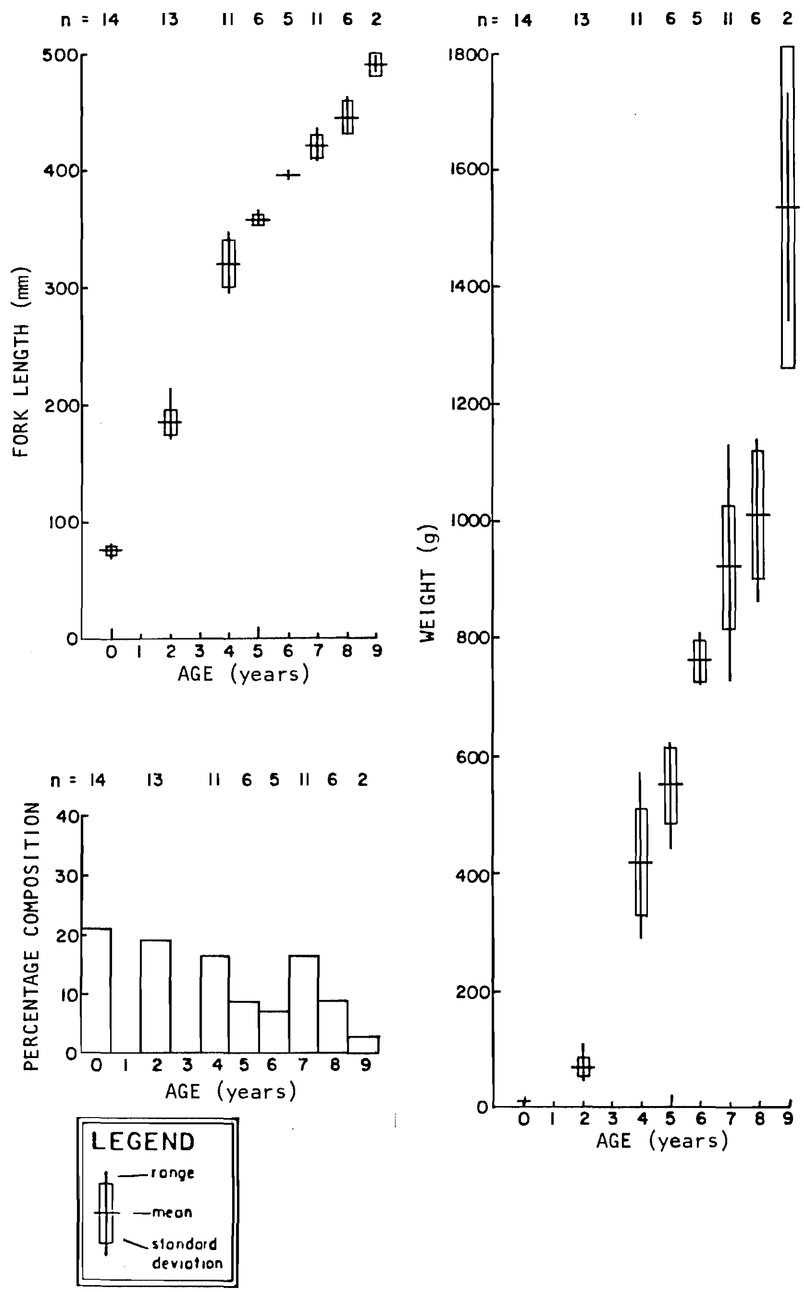

Figure 72. Age composition and age-growth relationships for lake whitefish from Unnamed Lake #10, September 1979.

rate of 499 cysts/45.4 kg of fish. Due to this high infestation rate, these fish would have little commercial value.

4.10.6.2 Northern Pike. Of the nine northern pike captured in the gillnet sets, eight were sampled for life history information. Length ranged from 545 to 882 mm and weight from 1150 to 5900 g. The sample consisted of three age 7 fish, three age 9 fish, one age 11 fish, and one age 13 fish (Figure 73).

The mean condition factor was 0.81 ± 0.02 (SE), indicating the fish were in excellent condition. All of the fish in the sample, which included three males and five females, were mature. Nine pike stomachs were examined for stomach contents; eight were empty and one contained a lake whitefish that was approximately 350 mm long.

4.10.6.3 Walleye. Of the 87 walleye captured in the gillnets, 33 were sampled to collect life history information. Length ranged from 101 to 573 mm and weight from 6 to 2280 g. Age ranged from age 0 (young-of-the-year) to age 11, but no 1- or 2-year-old fish were present in the sample (Figure 74). Twenty-four percent of the sample were 8-year-olds. The walleye exhibited a slow growth rate, reaching a mean length of only 366.7 mm and a mean weight of only 525.0 g at age 6. This may be due to the presence of an inadequate food supply in relation to an apparently large walleye population.

The mean condition factor calculated for walleye was 1.08 ± 0.02 (SE), indicating that they were in only fair physical condition. The length(mm)-weight(g) relationship was:

$$W = 1.019 \times 10^{-6} L^{3.395} \text{ where } r^2 = 0.996, N = 33.$$

All of the fish age 4 or older were mature, with the exception of one age 6 female that was classed as immature. Twenty-six walleye stomachs were examined for food contents. Fifteen were empty while the remaining 11 stomachs contained ninespine stickleback, with some containing more than 50 individuals.

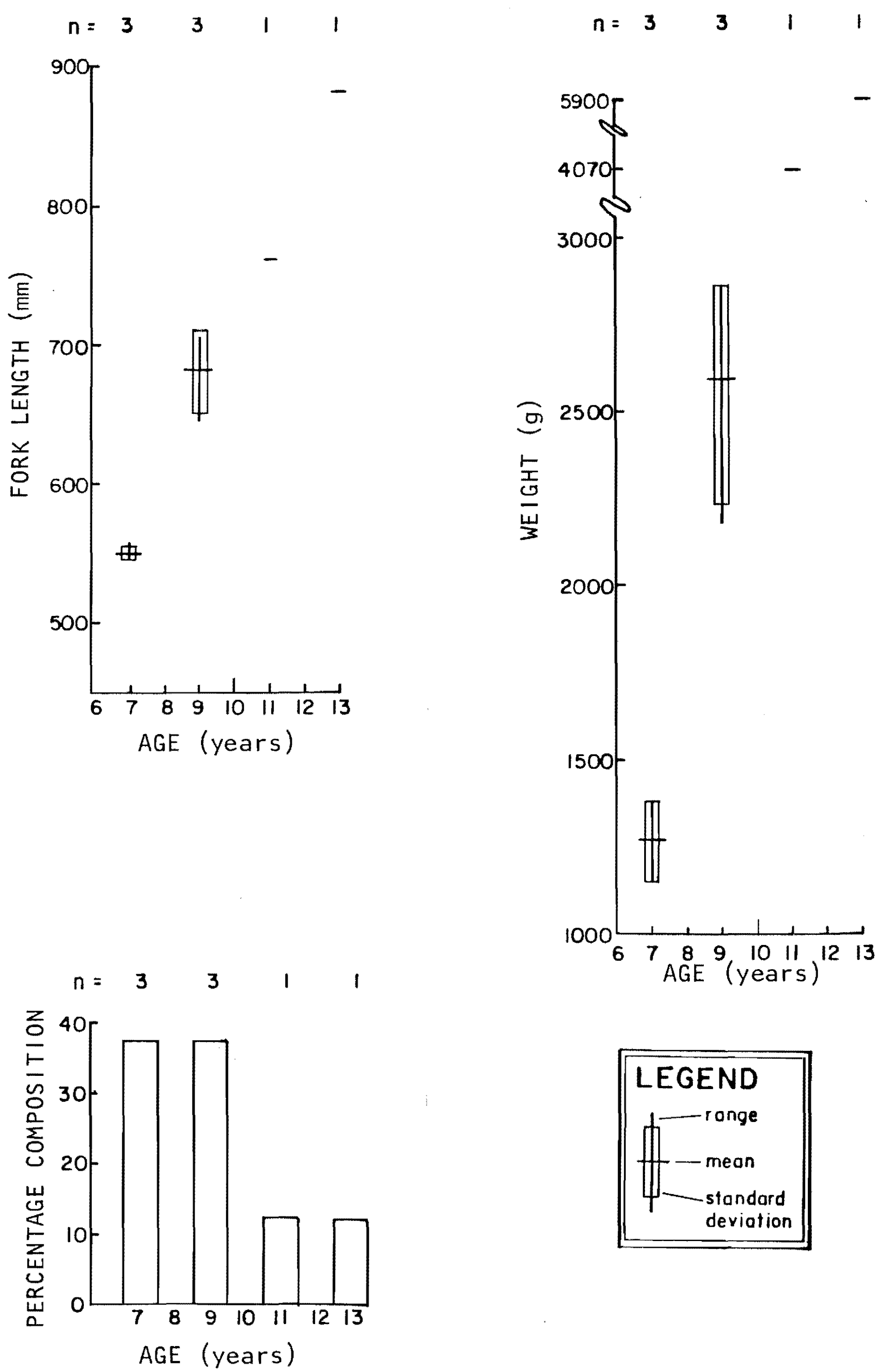

Figure 73. Age composition and age-growth relationships for northern pike from Unnamed Lake #10, September 1979.

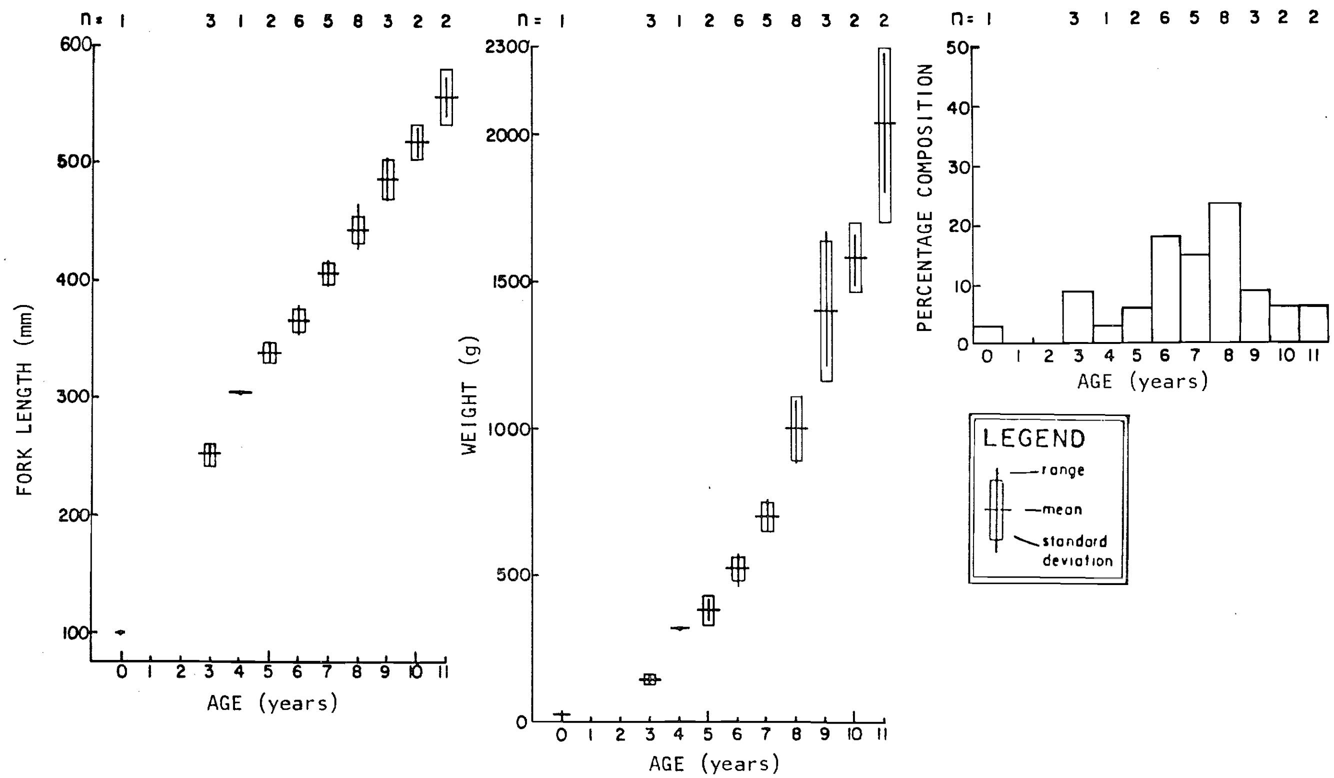

Figure 74. Age composition and age-growth relationships for walleye from Unnamed Lake #10, September 1979.

4.10.6.4 White Sucker. The lengths of the 11 white sucker captured in the gillnets ranged from 250 to 428 mm and the weights ranged from 233 to 1270 g. The sample was composed of one age 3, five age 4, and five age 5 fish.

4.10.6.5 Potential Production. Applying the regression equations developed by Ryder (1965) and Allan (1975) relating morphoedaphic index to harvestable fish production, it was estimated that Lake #10 would produce between 5.0 and 6.7 kg/ha/yr or between 1690 and 2270 kg/yr for the lake. Based on the percentage (by weight) of sportfish in the gillnet catch (57%), it was estimated that harvestable sportfish production would be in the order of 960 to 1290 kg/yr. Walleye would contribute the major portion of the sportfish catch while northern pike would likely constitute only a minor component.

4.10.7 Discussion

Test net results suggest the presence of a large population of lake whitefish and walleye in this lake. Although extensive gravel-rubble areas were not identified, localized areas with gravel-rubble substrates and areas with sand substrates appeared to be adequate to meet the spawning requirements of these species. Northern pike abundance may be limited by the amount of spawning and rearing habitat available, although some suitable habitat occurred in the bays in the west end of the lake.

The presence of a large population of walleye in this lake, the abundance of sand beaches, the scenic setting of the lake, and its relatively large size in comparison to the other lakes studied make Lake #10 attractive from a recreational and sport fishery point of view.

The lake currently supports a limited amount of sport fishing by anglers flown in from Fort McMurray (J. Bergeron, pers. comm.).

5. DISCUSSION

Pertinent physical and biological results obtained during the study are summarized for the 10 survey lakes in Table 33. The summary table provides a basis for the discussion of the significance of these findings which follows.

5.1 MORPHOMETRY

Unnamed Lake #10 (locally called Keith Lake) was the largest of the lakes studied, having a surface area of 338.9 ha. Unnamed Lake #1, with a surface area of 67.4 ha, was the smallest. Unnamed Lake #10 was also the deepest, having a maximum depth of 16.0 m. The shallowest lake was Unnamed Lake #8, which had a maximum depth of only 6.0 m. All of the lakes sampled had sufficient depth to support sportfish populations. Unnamed Lake #8, however, apparently did not support a lake whitefish population. The shallow nature of this lake, which contributes to high maximum temperatures during summer and low dissolved oxygen levels during winter, may result in conditions unsuitable for lake whitefish.

The mean depth of a lake is an important physical parameter since it has been shown to be inversely correlated with fish yield (Rawson 1952; Ryder 1965; Matuszek 1978). Unnamed Lake #3 had the lowest mean depth (1.9 m), while Unnamed Lake #10 had the highest (8.0 m). The shallow mean depth of most of the lakes studied indicates that a large percentage of their volume is within the photic zone. Similarly, lakes with a low mean depth generally have a large littoral zone. Both factors would favour higher biological productivity.

5.2 WATER QUALITY

The 10 lakes sampled were situated close to one another and had noticeable similarities in morphometry, substrates, and surrounding landforms. Accordingly, they were similar in water quality, having fairly clear, unstained, well-oxygenated waters, with similar

Table 33. Summary of survey information for the 10 study lakes.

Parameter	Lake Number 1	2	3	4	5	6	7	8	9	10
Morphometry										
Surface area (ha)	67.4	156.3	116.3	103.4	157.2	116.5	169.7	112.2	215.1	338.9
Maximimum depth (m)	8.5	15.5	8.0	11.5	8.5	9.0	6.0	8.3	10.5	16.0
Mean depth (m)	5.2	4.2	1.9	4.8	3.9	4.2	2.1	3.8	5.1	8.0
Water Quality										
Suitable for fish	✓	✓	✓	✓	✓	✓	✓	0	✓	✓
Uncertain for fish	0	0	0	0	0	0	0	✓	0	0
Substrate and shoreline features										
Shoreline - sand beaches present	0	✓	✓	✓	0	0	✓	0	✓	✓
- flooded and/or few sand beaches	✓	0	0	0	✓	✓	0	✓	0	0
Central basin - silt	✓	0	0	✓	✓	✓	0	✓	✓	✓
- flocculent organic	0	✓	✓	0	0	0	✓	0	0	0
Approximate percentage gravel-rubble	<1	<1	<1	<1	7	8	13	9	nil	2
Aquatic Vegetation[a]										
Floating-leafed										
Nuphar sp.	+++	-	+	-	+++	+++	+	+++	+	-
Others	+	+	++	+	++	++	++	+	++	+
Emergents										
Scirpus sp.	++	++	++	++	+++	+++	++	+++	++	+
Phragmites sp.	++	-	++	+	+++	+++	++	+++	++	-
Carex sp.	+++	++	+++	++	+++	+++	+	+++	++	+
Equisetum sp.	-	-	-	-	++	++	-	+++	++	-
Typha sp.	+	-	+	++	+	+	+	++	-	-
Others	+	+	+	+	+	+	+	++	+	-
Fish[b]										
Yellow walleye	-	+++	-	++	+++	+++	-	-	-	+++
Yellow perch	-	+	+	+	+	+	-	++	+	++
Northern pike	++	++	+++	+	++	++	++	+++	++	+
Lake whitefish	+++*	+++*	+++	+++*	+	+	+++*	-	+++*	+++*
Cisco	-	-	-	-	+	+	-	-	-	-
Spottail shiner	-	+++	+++	+++	++	++	-	+	+++	+++
Iowa darter	-	+	+	-	-	-	++	+++	+	-
Ninespine stickleback	++	-	+	+	+++	++	-	-	+	++
White sucker	-	++	++	-	+	++	-	+	++	+
Burbot	-	-	-	-	+	-	-	-	-	-

[a] Aquatic Vegetation:
- \- not noted or occurred only in very low densities
- \+ occurred in low densities in places
- ++ locally common or widespread in low abundance
- +++ locally predominant or widespread in moderate abundance

[b] Fish:
- \- not collected, observed, or noted in fish stomachs
- \+ only collected, observed, or noted in fish stomachs in low numbers
- ++ common
- +++ abundant
- * lake whitefish or cisco high infestation of *T. crassus* plerocercoids (>35/45.4 kg)

concentrations of major ions. When sampled, most of the lakes were isothermal at temperatures ranging from 12°C to 16°C. These lakes probably do not develop strong thermal stratification, since bottom temperatures were fairly high when sampled. It is likely that they are well mixed by winds since they are not excessively deep (maximum depths average about 10 m). Dissolved oxygen concentration was also uniform with depth in the survey lakes, and oxygen saturation was in the range of 80% to 105%.

The means and ranges of water quality results for the 10 lakes are summarized in Table 34. Calcium and bicarbonate were the major ions in each of the lakes during September. Total dissolved solids (i.e., total filterable residue) ranged from 84 to 142 mg/L and averaged 115 mg/L. Total alkalinity ranged between 65 and 99 mg/L and averaged 77 mg/L (as $CaCO_3$). The pH values exhibited a high range of 7.5 to 9.1. Factors not assessed in this study, such as photosynthesis, may have had significant influences on pH in these lakes.

Only one lake (Lake #8, Site L1) had total phosphorus concentrations above 0.016 mg/L (the analytical detection limit). Moderately high Secchi disc visibilities and low turbidities indicate that plankton biomass was not great at the time of sampling. Ammonia nitrogen was less than 0.05 mg/L in most of the lakes and did not exceed 0.2 mg/L. Reactive silica averaged 6.3 mg/L and total organic carbon averaged 10.5 mg/L at the time of sampling.

The study lakes lie across the boundary of the Canadian Shield and Saskatchewan and Great Slave Plain physiographic divisions (Atlas of Alberta 1969). Although some of the lakes (i.e., Lake #9 and Lake #10) are technically on the Canadian Shield, the extensive surficial sand deposits in the area do not permit differentiation of water quality among the 10 lakes based on bedrock geology. The lakes exhibited total solute concentrations somewhat intermediate between those of shield lakes and those of lakes in sedimentary bedrock. Alkalinities are similar to those reported for other lakes in the immediate area (Table 35).

Table 34. Summary of water quality analyses for lakes in the Richardson Tower area, September 1979.

Parameter	Lake Number										$\bar{x}$	
	1	2	3[a]	4	5	6	7	8[a]	9	10	mg/L	meq/L
Na	4.0[b]	3.1	2.4	2.0	3.6	3.6	1.4	1.2	1.7	1.9	2.5	0.11
K	0.6	0.6	0.3	0.1	0.7	0.7	0.7	0.9	0.9	0.8	0.6	0.016
Ca	17.7	17.7	17.2	21.0	24.1	24.5	16.4	20.6	18.0	26.1	20.3	1.01
Mg	4.9	5.8	5.9	6.3	7.4	7.5	8.3	8.0	4.9	9.1	6.8	0.56
SO_4	3.7	7.4	5.8	1.6	2.1	2.1	4.9	8.7	9.9	8.2	5.4	0.11
Cl	0.3	2.6	1.8	1.9	0.3	0.3	2.4	2.2	2.4	1.6	1.6	0.045
CO_3	0	11	7	0	0	0	10	0	0	1	3	0.1
HCO_3	79	59	76	95	101	103	71	97	79	118	88	1.4
Alkalinity (as $CaCO_3$)												
Total	65	66	74	78	83	84	74	80	65	99	77	1.53
P'thalein	0	9	6	0	0	0	8	0	0	1	3	
pH (pH units)	8.0	9.1	8.7	8.2	8.2	8.2	8.9	7.8	8.3	8.4	8.4	
Hardness, total (as $CaCO_3$)	64.4	68.1	67.2	78.3	90.7	92.1	75.2	84.1	65.1	102.7	78.8	
Total filterable residue												
Evap. @ 105°C	84	118	115	118	118	120	114	104	118	142	115	
Ignit. @ 550°C	54	78	51	44	68	76	50	47	50	88	61	
Conductivity (µS/cm)	138	136	146	149	170	178	138	155	130	185	153	
Turbidity (NTU)	4.2	1.4	2.1	2.8	1.8	1.9	2.0	2.3	2.2	1.7	2.2	
Total P	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	-	<0.016	<0.016	-	
Ammonia-N	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.2	0.08	0.06	<0.05	-	
Reactive silica	7.0	4.0	4.7	5.7	8.8	7.8	3.1	6.9	10.3	4.5	6.3	
Total organic carbon	6.3	13.2	18.2	7.6	8.8	7.3	6.3	8.4	12.2	16.8	10.5	
Fe (total)	0.37	0.17	0.13	0.24	0.15	0.12	0.08	0.19	0.08	0.08	0.16	

[a]Values are means of results from two sites

[b]Values expressed as mg/L unless noted otherwise

Table 35. Total alkalinity reported for lakes adjacent to the Richardson Tower study area.

Lake	Total Alkalinity - mg/L and (meq/L)		
	Turner (1968)	Bradley (1969)	Hesslein (1979)
	July-Aug./67	July/67	Oct./76
Pearson		63 (1.25)	86 (1.71)
Larocque	75 (1.50)		66 (1.32)
Barber	35 (0.7)		
Unnamed (Tp. 102-103, R5, W4)	122 (2.43)		62 (1.23)

The physical-chemical suitability of the water of most of these lakes for fish habitat appears to be high. This assessment is supported by the presence of populations of several species of fish in each lake surveyed. Most lakes were well oxygenated in September, and contained low plankton biomass (as indicated by turbidity and Secchi visibility). This suggests that these lakes do not contain a sestonic organic content that would lead to serious oxygen deficiencies due to organic decomposition in winter. Lake #8 (east basin) and Lake #1, however, showed oxygen values about 80% of saturation when all other sites were 90% saturated or greater. Whether this indicates that significant oxygen deficiencies would develop at extreme times, such as during ice-cover, is not known. Additional sampling is required to determine oxygen regimes with a high degree of certainty. Lake #8, although not markedly brown-coloured, appeared to have somewhat darker coloured water than the rest of the lakes. The east basin of this lake was the only location with measurable concentrations of total phosphorus and both basins had ammonia concentrations higher than most of the other lakes. These facts may indicate a higher organic content occurs in this lake which imparts a higher oxygen demand to its waters.

5.3 SUBSTRATE

The primary bottom type in all of the lakes was either silt or an organic sediment. The organic sediment, which was predominant in Lake #2, Lake #3, and Lake #7, was orange to light brown in colour and was flocculent with a very low density. This very soft material would likely provide a poor habitat for benthic macroinvertebrates. Esso Resources Canada Limited (1979) noted that invertebrate standing crop was relatively low on a similar organic substrate in Leming Lake, Alberta.

Most of the lakes sampled had a large amount of sand substrate or a substrate consisting of a thin layer of silt or organic material over a hard sand substrate (range--4% sand substrate in Lake

#1 to 33% in Lake #4). Gravel or rubble substrates contributed a very small percentage of the bottom material in most of the lakes (less than 1% of the area in five of the lakes and less than 10% in all but one lake). Unnamed Lake #7 had the greatest amount of gravel-rubble substrate (13% of the area). Since this type of substrate is the preferred spawning habitat for lake whitefish and walleye, it is postulated that the small amount of gravel-rubble may affect reproduction of these species in some of the lakes (i.e., Lakes #1, #2, #3, #4, #9, and #10). Walleye were present in only two of these lakes (Lakes #2 and #10) while lake whitefish were present in all of them. It is apparent, therefore, that lake whitefish, and probably walleye, can successfully spawn on a hard sand substrate. Bidgood (1972) reported lake whitefish spawning on sand, but he felt that survival may be reduced since the eggs would be more susceptible to predation.

5.4 FISH

Ten species of fish were either collected or observed in the 10 study lakes (Table 33). Northern pike were present in all of the lakes. Lake whitefish occurred in all lakes except Lake #8, and walleye were present in five lakes (Lakes #2, #4, #5, #6, and #10). Yellow perch were noted in most of the lakes; however, they were either not abundant or too small in size to contribute substantially to a sport fishery. Cisco were captured only in Lakes #5 and #6 where they appeared to be present in low numbers.

All of the 10 lakes studied contained sportfishes, indicating that physical and chemical conditions in these lakes are suitable to support such fish populations. Northern pike, which were present in all of the study lakes, appeared to be most abundant in Lakes #3 and #8. Both of these lakes supported extensive growths of aquatic vegetation which is an essential habitat requirement for successful northern pike spawning and rearing (Fabricius and Gustafson 1958). Lake #1, Lake #5, and Lake #6 also supported substantial growths of aquatic vegetation and appeared to have moderate populations of northern pike. Lake #10 had very little emergent or floating-leafed vegetation and appeared to have a low northern pike population. Extensive growths of aquatic vegetation also provide prime spawning and rearing habitat for species such as yellow perch, spottail shiner, and ninespine stickleback (Scott and Crossman 1973).

Walleye were present in the three deepest lakes (Lake #2, Lake #4, Lake #10). They were also present in Lake #5 and Lake #6 where maximum depths were less than those recorded in the other survey lakes which did not support walleye (e.g., Lake #9). The reason for the absence of walleye populations in Lakes #1, #3, #7, #8, and #9 is not clear but may be related to the shallow depths in some of these lakes.

Table 36 contains length-weight regression formulas and mean condition factors calculated for lake whitefish, northern pike, and walleye from the study lakes. Combined age-length data (i.e., data from all 10 study lakes) for these three species are presented in Figures 75 to 77, respectively. Comparable age-length data for other populations in northeastern Alberta are included. McCart et al. (1979) examined lakes in the vicinity of Cold Lake while Turner (1968a, 1968b) surveyed lakes in the Birch Mountains and lakes south of Lake Athabasca. The age-length relationship of lake whitefish in the study area was similar to that determined in the other studies. The growth of walleye in the study lakes was similar to that determined for populations in the Cold Lake area and lakes south of Lake Athabasca; however, walleye grew faster in lakes in the Birch Mountains. Northern pike grew at a similar rate in lakes in the present study area and in the Cold Lake area. Pike apparently grew faster in the areas examined by Turner (1968a, 1968b).

Table 37 compares the surface areas, morphoedaphic indices, and estimates of harvestable fish production for the 10 study lakes. Based on the regression equations relating harvestable fish production and the morphoedaphic index it appears that Lake #3 is the most productive per unit area. This is primarily a reflection of its shallow

Table 36. Weight-length regression formulas and mean condition factors for lake whitefish, northern pike, and walleye from the study lakes.

	LAKE WHITEFISH		NORTHERN PIKE		WALLEYE	
	Regression Formula	Condition Factor	Regression Formula	Condition Factor	Regression Formula	Condition Factor
Lake #1	$W = 1.385 \times 10^{-6} L^{3.342}$ $r^2 = 0.99$, N = 52	1.38 ± 0.02	$W = 8.671 \times 10^{-4} L^{2.205}$ $r^2 = 0.81$, N = 20	0.64 ± 0.02		
Lake #2	$W = 1.026 \times 10^{-5} L^{3.038}$ $r^2 = 0.96$, N = 34	1.28 ± 0.01	$W = 8.126 \times 10^{-7} L^{3.330}$ $r^2 = 0.97$, N = 22	0.67 ± 0.02	$W = 3.553 \times 10^{-6} L^{3.180}$ $r^2 = 0.98$, N = 33	1.04 ± 0.03
Lake #3	$W = 2.770 \times 10^{-6} L^{3.269}$ $r^2 = 0.98$, N = 48	1.43 ± 0.02	$W = 2.502 \times 10^{-6} L^{2.778}$ $r^2 = 0.74$, N = 34	0.64 ± 0.01		
Lake #4	$W = 2.588 \times 10^{-6} L^{3.288}$ $r^2 = 0.99$, N = 54	1.44 ± 0.02	$W = 2.580 \times 10^{-6} L^{3.150}$ $r^2 = 0.99$, N = 18	0.65 ± 0.01	$W = 3.981 \times 10^{-6} L^{3.162}$ $r^2 = 0.99$, N = 33	1.06 ± 0.01
Lake #5	NC[a]	1.86 ± 0.04 N = 6	$W = 6.185 \times 10^{-5} L^{2.634}$ $r^2 = 0.94$, N = 31	0.65 ± 0.01	$W = 3.576 \times 10^{-6} L^{3.184}$ $r^2 = 0.98$, N = 42	1.08 ± 0.02
Lake #6	NC[a]		$W = 7.817 \times 10^{-6} L^{2.963}$ $r^2 = 0.99$, N = 18	0.62 ± 0.01	$W = 5.331 \times 10^{-6} L^{3.105}$ $r^2 = 0.97$, N = 44	0.99 ± 0.02
Lake #7	$W = 3.194 \times 10^{-6} L^{3.249}$ $r^2 = 0.97$, N = 69	1.33 ± 0.02	$W = 3.318 \times 10^{-5} L^{2.753}$ $r^2 = 0.97$, N = 25	0.68 ± 0.01		
Lake #8			$W = 2.894 \times 10^{-5} L^{2.719}$ $r^2 = 0.97$, N = 49	0.63 ± 0.01		
Lake #9	$W = 7.313 \times 10^{-6} L^{3.102}$ $r^2 = 0.98$, N = 48	1.35 ± 0.02	$W = 3.787 \times 10^{-6} L^{3.093}$ $r^2 = 0.99$, N = 31	0.67 ± 0.01		
Lake #10	$W = 4.250 \times 10^{-6} L^{3.175}$ $r^2 = 0.99$, N = 69	1.12 ± 0.02	NC[a]	0.81 ± 0.02 N = 9	$W = 1.019 \times 10^{-6} L^{3.395}$ $r^2 = 0.99$, N = 33	1.08 ± 0.02

[a] Not calculated due to small sample size ($N < 15$)

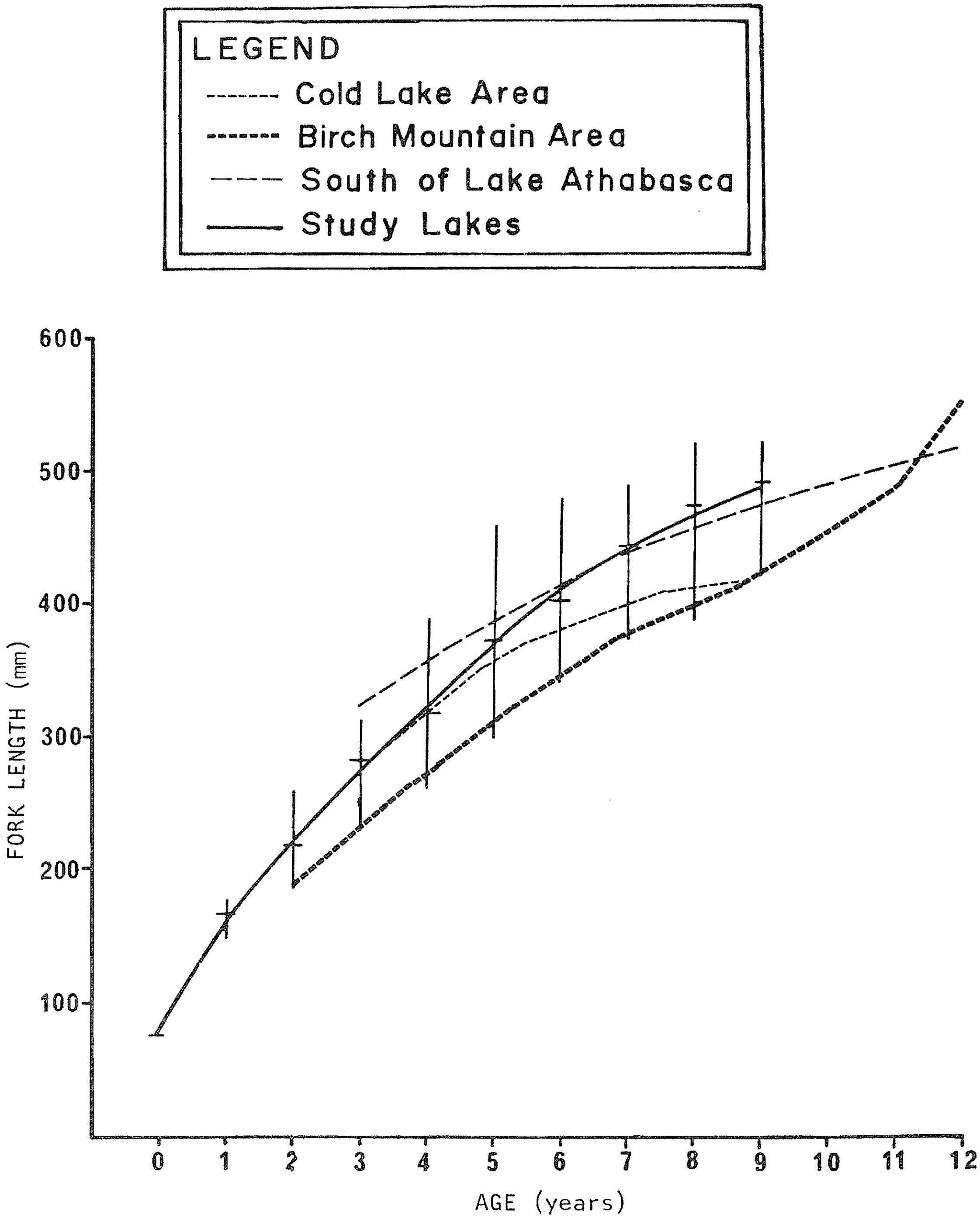

Figure 75. Comparison of age-length data for lake whitefish from the lakes in the present study, in the Cold Lake area (McCart et al. 1979), in the Birch Mountain area (Turner 1968a), and south of Lake Athabasca (Turner 1968b). The vertical lines indicate the range of the mean fork length at each age for the lakes in the present study.

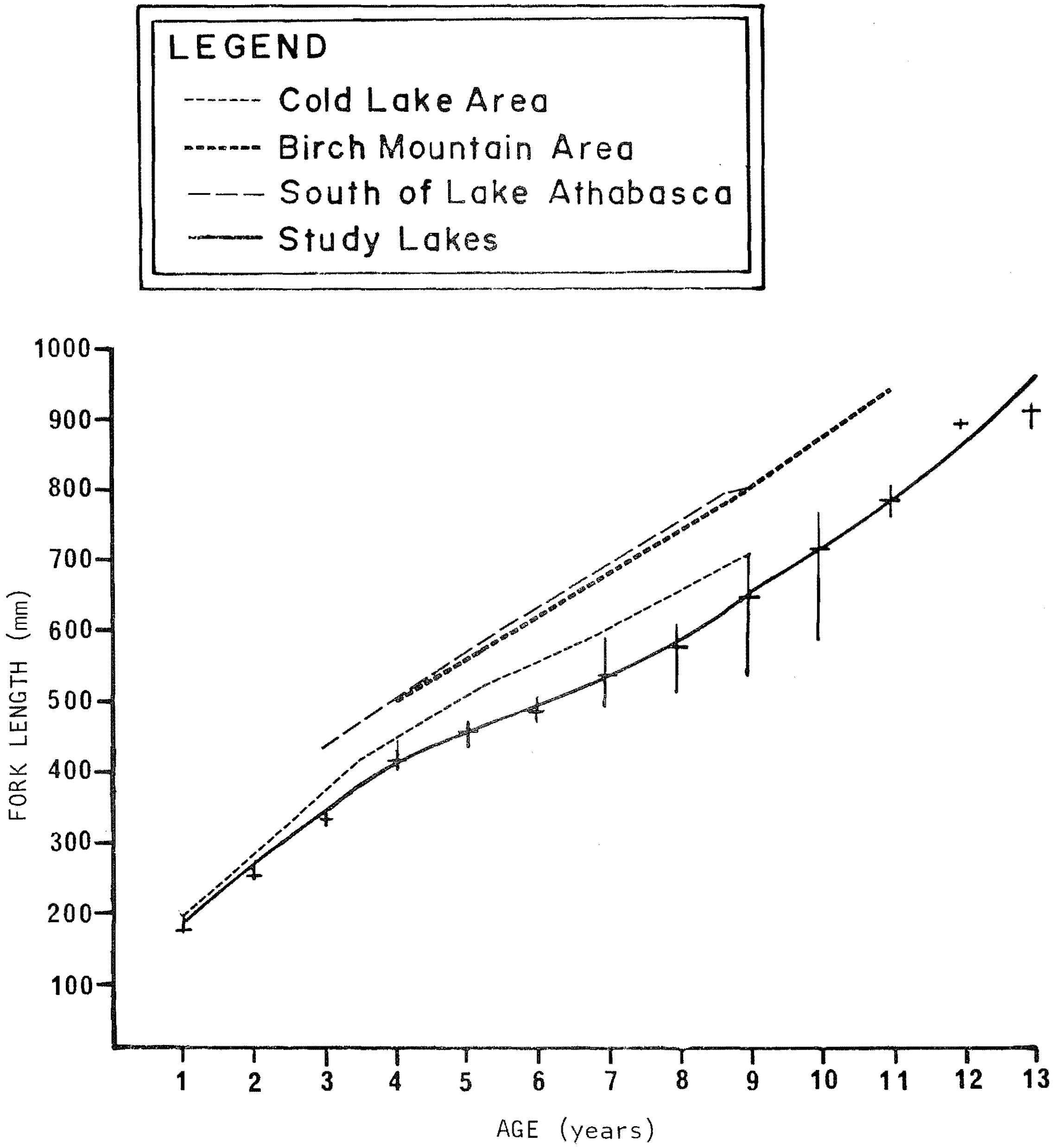

Figure 76. Comparison of age-length data for northern pike from the lakes in the present study, in the Cold Lake area (McCart et al. 1979), in the Birch Mountain area (Turner 1968a), and south of Lake Athabasca (Turner 1968b). The vertical lines indicate the range of the mean fork length at each age for the lakes in the present study.

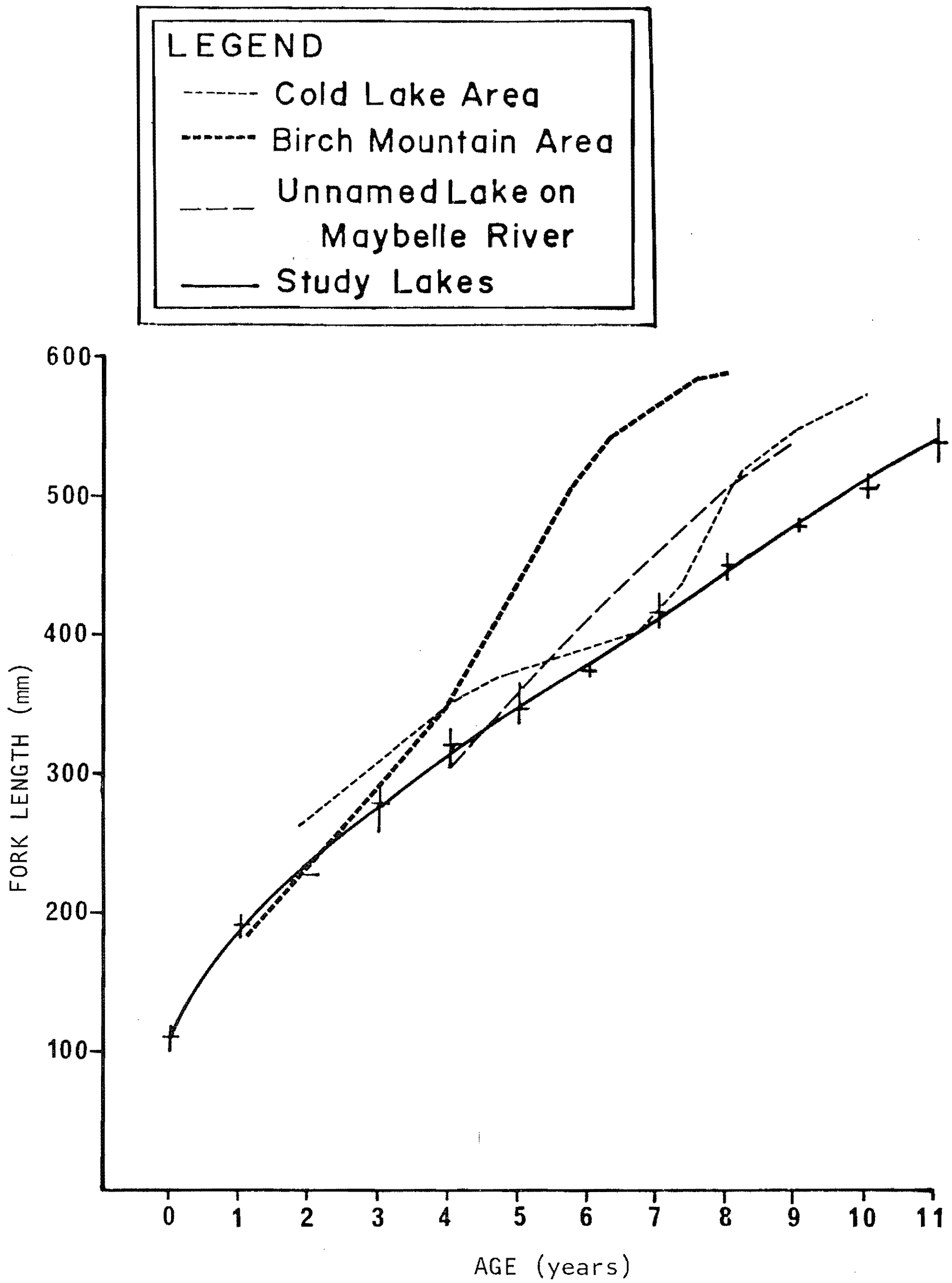

Figure 77. Comparison of age-length data for walleye from the lakes in the present study, in the Cold Lake area (McCart et al. 1979), in the Birch Mountain area (Turner 1968a), and in Unnamed Lake on the Maybelle River (Turner 1968b). The vertical lines indicate the range of the mean fork length at each age for the lakes in the present study.

Table 37. Summary of harvestable fish production estimates for 10 lakes in the Richardson Tower area (see Figure 1 for lake location).

Lake Number	Surface Area (ha)	Morphoedaphic Index (metric units)	Estimate of Harvestable Fish Production Using Regression Model By: Ryder (1965) (kg/ha/yr)	Ryder (1965) (kg/yr)	Allan (1975) (kg/ha/yr)	Allan (1975) (kg/yr)	Sportfish[a] kg/yr
1	67.4	16.2	4.8	320	6.5	440	32- 44
2	156.3	28.1	6.1	950	8.2	1280	590- 790
3	116.3	61.0	8.6	1000	11.5	1340	230- 310
4	103.4	24.6	5.8	600	7.8	810	160- 210
5	157.2	30.2	6.3	990	8.5	1340	840-1140
6	116.5	28.6	6.2	720	8.3	970	560- 760
7	169.7	54.3	8.2	1390	10.9	1850	670- 890
8	112.2	27.4	6.0	670	8.1	910	650- 880
9	215.1	23.1	5.6	1200	7.6	1640	380- 520
10	338.9	17.8	5.0	1690	6.7	2270	960-1290

[a] Based on percentage by weight of sportfish in the gillnet catch.

mean depth. Lake #1 had the lowest morphoedaphic index as well as the lowest estimate of harvestable fish production. Total harvestable fish production for the 10 study lakes ranged from 320 to 440 kg/yr for Lake #1 to 1690 to 2270 kg/yr for Lake #10. Harvestable sportfish production, calculated using the percentage (by weight) of sportfish in the gillnet catch, ranged from 32 to 44 kg/yr in Lake #1 to 960 to 1290 kg/yr in Lake #10. Since the percentage of sportfish generally was based on only one overnight gillnet set, these calculations could be subject to considerable error. As such, they should be used only to give an estimate of sportfish potential in each lake.

The Terms of Reference for the present study required an assessment of the physical and chemical suitability of the study lakes to support introduced species of fish (i.e., trout). All of the study lakes, with the possible exception of Lake #8, provide suitable habitat for species such as rainbow trout (*Salmo gairdneri*) or brook trout (*Salvelinus fontinalis*). Generally, maximum depths greater than 5.5 m are required for overwinter survival of these species (Alberta Fish and Wildlife Division 1970) and to ensure that maximum summer temperature limits are not exceeded. It is doubtful that trout would successfully reproduce in any of the lakes, since none has inlet or outlet streams suitable for trout spawning.

Due to the presence of piscivorous indigenous species (e.g., northern pike) in each of the 10 study lakes, they would have to be treated with a fish toxicant (e.g., rotenone) prior to stocking with a trout species to ensure survival of the introduced species. This would be expensive. For example, appropriate treatment costs for fish toxicant only (at concentration of 1.4 ppm[1]) would be $22 000 (based on $35/4.5 L for toxicant) for the smallest lake (Lake #1 - 67.4 ha). Prior to any stocking program, more detailed site investigations would have to be conducted to determine possible requirements for fish

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[1] Concentration used during treatment of Carson Lake, Alberta (Makowecki et al. 1978).

barriers on outlet and inlet streams to prevent the return of undesirable fish species after treatment.

5.5 ACIDIFICATION RISK

Increasing emissions of sulphur and nitrogen oxides in industrialized regions of the world have increased the acidity of precipitation over large areas of eastern North America and Europe (Likens and Bormann 1974, cited in United States-Canada Research Consulting Group 1979). Consequently, many poorly buffered lakes and streams in these regions have shown declines in pH and alkalinity, and some have lost fish populations (Wright and Gjessing 1976; Glass et al. 1979). In the Athabasca Oil Sands, conventional oil extraction plants currently emit considerable amounts of sulphur dioxide and total emissions may increase with further development of extraction facilities (Jantzie et al. 1979).

The ability of a lake to resist acidification is primarily determined by alkalinity and may generally be referred to as its buffering capacity. Glass et al. (1979) and the United States-Canada Research Consultation Group (1979) present criteria of sensitivity to acidification based on alkalinity and related parameters (Table 38). This table also contains values of the calcite saturation index (CSI) that Conroy et al. (1974) and Kramer (1976) have advanced as an indicator of susceptibility to acidification.

Recently, Hesslein (1979) has developed models to predict the resulting steady-state alkalinity of a lake subjected to given precipitation acidity and the time required to reach that equilibrium state. His steady-state model in its simplest form is:

$$[Alk]_{tf} = [Alk]_{t0} - \frac{[H+]_{tf}}{0.4}$$

where $[Alk]_{tf}$ is the future alkalinity of the lake in eq/L, $[Alk]_{t0}$ is the present alkalinity, $[H+]_{tf}$ is the hydrogen ion concentration in future rain, and 0.4 is the decimal fraction of precipitation that is delivered to the lake as runoff.

Table 38. Acidification sensitivity criteria proposed for various areas of North America.

Sensitivity	Alkalinity meq/L	HCO_3 mg/L	Ca mg/L	Cond. µS/cm	CSI[a]
U.S.-Can. Res. Consulting Group (1979)--Eastern Canada					
Highly sensitive	0 -0.2	1-12	0-4	0-30	
Moderately sensitive	0.2-0.4	12-24	4-8	22-70	
Least sensitive	>0.4	>24	>8	>60	
Glass et al. (1979)--Northwestern Ontario and Northern Minnesota					
Susceptible	0 -0.3				
Potentially susceptible	0.3-0.62				
Not susceptible	>0.62				
Conroy et al. (1974)--Sudbury region, Ontario					
No H+ assimilation capacity					>5
Marginal H+ assimilation capacity					3-5
Adequate H+ assimilation capacity					<3

[a] CSI = calcite saturation index (Conroy et al. 1974; Kramer 1976).

To assess the acidification susceptibility of the 10 study lakes near Richardson Tower, data on alkalinity, calcium and bicarbonate concentrations, and conductivity were compared to the criteria summarized in Table 38. A predicted alkalinity was also calculated for each lake utilizing Hesslein's steady-state model. A summary of these parameters for the study lakes is presented in Table 39. Predicted alkalinity was calculated for future precipitation of pH 4. This likely represents the extreme case, since annual average pH in the most affected regions of eastern North America is apparently about 4.1 (Likens et al. 1979, cited in United States-Canada Research Consulting Group 1979).

Examination of the water quality data in Table 39 shows that the 10 lakes surveyed in this study fall into the least sensitive categories with regard to acidification susceptibility. The lakes are reasonably well buffered and near saturation with respect to calcium carbonate. Also, predicted future alkalinities for precipitation of pH 4 indicate that declines in alkalinity would not be great (13% to 19%) even if acidic fallout were to reach such a severe level. Although the study lakes were sampled at only one point in time, the measured alkalinities are probably a good representation of the true alkalinities in these lakes. Seasonal changes in alkalinity in other lakes examined in the AOSERP study area (Noton and Chymko 1977; Smith 1979) would not be great enough to affect the acidification assessment for these lakes. Further, alkalinities reported for other lakes in the immediate area in different years and seasons (Table 35) are similar to those reported here. Thus, the assessment of acidification risk for the 10 lakes in the present study is adequate.

Hesslein's (1979) formula for predicting future alkalinity is based on the observation that the ionic content of lake water is usually an expression of the geochemistry of the drainage basin (Wetzel 1975), and, therefore, lake alkalinity will reflect the general buffering capability of both the lake and its watershed. In this study area, bedrock geology includes Canadian Shield and sedimentary

Table 39. Alkalinity related parameters of the study lakes and predicted steady-state alkalinities.

Lake	Total Alkalinity mg/L	Total Alkalinity meq/L	HCO_3 mg/L	Ca mg/L	Cond. µS/cm	CSI[a]	Total[b] Alk_{tf} mg/L	Total[b] Alk_{tf} meq/L
1	65	1.30	79	17.7	138	+0.25	53	1.05
2	66	1.32	59	17.7	136	-0.77	54	1.07
3	74	1.48	76	17.2	146	-0.07	62	1.23
4	78	1.56	95	21.0	149	-0.11	66	1.32
5	83	1.66	101	24.1	170	-0.20	71	1.41
6	84	1.68	103	24.5	178	-0.21	72	1.43
7	74	1.48	71	16.4	138	-1.68	62	1.23
8	80	1.59	97	20.6	155	+0.29	68	1.34
9	65	1.30	79	18.0	130	-0.07	53	1.05
10	99	1.98	118	26.1	185	-0.51	87	1.73

[a] CSI - calculated by method of Kramer (1976).

[b] Alk_{tf} - predicted steady-state alkalinity for precipitation of pH 4, using model of Hesslein (1979).

deposits, but both are fully overlain by eolian and morainal material containing much sand and thinly covered sand dunes (Intera Environmental Consultants Ltd. 1979). These deposits likely influence the water quality of the study lakes significantly and apparently impart a good buffering capacity to other lakes in the immediate area as well (see Table 35). The capacity of these deposits to buffer inputs of acid is not directly measured but is implied from the alkalinity of lake waters. Hesslein (1979) points out that the main weakness in his models is "the uncertainty in the response of the terrestrial system to acid rain", and this is likely the biggest unknown in assessing the acidification risk of any waterbody. Although there does not seem to be any sizable risk of acidification of the lakes in this study, Hesslein (1979) notes that there remains the possibility of terrestrial alkalinity being eventually neutralized by acidic precipitation. This would then result in greater inputs of acid to the waterbodies in the drainage systems. Kramer (1976) states that calcareous rock and soil have a "very large" capacity to neutralize acid rain; however, the level of calcareous material in the drainage basins of the study lakes has not been directly assessed. It is inferred to be at least moderately high since the lakes in these basins are fairly well-buffered and are of the calcium bicarbonate type.

The time dependent model developed by Hesslein (1979) predicts the number of years for a lake to achieve a new equilibrium alkalinity given a certain rainfall acidity. As well as assumptions inherent in the steady-state model, this model involves the assumption that the pH of precipitation is constant with time. Since a decline in the pH of precipitation would not be sudden and may be irregular due to weather fluctuations, predicting time dependent changes in pH and alkalinity with this formula would give inaccurate results. In any case, knowing the true rate of change is of questionable value since the steady-state model does not predict a great change in alkalinity of these lakes even for very acidic precipitation.

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7. AOSERP RESEARCH REPORTS

1. AOSERP First Annual Report, 1975
2. AF 4.1.1 Walleye and Goldeye Fisheries Investigations in the Peace-Athabasca Delta--1975
3. HE 1.1.1 Structure of a Traditional Baseline Data System
4. VE 2.2 A Preliminary Vegetation Survey of the Alberta Oil Sands Environmental Research Program Study Area
5. HY 3.1 The Evaluation of Wastewaters from an Oil Sand Extraction Plant
6. Housing for the North--The Stackwall System
7. AF 3.1.1 A Synopsis of the Physical and Biological Limnology and Fisheries Programs within the Alberta Oil Sands Area
8. AF 1.2.1 The Impact of Saline Waters upon Freshwater Biota (A Literature Review and Bibliography)
9. ME 3.3 Preliminary Investigations into the Magnitude of Fog Occurrence and Associated Problems in the Oil Sands Area
10. HE 2.1 Development of a Research Design Related to Archaeological Studies in the Athabasca Oil Sands Area
11. AF 2.2.1 Life Cycles of Some Common Aquatic Insects of the Athabasca River, Alberta
12. ME 1.7 Very High Resolution Meteorological Satellite Study of Oil Sands Weather: "A Feasibility Study"
13. ME 2.3.1 Plume Dispersion Measurements from an Oil Sands Extraction Plant, March 1976
14.
15. ME 3.4 A Climatology of Low Level Air Trajectories in the Alberta Oil Sands Area
16. ME 1.6 The Feasibility of a Weather Radar near Fort McMurray, Alberta
17. AF 2.1.1 A Survey of Baseline Levels of Contaminants in Aquatic Biota of the AOSERP Study Area
18. HY 1.1 Interim Compilation of Stream Gauging Data to December 1976 for the Alberta Oil Sands Environmental Research Program
19. ME 4.1 Calculations of Annual Averaged Sulphur Dioxide Concentrations at Ground Level in the AOSERP Study Area
20. HY 3.1.1 Characterization of Organic Constituents in Waters and Wastewaters of the Athabasca Oil Sands Mining Area
21. AOSERP Second Annual Report, 1976-77
22. Alberta Oil Sands Environmental Research Program Interim Report to 1978 covering the period April 1975 to November 1978
23. AF 1.1.2 Acute Lethality of Mine Depressurization Water on Trout Perch and Rainbow Trout
24. ME 1.5.2 Air System Winter Field Study in the AOSERP Study Area, February 1977.
25. ME 3.5.1 Review of Pollutant Transformation Processes Relevant to the Alberta Oil Sands Area

26. AF 4.5.1 Interim Report on an Intensive Study of the Fish Fauna of the Muskeg River Watershed of Northeastern Alberta
27. ME 1.5.1 Meteorology and Air Quality Winter Field Study in the AOSERP Study Area, March 1976
28. VE 2.1 Interim Report on a Soils Inventory in the Athabasca Oil Sands Area
29. ME 2.2 An Inventory System for Atmospheric Emissions in the AOSERP Study Area
30. ME 2.1 Ambient Air Quality in the AOSERP Study Area, 1977
31. VE 2.3 Ecological Habitat Mapping of the AOSERP Study Area: Phase I
32. AOSERP Third Annual Report, 1977-78
33. TF 1.2 Relationships Between Habitats, Forages, and Carrying Capacity of Moose Range in northern Alberta. Part I: Moose Preferences for Habitat Strata and Forages.
34. HY 2.4 Heavy Metals in Bottom Sediments of the Mainstem Athabasca River System in the AOSERP Study Area
35. AF 4.9.1 The Effects of Sedimentation on the Aquatic Biota
36. AF 4.8.1 Fall Fisheries Investigations in the Athabasca and Clearwater Rivers Upstream of Fort McMurray: Volume I
37. HE 2.2.2 Community Studies: Fort McMurray, Anzac, Fort MacKay
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