May 2011

# APPENDIX E

## ARCHAEOLOGY STUDY

Appendix E.1 Saskatchewan Research Council - Thor Lake Area (NWT) Environmental Baseline Survey January 1989

**Appendix E.1**

**Saskatchewan Research Council - Thor Lake Area (NWT) Environmental Baseline Survey**
**January 1989**

Saskatchewan
Research Council

(306)
Regina 787-9400
Saskatoon 933-5400

# THOR LAKE AREA (NWT) ENVIRONMENTAL BASELINE SURVEY

by


Guy Melville 933-8173
Bob Godwin
Dale Russell
John Polson 933-7817 FAX


Publication


E-901-1-E-89

January, 1989

# THOR LAKE AREA (NWT) ENVIRONMENTAL BASELINE SURVEY

for

SENES Consultants Limited

by

Guy Melville (Editor and Senior Author)
Bob Godwin (Chapter 4)
Dale Russell (Chapter 6)
John Polson (Chapter 5)

SRC Publication No. E-901-1-E-89

January, 1989

## ACKNOWLEDGEMENTS

This study was funded by Senes Consultants Ltd. of Toronto.

We wish to thank a number of people for their contributions to the project. Barry Paquin ably assisted in the collection and processing of aquatic study samples. Bob MacPherson piloted the wildlife crew on their surveys. Darlene Diduck was most helpful in terms of putting the manuscript together (typing, page layout). Dan Richert, Bill Musker, Carol Beaulieu, Brett Smith, Julio Matamala and Mary Moody all provided valuable technical assistance as well.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

# LIST OF TABLES

## LIST OF TABLES (Continued)

# LIST OF FIGURES

LIST OF FIGURES (Continued)

CHEMICAL ELEMENTS

| | |
|---|---|
| actinium | (Ac) |
| aluminum | (Al) |
| americium | (Am) |
| antimony | (Sb) |
| argon | (Ar) |
| arsenic | (As) |
| astatine | (At) |
| barium | (Ba) |
| berkelium | (Bk) |
| beryllium | (Be) |
| bismuth | (Bi) |
| boron | (B) |
| bromine | (Br) |
| cadmium | (Cd) |
| calcium | (Ca) |
| californium | (Cf) |
| carbon | (C) |
| cerium | (Ce) |
| cesium | (Cs) |
| chlorine | (Cl) |
| chromium | (Cr) |
| cobalt | (Co) |
| copper | (Cu) |
| curium | (Cm) |
| dysprosium | (Dy) |
| einsteinium | (Es) |
| erbium | (Er) |
| europium | (Eu) |
| fermium | (Fm) |
| fluorine | (F) |
| francium | (Fr) |
| gadolinium | (Gd) |
| gallium | (Ga) |
| germanium | (Ge) |
| gold | (Au) |
| hafnium | (Hf) |
| helium | (He) |
| holmium | (Ho) |
| hydrogen | (H) |
| indium | (In) |
| iodine | (I) |
| iridium | (Ir) |
| iron | (Fe) |
| krypton | (Kr) |
| lanthanum | (La) |
| lawrencium | (Lr) |
| lead | (Pb) |
| lithium | (Li) |
| lutetium | (Lu) |
| magnesium | (Mg) |
| manganese | (Mn) |
| mendelevium | (Md) |
| mercury | (Hg) |
| molybdenum | (Mo) |
| neodymium | (Nd) |
| neon | (Ne) |
| neptunium | (Np) |
| nickel | (Ni) |
| niobium | (Nb) |
| nitrogen | (N) |
| nobelium | (No) |
| osmium | (Os) |
| oxygen | (O) |
| palladium | (Pd) |
| phosphorous | (P) |
| platinum | (Pt) |
| plutonium | (Pu) |
| polonium | (Po) |
| potassium | (K) |
| praseodymium | (Pr) |
| promethium | (Pm) |
| protactinium | (Pa) |
| radium | (Ra) |
| radon | (Rn) |
| rhenium | (Re) |
| rhodium | (Rh) |
| rubidium | (Rb) |
| ruthenium | (Ru) |
| samarium | (Sm) |
| scandium | (Sc) |
| selenium | (Se) |
| silicon | (Si) |
| silver | (Ag) |
| sodium | (Na) |
| strontium | (Sr) |
| sulphur | (S) |
| tantalum | (Ta) |
| technetium | (Tc) |
| tellurium | (Te) |
| terbium | (Tb) |
| thallium | (Tl) |
| thorium | (Th) |
| thulium | (Tm) |
| tin | (Sn) |
| titanium | (Ti) |
| tungsten | (W) |
| unnilhexium | |
| unnilpentium | (Unp) |
| unnilquadium | (Unq) |
| uranium | (U) |
| vanadium | (V) |
| xenon | (Xe) |
| ytterbium | (Yb) |
| yttrium | (Y) |
| zinc | (Zn) |
| zirconium | (Zr) |

# 1 SUMMARY

This environmental baseline survey was undertaken in September, 1988, in response to a request from Senes Consultants Ltd., regarding the development of the Thor Lake Joint Venture ore body. The Thor Lake project is located approximately 100 km east-southeast of Yellowknife, near the north shore of Great Slave Lake, NWT. Beryllium (Be) and rare earth elements are found in the ore deposits targeted for mining. The proposed mine is relatively small in size.

## Aquatic Studies

From an aquatic aspect, the two objectives of greatest immediate interest are characterization of the water quality and large-fish populations in lakes in close proximity to the mine development site. Other aquatic components considered include lake morphometrics, interlake surface water improvements, phytoplankton biomasses and arthropod zooplankton communities. Additional work will be carried out in 1989.

There are four watersheds of concern in this study. The first involves drainage from small Cressy Lake, the prospective tailings disposal area. Fred Lake, Fred Stream and Lake "A" are situated in this watershed. The second is the watershed downstream from Den Lake, which begins adjacent to both the intended open pit and waste rock dump. "B" Lake and others occur below Den Lake; drainage from this watershed enters large Blachford Lake to the north. A third watershed consists of Thor Lake and many smaller water bodies which drain into it. Thor Lake is one of the two largest lakes in close proximity to the mine development area. Ring Lake, the proposed alternate tailings area, is part of

this watershed. The other larger lake is Elbow, the fourth "watershed." Elbow Lake is the lake to which Thor Lake is compared.

Thor and Elbow Lakes are generally similar in terms of their small sizes. However, the mean depth of Elbow Lake is twice that of Thor Lake, because Elbow has a deep north basin. Thus, the volume of Elbow Lake is approximately double the volume of Thor Lake. The other four study lakes (Cressy, Ring, A, B) have very small surface areas, much smaller than the areas of Thor and Elbow Lakes. Cressy and A Lakes are relatively deep for their surface areas. Ring and B Lakes are very shallow, and undoubtedly freeze to the bottom in many years.

Lake A develops a pronounced thermocline (thermo-density gradient with depth), while Elbow Lake appears to develop a thermocline as well. Ring and B Lakes are far too shallow to develop thermoclines; Thor and Cressy Lakes are probably too shallow as well.

$O_2$ concentrations in the upper waters of all lakes were near saturation. Concentrations were low only near lake bottoms, or below thermoclines where they occurred. All lake waters were moderately hard to hard, and moderately well to well buffered. Trace element and radionuclide concentrations were generally low to very low. They were often below detection limits and Canadian guidelines for aquatic life, where guidelines exist.

A very low rate of discharge was obtained for tiny Fred Stream. No flowing water was observed immediately below Cressy, Ring and B Lakes. Continuous peatland made up shorelines where one could otherwise expect outflow from these lakes; the same was true of Elbow Lake. No open water occurred in the peatland between Cressy and Fred Lakes. This area was investigated on foot.

Chlorophyll a concentrations suggest that Cressy Lake is eutrophic (nutrient rich), Thor Lake is mesotrophic and the other lakes are oligotrophic (nutrient poor).

Each of the study lakes contains one of two basic arthropod zooplankton community types. The communities in Cressy, Ring and B Lakes are characterized by large-bodied zooplankters, while small-bodied zooplankters predominate in Thor, Elbow and A Lakes. The difference between the two types can be attributed largely to a difference in the degree of fish predation. The presence of the copepod Limnocalanus macrurus, a glacial opportunist (found in glacial remnant systems) in Elbow and A Lakes is noteworthy.

The large-fish species were lake whitefish, cisco and northern pike in Thor and Elbow Lakes. No large fish were caught in Cressy Lake with intensive fishing. It may be referred to as fishless. When ice covered, this little lake could be devoid of $O_2$ in some years; this winterkill characteristic, plus isolation which prevents immigration, would explain the absence of fish there. Tiny Ring and B Lakes also appear fishless. However, Lake A may contain fish, although this possibility is yet to be confirmed.

Large fish in Thor Lake were much more abundant, in terms of biomass and numbers, than in Elbow Lake. These results are explained by the fact that Thor Lake is a warmer, more nutrient rich system than Elbow Lake. Whitefish made up two thirds to three quarters of the catch, while pike made up most of the remainder.

Large-fish populations were made up primarily of larger individuals within narrow size ranges. There were very few older juvenile whitefish and pike. The populations are typical of the pattern predominant in unexplained arctic and subarctic large-fish populations.

Large-fish in Elbow Lake grew at greater rates, in terms of biomass accumulation, than did large-fish in Thor Lake. These results suggest that more intraspecific competition occurs in Thor Lake than in Elbow Lake.

Data on reproductive condition suggest that not all mature whitefish in Thor and Elbow Lakes spawn, or reproduce, every year.

Analyses of flesh and bone from Thor Lake whitefish and pike indicate that most trace elements and radionuclides are below the limits of detection.

The lakes in the Thor Lake area are generally similar to many lakes near Yellowknife, NWT, in terms of all the components studied.

## Terrestrial Plant Studies

From the aspect of terrestrial plants, the objectives are to: 1) characterize the vegetation communities and prepare a biophysical map, 2) identify the presence of rare plants in the development area, and 3) describe the elements found in a representative lichen of the region. The biophysical map is important for identifying wildlife habitats and sensitive areas for wildlife. A survey for rare plants is necessary for the purpose of protecting sites that may be important for the maintenance of a species. Lichens largely derive their nutrients from the air and, therefore, are useful for monitoring fine particulates which are emitted to the atmosphere, and then settle out.

Three species of plants of restricted range in the Northwest Territories were identified near Thor Lake: *Prunus pennsylvanica*, *Chamaer-*

hodos erecta and Campanula rotundifolia. All are species occurring at the northern edge of their ranges; none are endemic to the NWT. They occurred in areas with warm micro and local climates. Prunus pennsylvanica and Campanula rotundifolia may be widespread on suitable rock outcrops along the shore of Great Slave Lake. Chamaerhodos erecta is an inconspicuous species and may be easily missed in plant surveys. Thus its occurrence may be understated in collections from the area, particularly from crumbly rock substrates.

Elevated concentrations of some elements of interest (Ce, also La, Nd and Sm) occurred in the Cladina samples collected at the Den Lake site, nearest the ore deposit. These levels may occur naturally because of proximity to the ore body. Anthropogenic causes of elevated element levels cannot be ruled out because of the exploration activity. Concentrations of other elements, including radionuclides, were comparable to data in the literature.

Upon decommissioning of the mine site, caution must be taken to prevent mixing of mine rock wastes with replaced soils, or problems with reestablishing vegetation could occur. Beryllium is known to inhibit germination of seeds and the uptake of Ca and Mg by roots.

A mapped biophysical classification is arrived at, based on the vegetation, landforms and soils in the Thor Lake area. Eight vegetation communities are delineated, based on a field survey. The soils are described based largely on available literature but in combination with observations made in the field and from air photos. Seven biophysical units are described.

## Wildlife Studies

The purpose of the wildlife study is to characterize the wildlife potential of the Thor Lake mine lease. Investigations completed to date include aerial surveys for active beaver lodges and fall waterfowl. Studies to be completed include winter ungulate and spring raptor aerial surveys.

The region to the immediate west of the mine lease appears more attractive to beaver, with over 200% more lodges observed. The large number of inactive lodges there compared to the mine lease area also suggests that the habitat supports a more dynamic population with greater fluctuations. No suitable shallow water bodies or other features were observed during the survey which would indicate muskrat activity.

The distribution of waterfowl was not uniform, as twice as many birds were observed to the west of the mine lease area.

The habitats within the mine lease could support diverse resident wildlife. However, a more detailed assessment must wait until surveys for ungulates and raptors have been completed.

## Archaeology Studies

The objectives of the archaeology study were to: 1) review the relevant literature, 2) examine, on foot, areas which might have been used as campsites, whether in the historic period in precontact times, 3) record the locations of archaeological sites discovered, 4) record the characteristics of sites found, and 5) recover samples of exposed artifacts. The study location consisted of, primarily, areas to be affected by construction, as well as ones where disturbances had already occurred.

The north shore of Great Slave Lake immediately south of Thor Lake is of special archaeological interest. There are few protected locations conducive to camping along the shore because it is marked by sudden relief. The beach and point of land, marking the start of the road from Great Slave Lake to Thor Lake, could have provided one of few accessible camp spots in this section of shoreline.

Three sites were recorded. The Reg Site (KaPb-4) consists of prehistoric and recent material found at the docking area and adjacent road at Great Slave Lake. Four artifacts were collected; three white quartz biface fragments and one bone hide flesher. The biface fragments were from about 200 to 1500 years old, based on the distances between the current shoreline and the locations where the artifacts were found. The hide flesher, made from a large ungulate bone, is probably of recent vintage.

The second, or Lori site (KaPb-3), is a prehistoric lithic debitage scatter on the crest of the high ridge south of Den Lake and east of the mine site. The Strathcona site (KaPb-2) is the disused diamond-drilling exploration camp at the west end of Thor Lake.

The Reg site on Great Slave Lake seems to have been seldom used, perhaps because it lies half way between McKinley Point to the east and the mouth of the Francois River to the west. These latter landmarks are within a day's travel of each other. It was not expected that material would be found at the mine site, since it is situated on low-lying ground. People probably made little use of the area because there were excellent access routes into the interior by means of the nearby Francois and Beaulieu Rivers.

No further work is recommended at the Reg site, Great Slave Lake, because of the sparsity of artifacts. However, since cultural materials were found under the lichen cover on the north half of the beach, this area should be avoided by future development. Any further development should be placed in the south half of the beach, where development has already taken place.

## 2 GENERAL INTRODUCTION

This environmental baseline survey was undertaken in response to a request from Senes Consultants Ltd., regarding the development of the Thor Lake Joint Venture ore body. The Thor Lake project is located approximately 100 km east-southeast of Yellowknife, near the north shore of Great Slave Lake, NWT. Access to the property is by float or ski plane, and barge or winter road on Great Slave Lake. Eight kilometres of road connect Great Slave Lake and the site of the proposed mine.

Beryllium (Be) and rare earth elements are found in the ore deposits targeted for mining, part of the Blachford Lake alkaline complex. Syenites, granites and various phases of these rocks, including pegmatites, comprise the principal rock types. The geology of the area is Precambrian, of the Aphebian age.

The proposed mine site is relatively small in size, and will include: a small open pit mine, ore stock piles, waste rock piles, concentrator, effluent monitoring ponds and a tailings disposal site. A 520 m test adit exists, established for bulk ore sampling. The road to Great Slave Lake must also be considered in an environmental survey.

This report is organized into sections dealing with studies of aquatic environments (abiotic and biotic), terrestrial plants, wildlife and archaeology in the Thor Lake area. Specific objectives are outlined under major section headings.

# 3 AQUATIC STUDIES

## 3.1 Introduction

### 3.1.1 Objectives

The two objectives of greatest immediate interest are characterization of the water quality and large-fish populations in lakes in close proximity to the mine development site. Uncontaminated water is essential to the good health of life, while large fish are an important human food source.

Other aquatic components are also considered. These include lake morphometrics, interlake surface water movements, phytoplankton biomasses and arthropod zooplankton communities. Lake morphometrics are essential to the understanding of biological productivity in lakes. Phytoplankton constitute part of the base of an aquatic food web, while zooplankton are an intermediate link. Many crustacean zooplankton eat phytoplankton, and in turn are eaten by very young and small fish. Additional studies are to be carried out in 1989 (Melville et al. 1988).

Recent data for lakes near Yellowknife (e.g., Ostrofsky and Rigler 1987) provide a basis for comparison with all aspects of this study.

### 3.1.2 Objectives in Relation to Study Area

There are four watersheds of concern in this study (Figure 3.1). The first involves drainage from small Cressy Lake, the prospective tailings disposal area. The second is the watershed downstream from Den Lake, which begins adjacent to both the intended open pit and waste rock dump. A third watershed consists of Thor Lake and many smaller water bodies which drain into it. Thor Lake is one of the two largest lakes in close proximity to the mine development area. Ring Lake, the propos-

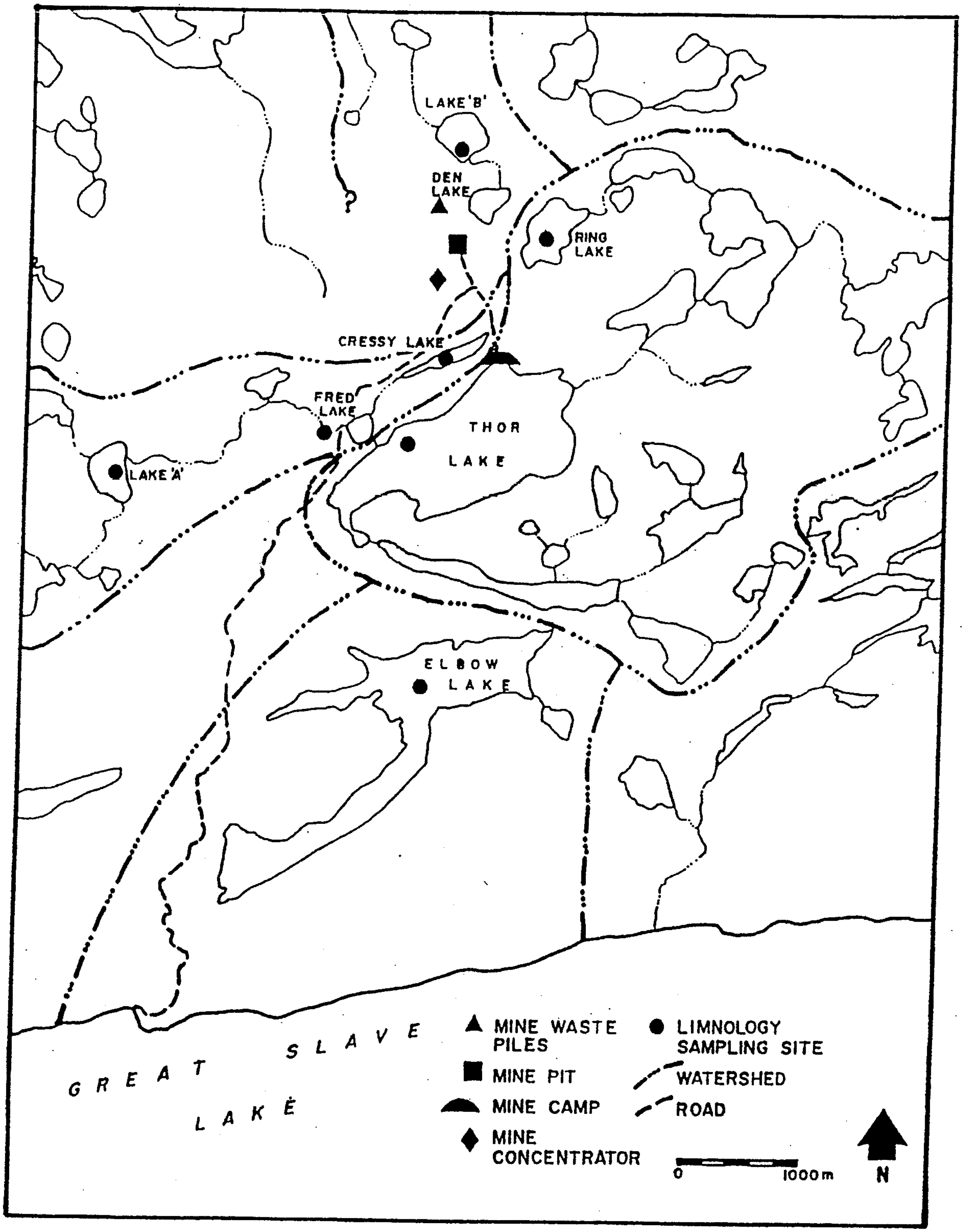



Figure 3.1 Map of the Watersheds in the Thor Lake Area. Major Proposed Mine Installations and Limnology Sampling Sites are Included. Camp and Roads are Already in Place.

ed alternate tailings area, is part of this watershed. The other larger lake is Elbow, the fourth "watershed." Water from Elbow Lake seeps into Great Slave Lake over a distance of 1.1 km.

#### 3.1.2.1 Cressy Lake Drainage

Water from Cressy Lake seeps southwest through peatlands into tiny Fred Lake, 0.4 km away (Figure 3.1). From Fred Lake, the water moves west through small Fred Stream and extensive peatlands into another small lake, "A". Beyond Lake A, the water travels southwest through many small lakes and peatlands, and eventually into Great Slave Lake.

Material to be discharged into the tailings disposal area will include treated tailings, discharge from the concentrator and excess mine drainage which cannot be used in the concentrator. Therefore, description of the water quality in the path of drainage from Cressy Lake, prior to the discharge of tailings, is a prime consideration in this study.

#### 3.1.2.2 Thor Lake Inflow System

The water quality objective applies to Thor Lake, which is downstream of Ring Lake (Figure 3.1), the alternate tailings disposal area. Thor Lake also abuts the mining camp area. This lake is big enough to have substantial large-fish populations, so characterization of such populations, and a description of the elemental composition of key species, are of immediate interest as well. Elbow Lake was chosen as a reference for Thor Lake.

#### 3.1.2.3 Watershed Below Den Lake

In addition, the water quality downstream from Den Lake (Figure 3.1) is described. This watershed contains the rock waste piles, in addition to the open pit and ore storage piles. The system could receive runoff from these features. The four lakes in the system are very small, but they lead to large Blachford Lake.

All lakes in the watershed are separated by peatlands.

### 3.1.3 Limnology Sampling Sites

Seven sites were selected, six lakes and one stream.

#### 3.1.3.1 Cressy Lake Drainage

Three sampling sites were chosen (Figure 3.1): Cressy Lake, Fred Stream just downstream of Fred Lake, and Lake A. The Fred Stream site is close to the area where water seeps through from Cressy Lake. The Cressy water is diluted in Fred Lake by inflow from Thor Lake. Lake A provides an indication of the overall quality of the water downstream of the proposed tailings.

#### 3.1.3.2 Thor Lake Inflow System

Two sites were chosen in this system, Ring and Thor Lakes (Figure 3.1). The Thor Lake water quality site is adjacent to the point of outflow into Fred Lake. This site provides an indication of the quality of the "dilution" water, which will mix with water in the area of Fred Lake where tailings water will seep through from Cressy Lake. A third sampling site was selected outside the Thor Lake drainage system, on Elbow Lake, for comparison with Thor Lake.

#### 3.1.3.3 Watershed Below Den Lake

A single site, Lake "B" adjacent to Den Lake, was selected in this watershed. Both of these tiny lakes could receive runoff directly from the waste rock piles, ore storage piles and the periphery of the open pit mine. Lake B also receives seepage from Den Lake.

## 3.2 Methods

All fieldwork was done in September 1988.

### 3.2.1 Abiotic

#### 3.2.1.1 Lake Morphometry

Depth profiles on almost 40 transects were obtained for Elbow Lake. The lake was sounded using a Furuno F21 echo sounder, mounted in a motorized canoe driven at constant speed. Several hand-line soundings were made in all study lakes.

Elbow Lake depth profiles were transferred to an outline lake map of known scale. A bathymetric map was then produced, by determining depth contours from the sounding profiles.

Bathymetric maps of Thor, Cressy and Ring Lakes were obtained from Strathcona Mineral Services Limited by way of Senes Consultants Limited. Lake morphometry variables were calculated from the bathymetric maps.

#### 3.2.1.2 Temperature and Water Quality

In situ measurements included temperature, oxygen ($O_2$), and conductivity profiles. These were obtained using commercial electronic meters. Transparency data for lakes were obtained using a Secchi disc.

Grab samples were taken of surface waters (ca. 1.0 m), while bottom waters in deeper lakes were sampled with a Kemnerer bottle. pH and alkalinity measurements were made in the field, by meter and titration (APHA 1975) respectively. Water for laboratory analyses were treated according to methods specified by the SRC analytical laboratory (1988). The SRC laboratory analyzed the samples for solids, major ions, micronutrients, trace elements and radionuclides.

#### 3.2.1.3 Stream Flow

Depths and current speeds were measured at 0.1 m intervals in Fred Stream, just downstream of the road between the mine site and Great Slave Lake. A discharge rate was calculated from these data. The composition of the stream bed was also noted.

A stream gauge was installed and surveyed at the sampling site.

### 3.2.2 Biotic

#### 3.2.2.1 Phytoplankton

Chlorophyll samples were taken as indicators of phytoplankton biomass in lakes. Untreated portions of the water quality samples were filtered by hand-operated suction pump, and the (Whatman GF/C) filters, with algae, preserved in methanol. Samples were refrigerated until they could be processed further.

In the laboratory, filters were removed, and sample absorbances at 650, 665 and 750 nm read on a spectrophotometer. Absorbance data were then converted to equivalent concentrations of chlorophyll.

### 3.2.2.2 Zooplankton

Zooplankton samples were taken with a 0.25 m diameter Wisconsin net fitted with No. 20 mesh. Duplicate total vertical lifts were taken at water quality sampling sites. Zooplankton were preserved in about 10% formalin.

Arthropod zooplankton were processed by microscope and identified to species, using Edmondson (1959), Pennak (1978) and Johannsen (1970). Abundance estimates of these zooplankters, and of rotifers grouped together, were also made. Samples were diluted and subsampled for the abundance counts, with the degree of dilution varying according to the size and density of the taxon involved. The efficiency of the sampling net was not considered.

### 3.2.2.3 Fish

Large-fish populations in Thor and Elbow Lakes were sampled with Rawson standard gang gillnets. One gang consists of six, 46 m nylon mesh panels connected in series. The panel mesh sizes are 38, 51, 76, 102, 127 and 140 mm respectively. Two net sets were placed in Thor Lake, one in Elbow. Two "half standard" gang net sets were carried out in Cressy Lake. Each panel in a half standard gang is 23 m long. All gang net sets were left in the water for 24 hours.

Single gill net pieces of two different mesh sizes were placed in Ring Lake for 48 hours. Four such nets were set in Thor Lake as well, prior to gang gillnetting, in order to make a preliminary assessment of the reproductive condition of whitefish. These nets were left in the water overnight.

The gill net panel length(s), mesh size(s) and duration of each net set varied according to lake morphometry. Figure 3.5 illustrates net set locations.

Fish caught were processed according to species and mesh size. Fork length and wet weight measurements of all individuals were collected in the field. Aging materials taken included otoliths for whitefish and cleithra for pike. Scales were taken for all ciscoes, and for many pike and whitefish. Sex and reproductive condition were determined for all fish. Stomach contents were enumerated according to major taxonomic groupings.

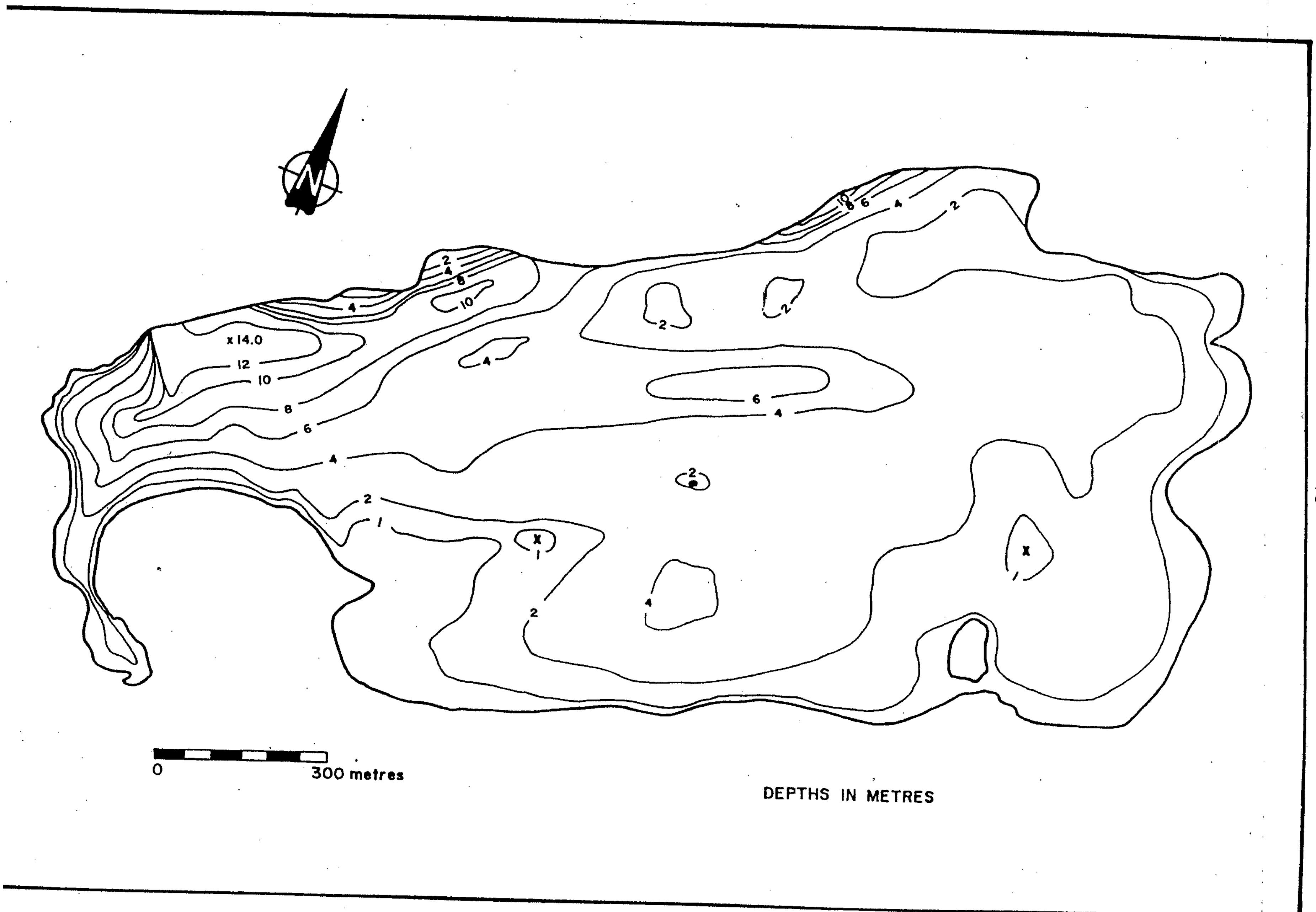
Some large fish from Thor Lake were kept for elemental analyses of tissues. Field preparations consisted of wiping the fish with paper towels, eviscerating them, then wiping the body cavities. Lengths and weights were recorded. Fish were frozen, one per plastic bag, and kept as such until they could be processed further in the SRC analytical laboratory.

## 3.3 Results and Discussion

### 3.3.1 Abiotic

#### 3.3.1.1 Lake Morphometry

Thor and Elbow Lakes (Figures 3.2, 3.3) are generally similar in terms of size, although there are some noteworthy differences (Table 3.1). The mean depth of Elbow Lake is twice that of Thor Lake, because Elbow has a deep north basin. Thus, the volume of Elbow Lake is approximately double the volume of Thor Lake. Also, the shoreline of Elbow Lake is much more irregular than the shoreline of Thor Lake, resulting in a high value for shore development. Both lakes are very similar to




ure 3.2 Bathymetric Map of Thor Lake.

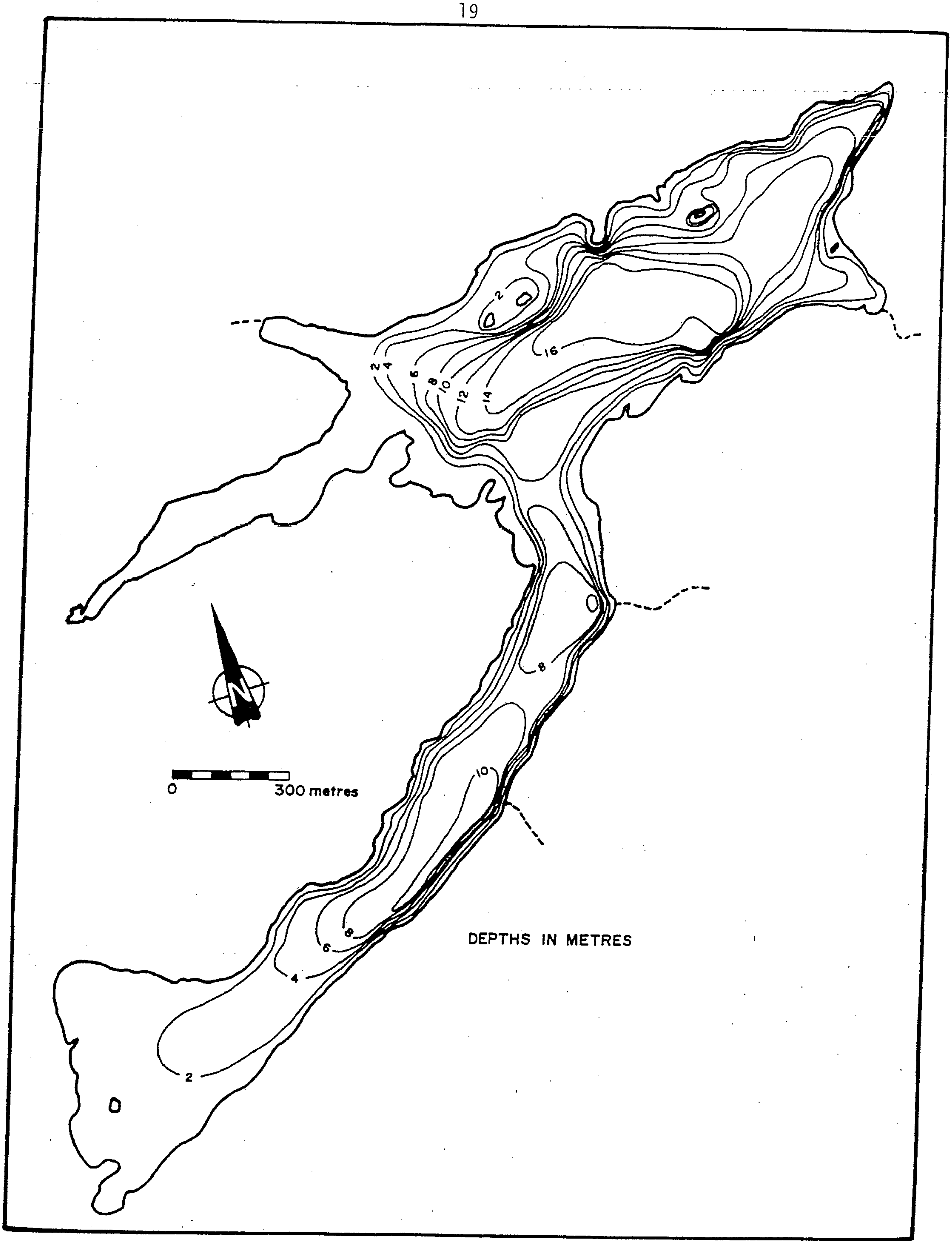



Figure 3.3 Bathymetric Map of Elbow Lake.

Table 3.1 Summary of Morphometric Characteristics of Four Lakes in the Thor Lake Area, September 1988.

| | Thor | Elbow | Cressy | Ring |
|---|---|---|---|---|
| Mean depth (m) | 3.2 | 5.9 | 3.4 | 0.56 |
| Maximum depth (m) | 13.5 | 18.9 | 6.5 | 1.2 |
| Water area (ha) | 136 | 125 | 6.16 | 11.5 |
| Water volume ($x10^6$ $m^3$) | 4.37 | 7.35 | 0.210 | 0.064 |
| Shoreline length (km) | 7.16 | 12.9 | 1.83 | 1.64 |
| Number of islands | 2 | 5 | 0 | 0 |
| Island shore length (km) | 0.582 | 4.34 | 0 | 0 |
| Total shore length (km) | 7.74 | 13.3 | 1.83 | 1.64 |
| Shore development | 1.87 | 3.35 | 2.09 | 1.36 |
| Volume development | 0.70 | 0.99 | 1.58 | 0.21 |

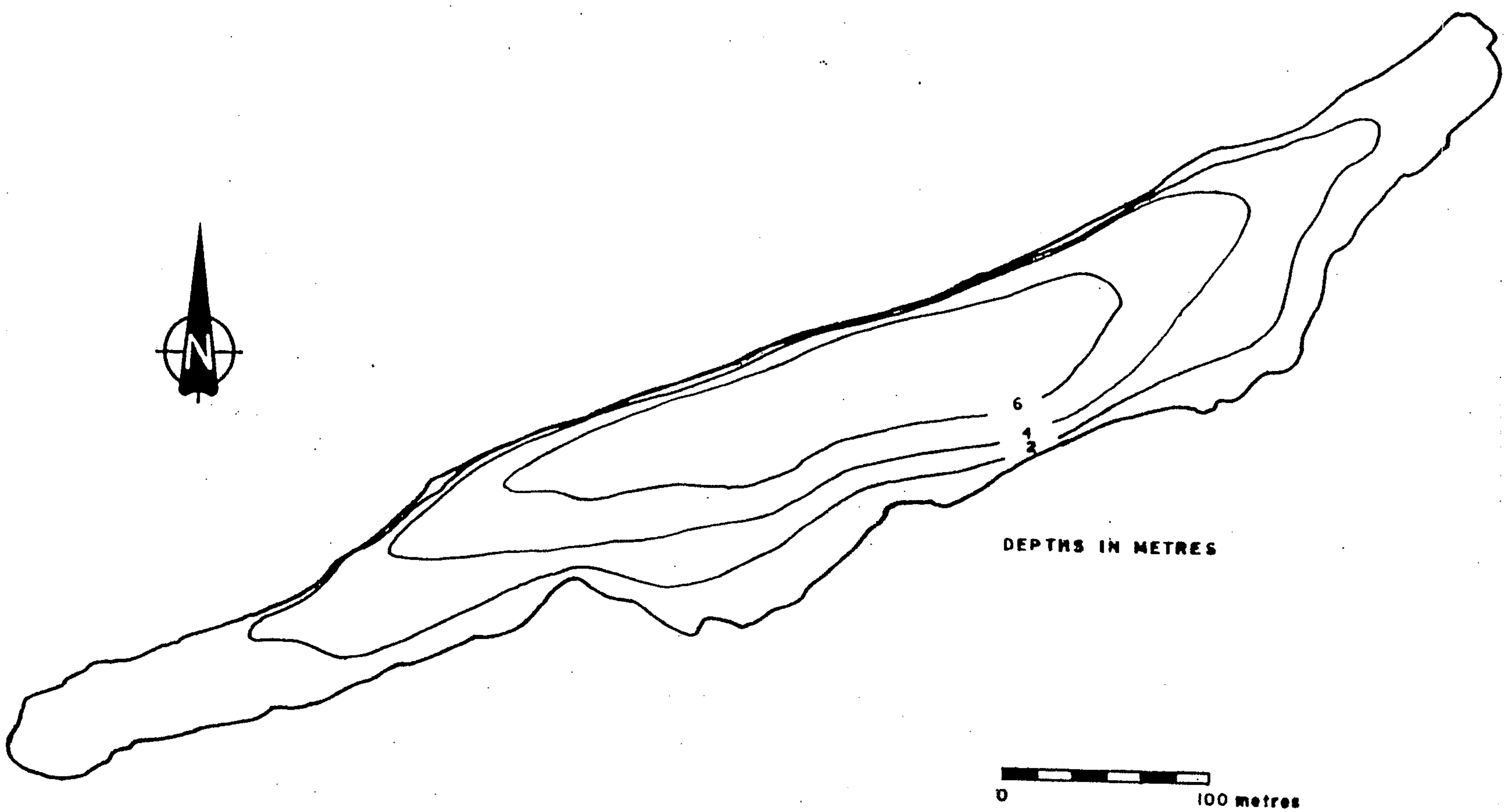
three lakes studied by Moore (1980), 100 km to the west near Yellowknife.

The other four study lakes have very small surface areas (Table 3.1 or Figure 3.1), much smaller than the areas of Thor and Elbow Lakes (Table 3.1). Cressy (Figure 3.4) and A Lakes are relatively deep for their surface areas. Lake A, at least 15 m deep, appears almost as deep as Elbow Lake, the deepest of the six study lakes. Cressy Lake has moderately high volume development, because the lake basin has concave walls. Lake A may also exhibit a higher level of volume development if it is deep over most of its area. Further sounding of Lake A will take place in late spring of 1989.

Ring Lake is very shallow (Table 3.1), and undoubtedly freezes to the bottom in many years. Only a few hand-line soundings were made in Lake B (maximum depth 1.5 m), but the macrophyte Potamegeton grew to the surface over the whole lake. These observations indicate that Lake B must also be very shallow, freezing to the bottom in many years.

#### 3.3.1.2 Lake Thermal Regimes

Temperature, oxygen ($O_2$) and conductivity data suggest that fall turnover or mixing was about to be completed in Elbow Lake (Table 3.2); this lake probably develops a thermocline (stable summertime thermo-density gradient), at least in the north basin. Data for all three variables are essentially constant for the first 10 m of depth, below which the data begin to change. One of the three similar lakes near Yellowknife develops a thermocline about 10 m deep, and undergoes fall overturn in September (Moore 1980).




gure 3.4 Bathymetric Map of Cressy Lake.

Table 3.2 Temperature (°C), Dissolved Oxygen ($O_2$, mg/L) and Specific Conductivity (SC, umhos/cm)* for Thor and Elbow Lakes, September 12-14, 1988.

| Depth (m) | Thor °C | Thor $O_2$ | Thor SC | Elbow °C | Elbow $O_2$ | Elbow SC |
|---|---|---|---|---|---|---|
| Surface | 10.5 | 9.7 | 307 | 12.9 | 9.2 | 310 |
| 1 | 10.5 | 9.6 | 307 | 12.9 | 9.3 | 310 |
| 2 | 10.5 | 9.6 | 307 | 12.9 | 9.2 | 310 |
| 3 | 10.5 | 9.6 | 307 | 12.9 | 9.1 | 310 |
| 4 | 10.5 | 9.6 | 307 | 12.9 | 9.2 | 310 |
| 5 | 10.5 | 9.6 | 307 | 12.9 | 9.2 | 310 |
| 6 | 10.8 | 9.6 | 305 | 12.9 | 9.1 | 310 |
| 7 | 10.9 | 9.6 | 304 | 12.9 | 9.1 | 310 |
| 8 | 10.9 | 9.4 | 304 | 12.9 | 9.1 | 310 |
| 9 | 10.9 | 9.4 | 304 | 12.9 | 8.4 | 310 |
| 10 | 10.6 | 6.2 | 341 | 12.8 | 8.2 | 311 |
| 11 | | | | 12.5 | 8.1 | 313 |
| 12 | | | | 12.2 | 7.3 | 315 |
| 12.5 | | | | 12.2 | 1.0 | 381 |

*Corrected to 25°C

Thor Lake probably does not develop a thermocline, since it is, on average, half as deep as Elbow Lake. Thor Lake too has a thermal regime similar to one of the NWT lakes studied by Moore (1980).

A distinct thermocline still existed in Lake A, at only 5.5 m (Table 3.3). This lake probably does not heat up as quickly, and to the same extent, as Thor and Elbow Lakes. It is deep for its very small surface area, and it is protected from the wind by large rock ridges.

Cressy Lake (Table 3.2) is too shallow to develop a thermocline.

#### 3.3.1.3 Water Quality

$O_2$ concentrations in the upper waters of all lakes were near saturation. Concentrations were low only near lake bottoms, or below thermoclines where they occurred. Moore's (1980) lakes are similar in these respects.

All lake waters were moderately hard to hard (Table 3.4). They were also moderately well to well buffered, as is indicated by pH and alkalinity data (Table 3.4). Lakes A and, in particular, B, were tea coloured. Levels of all general water quality variables (Table 3.4) were well within the ranges reported for lakes near Yellowknife (Moore 1980; Ostrofsky and Rigler 1987).

Of the major cations, Ca was highest, although Mg was high as well. Bicarbonate was by far the most abundant anion. These lakes differed from those of Moore (1980), in that sulfate levels were lower. Na and Cl concentrations were higher in one of the lakes studied by Moore (1980).

Trace element concentrations (Appendix A) were low to very low; levels of Be, Ce, Nb, Ta and Y were all below detection limits, i.e.,

Table 3.3 Temperature (°C), Dissolved Oxygen ($O_2$, mg/L) and Specific Conductivity (SC, umhos/cm)* for Lake "A" and Cressy Lake, September 13, 1988.

| | "A" | | | Cressy | | |
|---|---|---|---|---|---|---|
| Depth (m) | °C | $O_2$ | SC | °C | $O_2$ | SC |
| Surface | 10.1 | 9.6 | 282 | 11.5 | 9.1 | 211 |
| 1 | 10.1 | 9.6 | 282 | 11.5 | 9.0 | 211 |
| 2 | 10.5 | 9.4 | 280 | 11.3 | 8.9 | 212 |
| 3 | 10.5 | 9.6 | 280 | 11.3 | 8.8 | 212 |
| 4 | 10.8 | 9.5 | 278 | 11.0 | 8.0 | 213 |
| 5 | 10.2 | 9.2 | 282 | 11.0 | 7.6 | 213 |
| 5.5 | | | | 10.0 | 7.0 | 299 |
| 6 | 4.5 | 5.6 | 299 | | | |
| 7 | 3.0 | 5.5 | 315 | | | |
| 8 | 3.0 | 5.6 | 315 | | | |
| 9 | 3.0 | 5.4 | 315 | | | |
| 10 | 3.0 | 5.1 | 315 | | | |
| 11 | 3.0 | 5.1 | 315 | | | |
| 12 | 3.0 | 2.4 | 315 | | | |

*Corrected to 25°C

Table 3.4 Some General Water Quality Characteristics of Selected Lakes in the Thor Lake Area, September 1988.

| | | Thor | Elbow | Cressy | A | Ring | B |
|---|---|---|---|---|---|---|---|
| pH | surface | 7.9 | 7.6 | 7.5 | 8.0 | 7.5 | 7.7 |
| | bottom | 7.8 | 7.7 | -- | -- | -- | -- |
| Alkalinity ($mg/L\ CaCO_3$) | surface | 73 | 84 | 51 | 71 | 63 | 40 |
| | bottom | 78 | 83 | 51 | -- | -- | -- |
| Hardness* ($mg/L\ CaCO_3$) | surface | 149 | 161 | 105 | 142 | 133 | 89.4 |
| | bottom | 149 | 161 | 105 | -- | -- | -- |
| Total dissolved solids (mg/L) | surface | 190 | 188 | 152 | 188 | 204 | 164 |
| | bottom | 199 | 194 | 157 | -- | -- | -- |
| Total suspended solids (mg/L) | surface | 2 | 2 | 4 | 1 | 8 | 2 |
| | bottom | 2 | 3 | 3 | -- | -- | -- |
| Transparency depth (m) | | 2.8 | 3.3 | 2.0 | 2.0 | 1.3 (B) | 1.3 (B) |

*Hardness = Ca + Mg, corrected according to APHA (1975).

<0.001 mg/L. Element concentrations were also below or equal to Canadian guidelines for aquatic life, where guidelines exist (CCREM 1987), with one exception. This is Cr, which was present at concentrations that can have deleterious effects on zooplankton (CCREM 1987).

Radionuclide levels were all at or below 0.04 Bq/L in terms of radioactivity (Appendix A). $Ra^{226}$ levels were below the limits of detection, much lower than naturally occurring $Ra^{226}$ concentrations in two larger lakes in northern Saskatchewan (Swanson 1985). $Pb^{210}$ concentrations were lower than in Swanson's (1985) lakes, while U (as ug/L) levels were as low or lower. While U levels were below detection limits in five of six lakes in this study, they were as high as 1.9 ug/L in Cressy Lake; no explanation is offered for these differences in occurrence.

The water quality of Fred Stream (Appendix A Table A.3) was similar to that of the study lakes.

#### 3.3.1.4 Stream Flow

A discharge rate of 0.091 $m^3/s$ was obtained for Fred Stream, just below the road to Great Slave Lake. The rate is very low, compared to the average summer discharge rate of 3.0 $m^3/s$ in a shallow stream emanating from Grace Lake, NWT (Moore 1980). Fred Stream is tiny, 1.3 m wide by <0.5 m deep, which explains the low flow rate. The stream bed was silt over clay, with occasional pieces of broken bedrock embedded in the banks. There were no stream bed macrophytes in the area investigated.

No flowing water was observed immediately below Cressy, Ring and B Lakes. Continuous peatland made up shorelines where one could otherwise expect outflow from these lakes; the same was true of Elbow Lake. No open water occurred in the peatland between Cressy Lake and Fred Lake. This area was investigated on foot. Reg Savage, the caretaker on site, showed us a minute trickle of water flowing south across the road south of Elbow Lake. He thought that the water originated in Elbow Lake and eventually found its way into Great Slave Lake. The flow was too small to measure.

Two of the three lakes studied by Moore (1980) did not discharge through streams, similar to most of the lakes in the Thor Lake area.

### 3.3.2 Biotic

#### 3.3.2.1 Phytoplankton and Lake Trophic Status

Chlorophyll a concentrations (Table 3.5) suggest that Cressy Lake is eutrophic (nutrient rich), Thor Lake is mesotrophic and the other lakes are oligotrophic (nutrient poor). Trophic categorizations are based on the data of Shortreed and Stockner (1986) for 19 larger sub-arctic lakes in the Yukon territory. The oligotrophic designation may be questionable for Ring Lake, which contained large amounts of suspended organic material (Appendix A.3).

The range of lake trophy observed in the Thor Lake area corresponds to that observed by Ostrofsky and Rigler (1987), who studied 49 small to very small lakes near Yellowknife. They include chlorophyll a data for the lakes studied by Moore (1980).

#### 3.3.2.2 Zooplankton Abundance and Community Structure

Each of the study lakes contains one of two basic arthropod zooplankton community types. The communities in Cressy, Ring and B Lakes

Table 3.5 Algal Chlorophyll Concentrations (ug/L) of Selected Lakes in the Thor Lake Area, September 1988.

| Lake | | Chlorophyll a | b | Total |
|---|---|---|---|---|
| Thor | surface | 3.45 | 3.20 | 6.60 |
| | bottom | 3.98 | 2.18 | 6.15 |
| Elbow | surface | 0.68 | 4.10 | 4.78 |
| | bottom | 0.78 | 2.00 | 2.78 |
| Cressy | surface | 5.08 | 2.78 | 7.85 |
| | bottom | 6.48 | 4.63 | 11.1 |
| A | surface | 0.95 | 2.45 | 3.40 |
| Ring | | 0.60 | 1.56 | 2.18 |
| B | | 1.63 | 4.25 | 5.88 |

(Table 3.6) are characterized by large-bodied zooplankton, particularly the predators Chaoborus americanus and Hetercope septrionalis, and the primarily herbivorous Daphnia galeata mendotae. Smaller zooplankters tend to predominate in Thor and Elbow Lakes and, to a lesser extent, Lake A (Table 3.7). These zooplankters include the copepods Diaptomus sicilis and Cyclops spp., and the cladocerans Bosmina longirostris and Daphnia longiremis. The copepods Limnocalanus macrurus, Epischura lacustris and Diaptomus pribilofensis in Thor, Elbow and A Lakes are intermediate in size, but they are less abundant than the small zooplankters. Small-bodied zooplankton are less diverse and less abundant in Cressy, Ring and B Lakes, while Diaptomus pribilofensis is much more abundant in them.

The difference between the two zooplankton community types can be attributed largely to a difference in the degree of fish predation. Generally, there is an inverse relationship between the maximum body size attained by zooplankton, and the degree of fish predation (e.g., Vanni 1988). The reason for this is that fish prefer to eat larger zooplankton. Small zooplankters are less abundant in the absence of fish predation, because the largest zooplankters, such as Chaoborus and Heterocope, are voracious predators of small zooplankters.

The presence in Elbow and A Lakes of Limnocalcanus macrurus, a glacial opportunist (Dadswell 1974), is of interest. It is found only in lakes that were once inundated by proglacial lakes during Pleistocene glaciation, or in those that occurred near the former margins of proglacial lakes (here glacial Lake McConnell, see section 4.4.3.2). The species requires cold water as habitat. This condition is met in Lake A, below the thermocline in summer. It is probably met in Elbow Lake as

Table 3.6 Zooplankton Densities (/L) for Three Lakes in the Thor Lake Area, NWT, September 1988.

| Species/Groups | Lake Thor | Lake Elbow | Lake A |
|---|---|---|---|
| Copepoda | | | |
| Calanoida | | | |
| *Limnocalanus macrurus* | -- | 0.033 | 0.006 |
| *Epischura lacustris* | 0.002 | -- | -- |
| *Diaptomus sicilis* | | | |
| - adults | 0.055 | 0.027 | -- |
| - juveniles | 0.024 | 0.019 | |
| *Diaptomus pribilofensis* | | | |
| - adults | 0.002 | -- | 0.033 |
| - juveniles | -- | -- | 0.035 |
| Cyclopoida | | | |
| *Cyclops scutifer* | 0.749 | 0.146 | -- |
| *Cyclops bicuspidatus thomasi** | 3.60 | 0.243 | -- |
| Total naupliar juveniles | 0.600 | 1.94 | -- |
| Cladocera | | | |
| *Daphnia longiremis* | -- | 0.024 | -- |
| *Bosmina longirostris* | 3.30 | 0.243 | -- |
| Rotifera | | | |
| *Kellicottia longispina* | 3.00 | -- | 7.28 |
| Other small rotifers | 27.0 | 12.1 | 72.8 |

*May include juvenile copepodids of *Cyclops scutifer*.

Table 3.7 Zooplankton Densities (/L) for Three Lakes in the Thor Lake Area, NWT, September 1988.

| Species/Groups | Lake<br>Cressy | <br>Ring | <br>B |
|---|---|---|---|
| Diptera | | | |
| *Chaoborus americanus* | 0.036 | 0.005 | 0.010 |
| Copepoda | | | |
| Calanoida | | | |
| *Hetercope septrionalis* | 0.026 | 0.082 | 0.010 |
| *Diaptomus pribilofensis* | | | |
| - adults | 1.72 | 4.34 | 0.51 |
| - juveniles | 1.08 | 1.02 | -- |
| Cyclopoida | | | |
| *Cyclops bicuspidatus thomasi* | -- | 3.83 | -- |
| Total naupliar juveniles | 9.57 | 1.28 | -- |
| Cladocera | | | |
| *Daphnia galeata mendotae* | 0.036 | 0.041 | -- |
| Rotifera | | | |
| *Kellicottia longispina* | 14.6 | -- | 1.28 |
| Other small rotifers | 87.4 | -- | -- |

well, which appears to develop a thermocline. Cold temperatures may also help reduce fish predation on Limnocalanus, at least in Elbow Lake. The presence of Limnocalanus could potentially serve as a quality maintenance indicator for water below the tailings area of the mine lease.

#### 3.3.2.3 Fish Communities

The fish community in Thor Lake (Table 3.8) is typical of fish communities in similar lakes in this region of the NWT. Healey (1980) found lake trout, burbot and the small forage fish lake chub, in addition to the species outlined in Table 3.8. Thor and Elbow Lakes are somewhat smaller (shallower) than his study lakes, which would explain the absence of lake trout in this study. Some burbot could exist in the deeper holes in Thor Lake, and perhaps a few lake chub occur in the lake as well.

The fish community in Elbow Lake appears virtually identical to that in Thor Lake, although only the large fish portion has been effectively sampled. Lake whitefish, northern pike and cisco were caught in the gill net set. Ninespine sticklebacks were found in whitefish and pike stomachs.

No large fish were caught in Cressy Lake with intensive fishing effort. While Cressy Lake is deep enough to contain large fish, these results suggest that none occur there. Large zooplankton body sizes indicate that zooplanktivorous fish, including small forage fish such as stickleback, are probably absent. Since gill nets can catch all species of large fish irrespective of diet, and most small northern fish species can eat zooplankton, Cressy Lake may be referred to as fishless. When ice-covered, this eutrophic little lake could be devoid of oxygen in

Table 3.8 Fish Species Identified in Thor Lake, 1988.

| Common Name | Scientific Name |
| --- | --- |
| **Large Fish:** | |
| Lake whitefish | Coregonus clupeaformis |
| Cisco | Coregonus artedii |
| Northern pike | Esox lucius |
| **Small Fish:** | |
| Ninespine stickleback | Pungitius pungitius |
| Troutperch | Percopsis omyscomaycus |
| Sculpin species | Cottus sp. |

some years; this winterkill characteristic, plus isolation which prevents immigration, would explain the absence of fish there.

No fish were taken from Ring Lake. Gillnetting results, the extremely shallow depths of Ring Lake, and the large zooplankton body sizes all indicate that it too is fishless. Similar observations (zooplankton, depths) suggest that Lake B does not contain fish either. Gill nets will be set in Lake B in 1989 in order to obtain more direct evidence for this conclusion.

Lake A may contain some fish, although this is yet to be determined. Although small in surface area, it is twice as deep as Cressy Lake, thus less susceptible to winterkill conditions. The zooplankton community is more characteristic of lakes that contain fish than those without. Moreover, the zooplankton are not abundant, which could be explained in part by fish predation. Lake A will also be gillnetted in 1989.

A map of all gill net sets in the Thor Lake area is presented in Figure 3.5.

### 3.3.2.4 Large-Fish Relative Abundance

Large-fish in Thor Lake (Table 3.9) were three times more numerous than large fish in Elbow Lake (Table 3.10). They also had twice as much biomass as large fish in Elbow Lake. Whitefish made up two thirds to three quarters of the total catch in terms of both numbers and biomass. Whitefish were caught mostly by meshes of intermediate size, although large fish were taken in all mesh sizes (Tables 3.9 and 3.10). Pike were taken largely in smaller intermediate mesh sizes, while cisco, as expected, were caught only in the smallest mesh size.

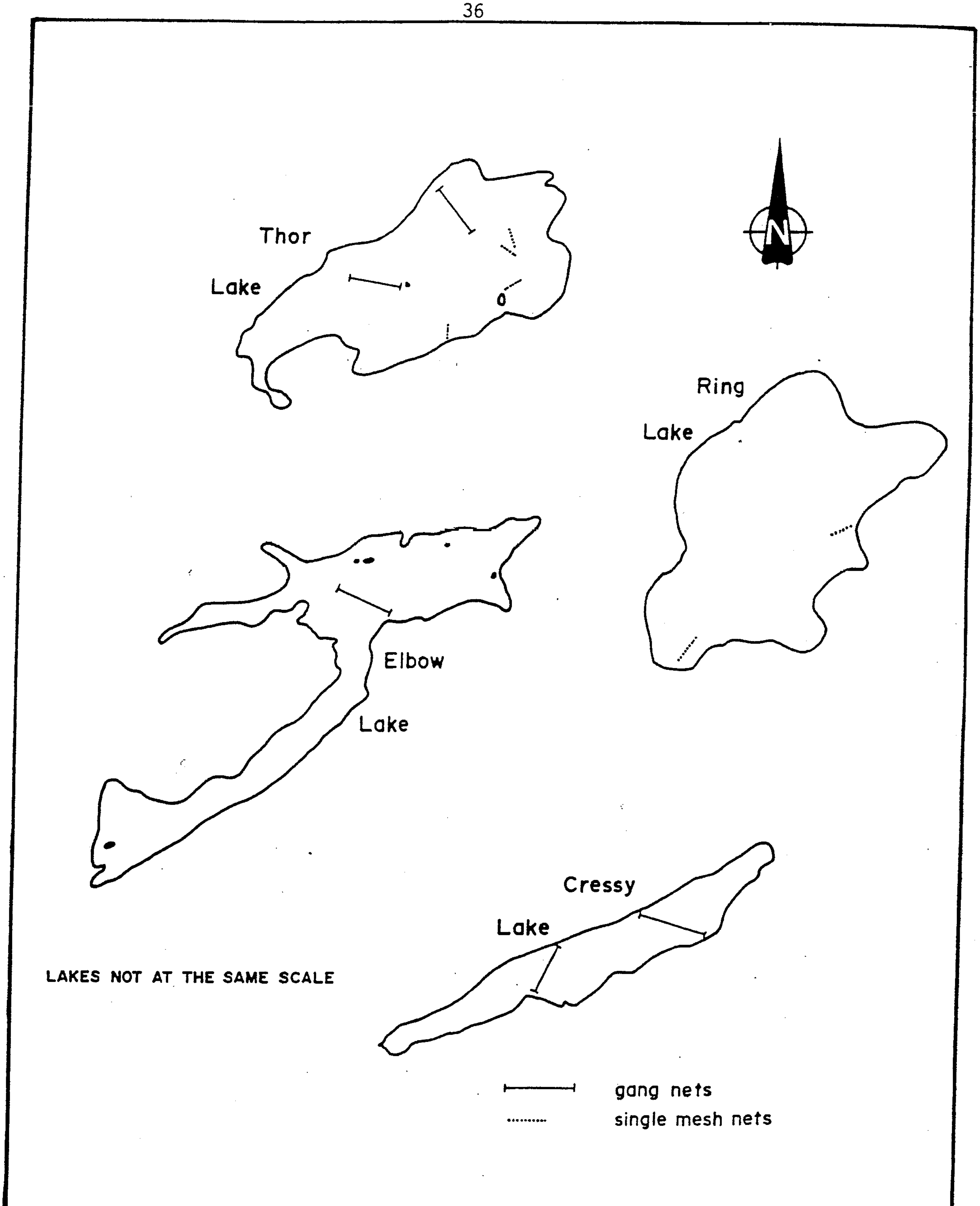



Figure 3.5 Map of Gill Net Sets in Thor Lake Area Lakes, September 1988. Gang Nets are of Standard Length in Thor and Elbow Lakes, Half Standard in Cressy

Table 3.9 Summary of Fish Caught in Thor Lake, September 1988. Two Standard Gang Gill Net Sets. All Weights are in g.

| Species | | Mesh Size (mm) 30 | 51 | 76 | 102 | 127 | 140 | Total | Average /Set | Percent of Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Northern pike | No. | 6 | 24 | 40 | 1 | 0 | 1 | 72 | 36 | 19.7 |
| | Wt. | 4185 | 17030 | 31930 | 860 | 0 | 860 | 54860 | 27430 | 23.5 |
| Lake whitefish | No. | 33 | 49 | 67 | 87 | 13 | 8 | 257 | 129 | 70.4 |
| | Wt. | 24490 | 36900 | 41000 | 55850 | 11590 | 7125 | 176900 | 88470 | 75.7 |
| Cisco | No. | 36 | -- | -- | -- | -- | -- | 36 | 18 | 9.9 |
| | Wt. | 1817 | -- | -- | -- | -- | -- | 1817 | 909 | 0.8 |
| Total | No. | 75 | 73 | 107 | 88 | 13 | 9 | 365 | 183 | 100 |
| | Wt. | 30490 | 53930 | 72930 | 56710 | 11590 | 7985 | 233600 | 116800 | 100 |

Table 3.10 Summary of Fish Caught in Elbow Lake, September 1988. One Standard Gang Gill Net Set. All Weights are in g.

| Species | | Mesh Size (mm) 38 | 51 | 72 | 102 | 127 | 140 | Total | Percent of Total |
|---|---|---|---|---|---|---|---|---|---|
| Northern pike | No. | -- | 2 | 17 | -- | -- | -- | 19 | 28.7 |
| | Wt. | -- | 2075 | 15510 | -- | -- | -- | 17590 | 31.4 |
| Lake whitefish | No. | 4 | 11 | 10 | 7 | 11 | -- | 43 | 65.2 |
| | Wt. | 2835 | 8965 | 8330 | 6930 | 11180 | -- | 38240 | 68.4 |
| Cisco | No. | 4 | -- | -- | -- | -- | -- | 4 | 6.1 |
| | Wt. | 181 | -- | -- | -- | -- | -- | 181 | 3.2 |
| Total | No. | 8 | 13 | 27 | 7 | 11 | -- | 66 | 100 |
| | Wt. | 3016 | 11040 | 23840 | 6930 | 11180 | -- | 56010 | 100 |

Large fish are more abundant in Thor Lake than in Elbow Lake, for reasons that are related in large part to its morphometry. It is half as deep, and has less rocky substrate than Elbow Lake. Consequently, Thor Lake is a warmer and more nutrient rich system than the latter lake. Thor Lake is probably not deep enough to develop a thermocline. Thus, the whole lake mixes, warming the lake and circulating chemical micronutrients needed for plant growth. Warmer temperatures promote growth. Soft bottom material also provides chemical micronutrient reserves for plants (algae, macrophytes), and physical habitat for macroinvertebrates, upon which many fish feed. The plants, in turn, provide food and additional substrate habitat for the invertebrates. These conditions are particularly suitable for lake whitefish.

Large fish are at least as abundant in Thor Lake as in similar lakes in northern Saskatchewan (Pipe et al. 1980). Data for Elbow Lake represent an intermediate level of abundance in relation to northern Saskatchewan lakes. Whitefish were generally less abundant in the lakes studied by Pipe et al. (1980), while walleye and white sucker were often present and as abundant as whitefish.

#### 3.3.2.5 Large-Fish Growth

Large-fish populations in Thor Lake and, in particular, Elbow Lake are made up primarily of larger individuals (Table 3.11). In Thor Lake, for example, 72% of the pike (Table 3.11) were four years old, and most of the remainder were five years old. Pike in Elbow Lake were, on average, two years older than those in Thor Lake. There were very few older juvenile whitefish and pike. The populations are typical of the

Table 3.11 Body Length Frequency Distributions for Lake Whitefish and Northern Pike in Thor and Elbow Lakes, September 1988.

| Length (cm) | Thor Females | Thor Males | Thor Total | Elbow Females | Elbow Males | Elbow Total |
|---|---|---|---|---|---|---|
| **Lake Whitefish** | | | | | | |
| 30 | 1 | 2 | 3 | | | |
| 33 | 4 | 2 | 6 | | | |
| 36 | 3 | 8 | 11 | 1 | | 1 |
| 39 | 38 | 33 | 71 | 7 | 10 | 17 |
| 42 | 34 | 18 | 52 | 9 | 10 | 19 |
| 45 | 4 | 1 | 5 | 2 | 2 | 4 |
| 48 | 1 | 1 | 2 | | | |
| Total | | | 150 | | | 42 |
| **Northern Pike** | | | | | | |
| 44 | | 2 | 2 | | 1 | 1 |
| 46 | 1 | 10 | 11 | | | |
| 48 | 12 | 3 | 15 | 2 | | 2 |
| 50 | 10 | 5 | 15 | 3 | 1 | 4 |
| 52 | 7 | 1 | 8 | 2 | | 2 |
| 54 | 5 | | 5 | 3 | | 3 |
| 56 | 1 | | 1 | 3 | 1 | 4 |
| 58 | | | | 2 | | 2 |
| Total | | | 57 | | | 18 |

pattern predominant in unexploited arctic and subarctic large-fish populations (Johnson 1976).

Whitefish and cisco growth rates in terms of biomass accumulation (weight versus length) are generally similar in comparisons between the sexes within lakes (Figures 3.6 to 3.12). However, comparisons between the lakes within sexes for each species (Figures 3.6 to 3.15) indicate that fish in Elbow Lake acquired biomass at greater rates than fish in Thor Lake. The growth rate differences suggest that more intraspecific competition is occurring in Thor Lake populations than in Elbow Lake populations, lake standing crop differences not withstanding (section 3.3.2.4). All biomass growth rates are within the ranges for these species in the north Saskatchewan lakes studied by Pipe et al. (1980).

#### 3.3.2.6 Large-Fish Feeding

The feeding of both the whitefish and pike (Table 3.12) is typical for these species (Scott and Crossman 1973; Pipe et al. 1980). The whitefish ate predominantly benthic invertebrates, while pike ate smaller fish. Noteworthy is the fact that whitefish in both lakes consumed the forage fish, ninespine stickleback, at levels that have been termed unusually high in other subarctic systems (Pipe et al. 1980).

#### 3.3.2.7 Coregonid Reproductive Condition

A slightly greater proportion of female whitefish was both mature and "green" (almost ready to spawn) in Elbow Lake, relative to Thor Lake (Table 3.13). This difference can probably be attributed to the slightly lower temperatures in Elbow Lake. More importantly, only two thirds of all mature females were green. The majority of the remaining mature

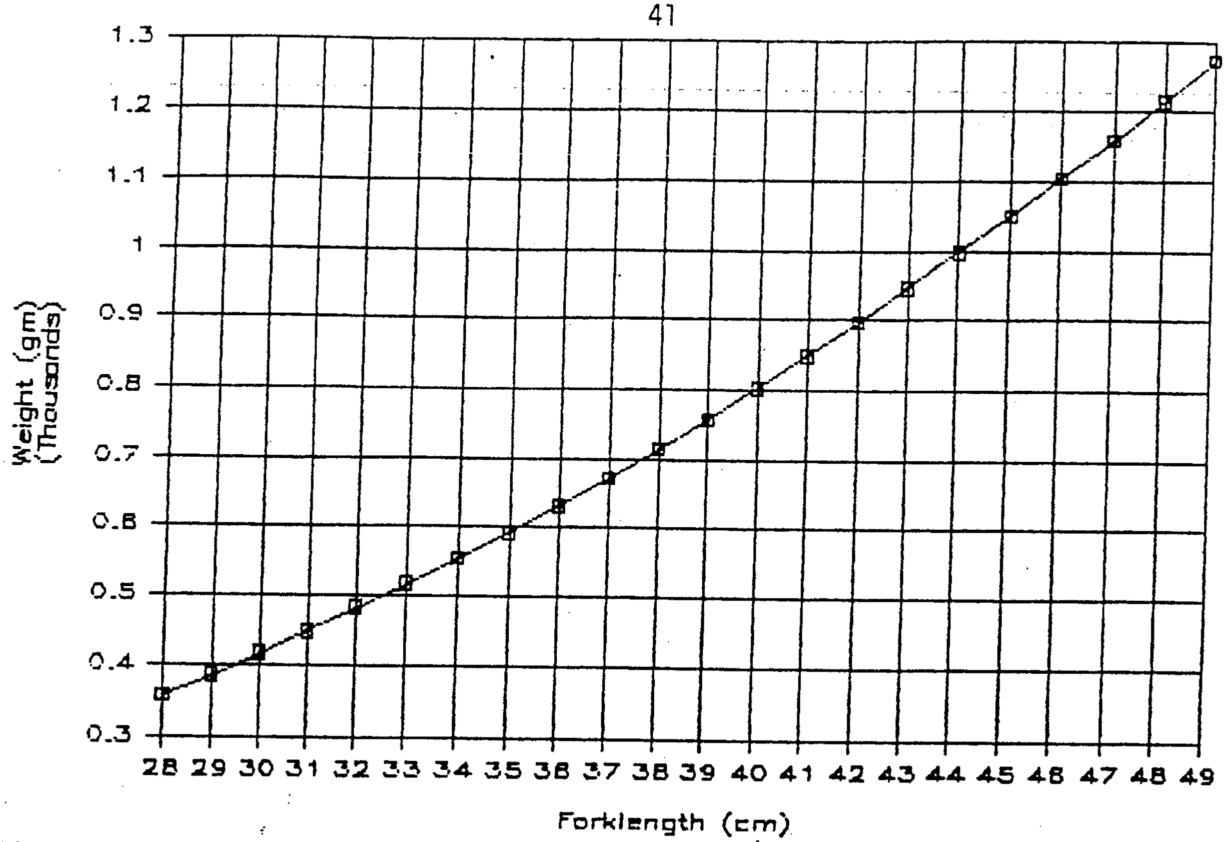



Figure 3.6 Wet Weight vs Fork Length for Female Lake Whitefish, Thor Lake. $Y = aX^b$, a = 0.18, b = 2.28, c (correlation) = 0.77.

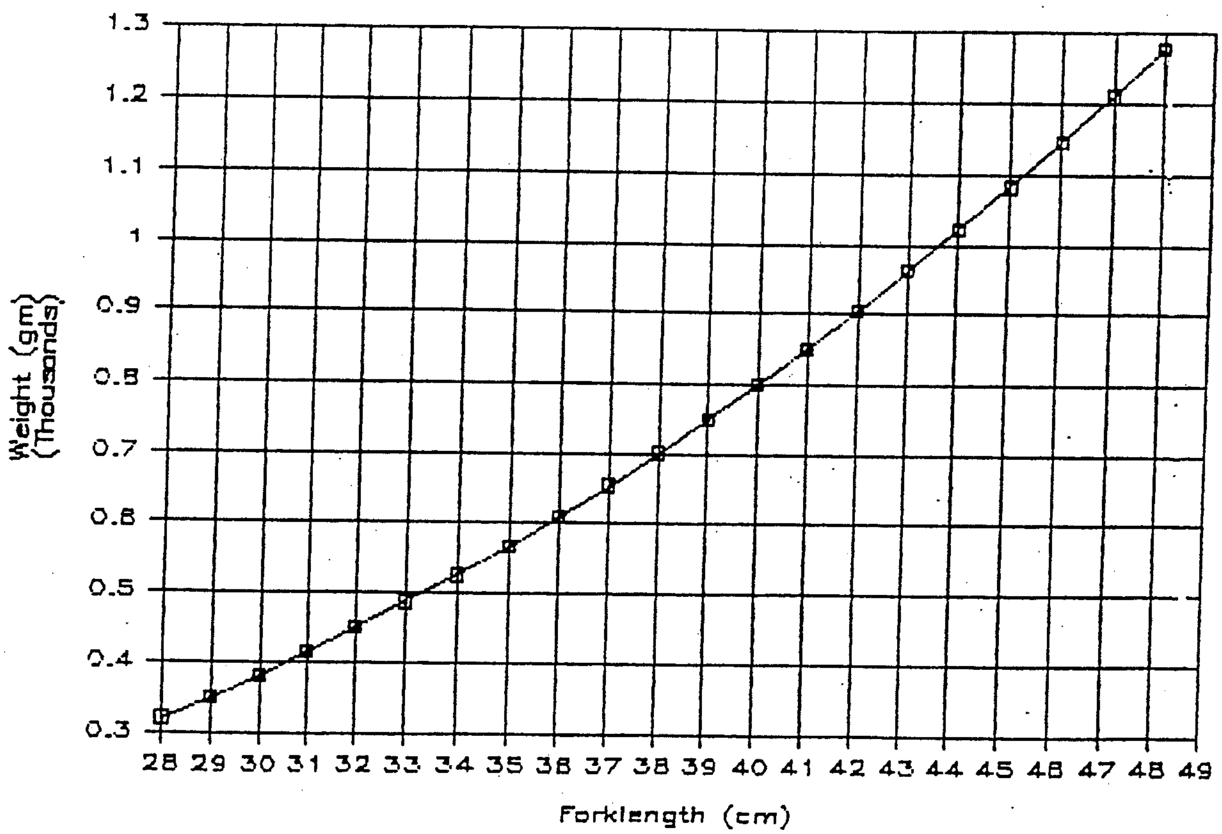



Figure 3.7 Wet Weight vs Fork Length for Male Lake Whitefish, Thor Lake. $Y = aX^b$, a = 0.06, b = 2.57, c (correlation) = 0.87.

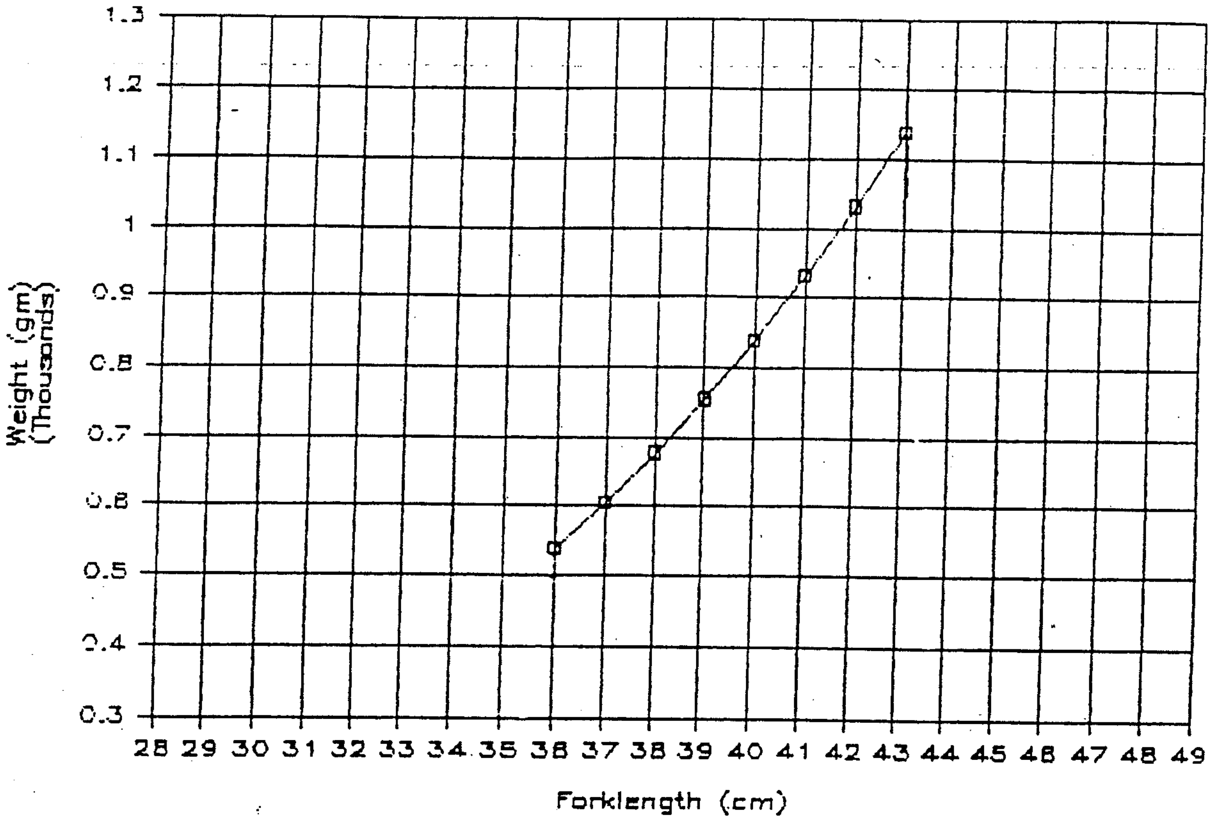



Figure 3.8 Wet Weight vs Fork Length for Female Lake Whitefish, Elbow Lake. $Y = aX^b$, a = 0.00, b = 4.20, c (correlation) = 0.79.

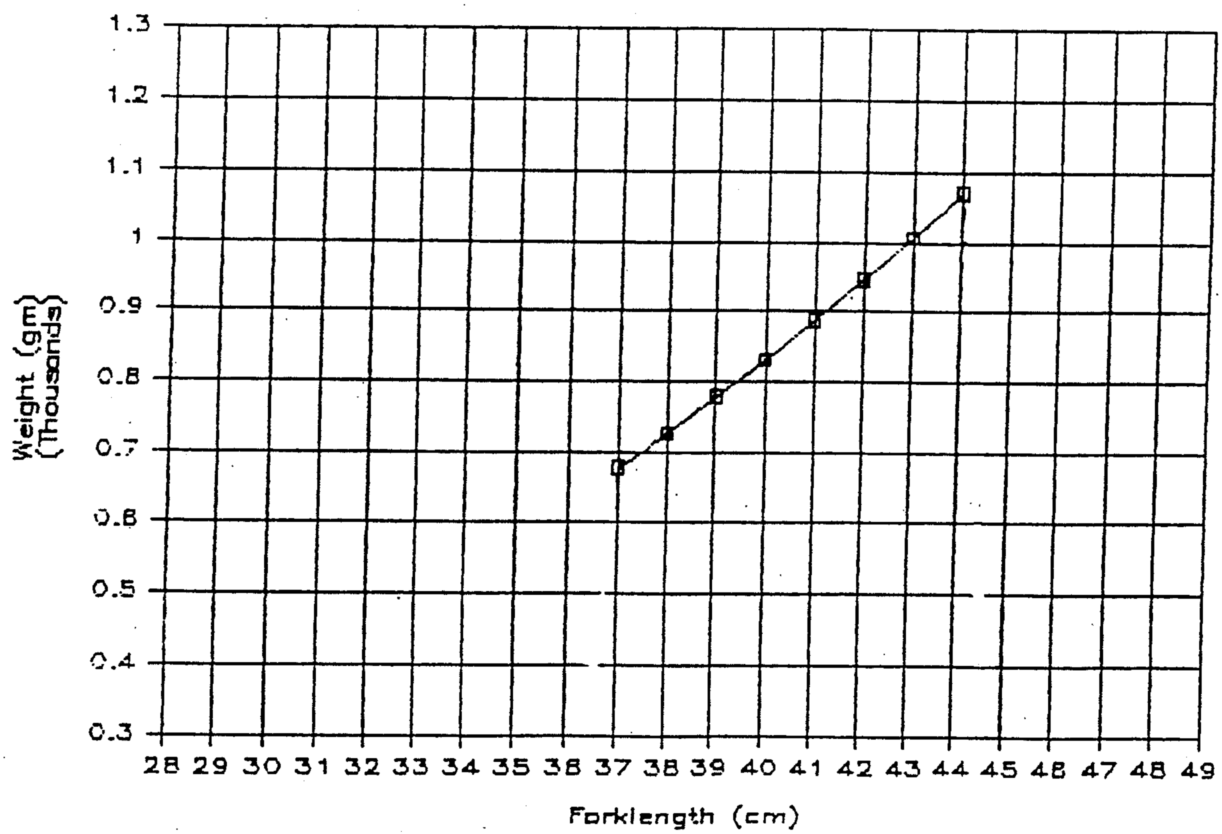



Figure 3.9 Wet Weight vs Fork Length for Male Lake Whitefish, Elbow Lake. $Y = aX^b$, a = 0.05, b = 2.64, c (correlation) = 0.72.

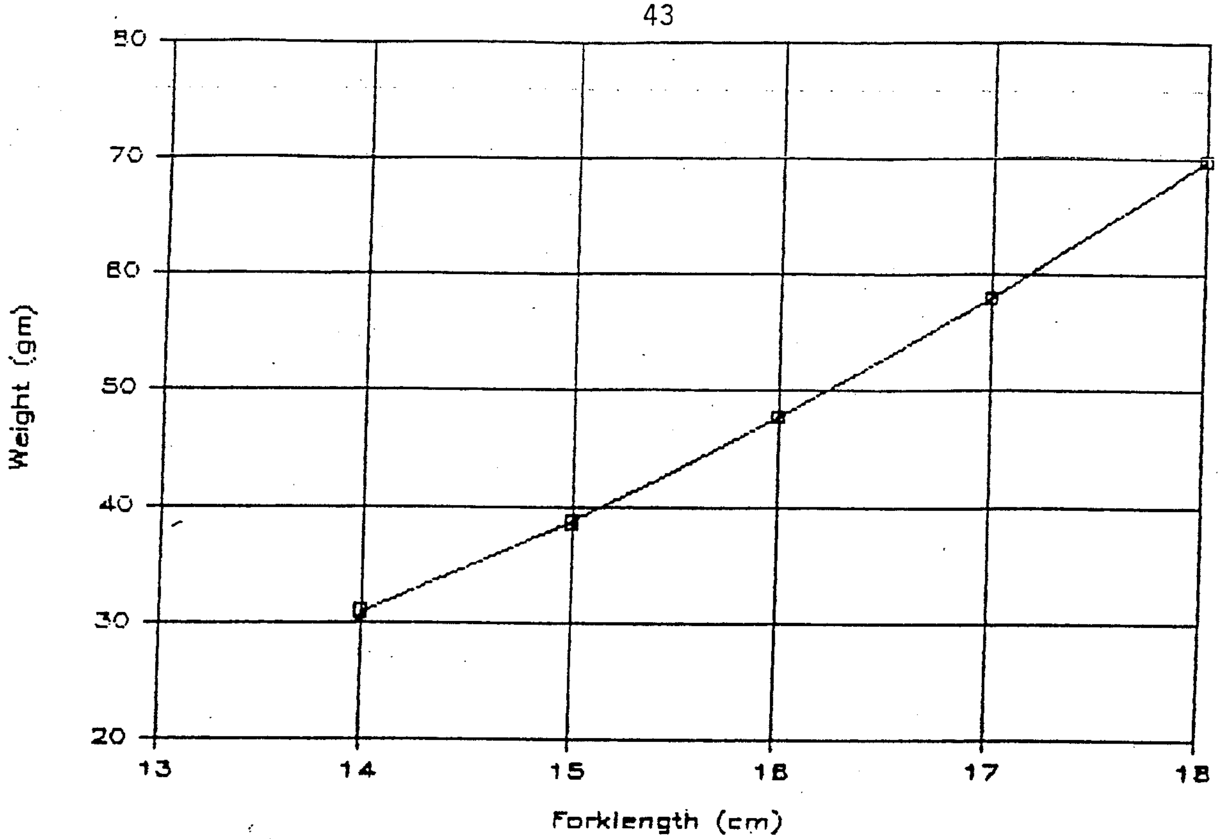



Figure 3.10 Wet Weight vs Fork Length for Female Ciscoes, Thor Lake.
$Y = aX^b$, a = 0.01, b = 3.22, c (correlation) = 0.83.

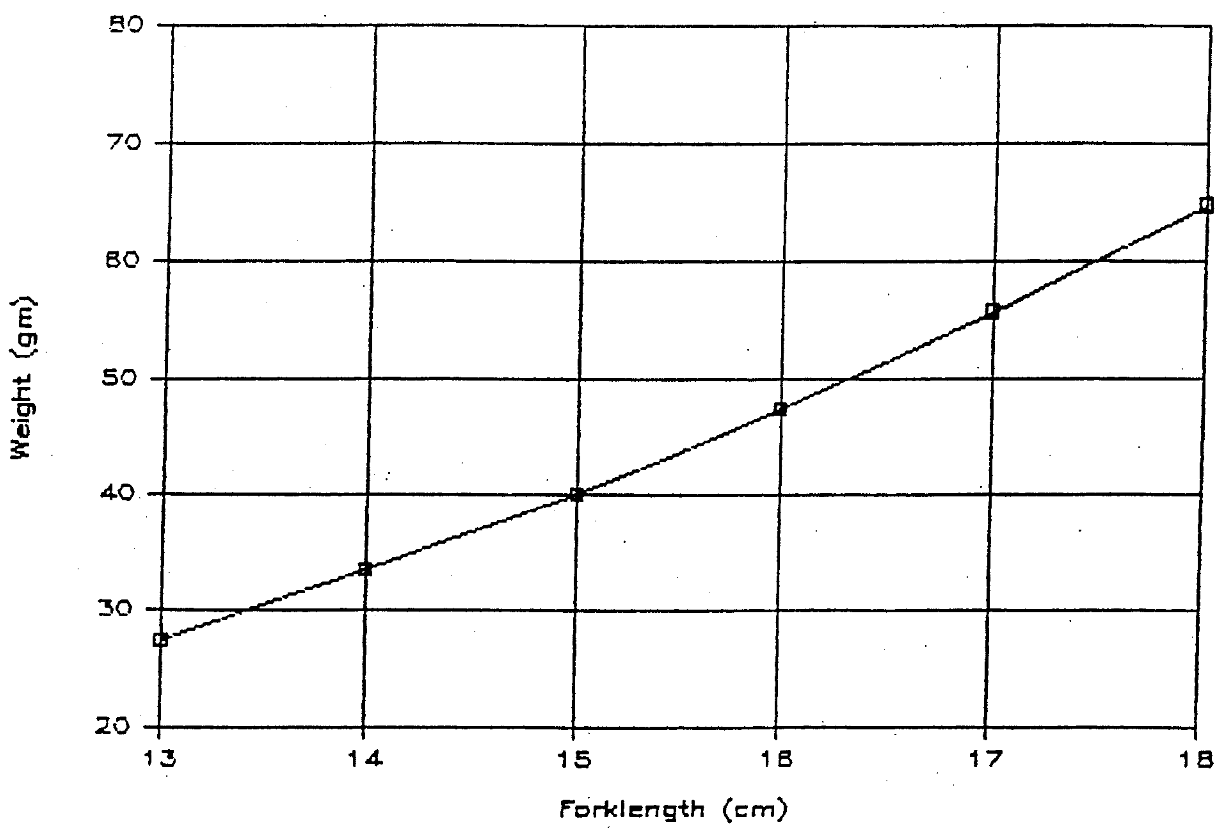



Figure 3.11 Wet Weight vs Fork Length for Male Ciscoes, Thor Lake.
$Y = aX^b$, a = 0.03, b = 2.64, c (correlation) = 0.84.

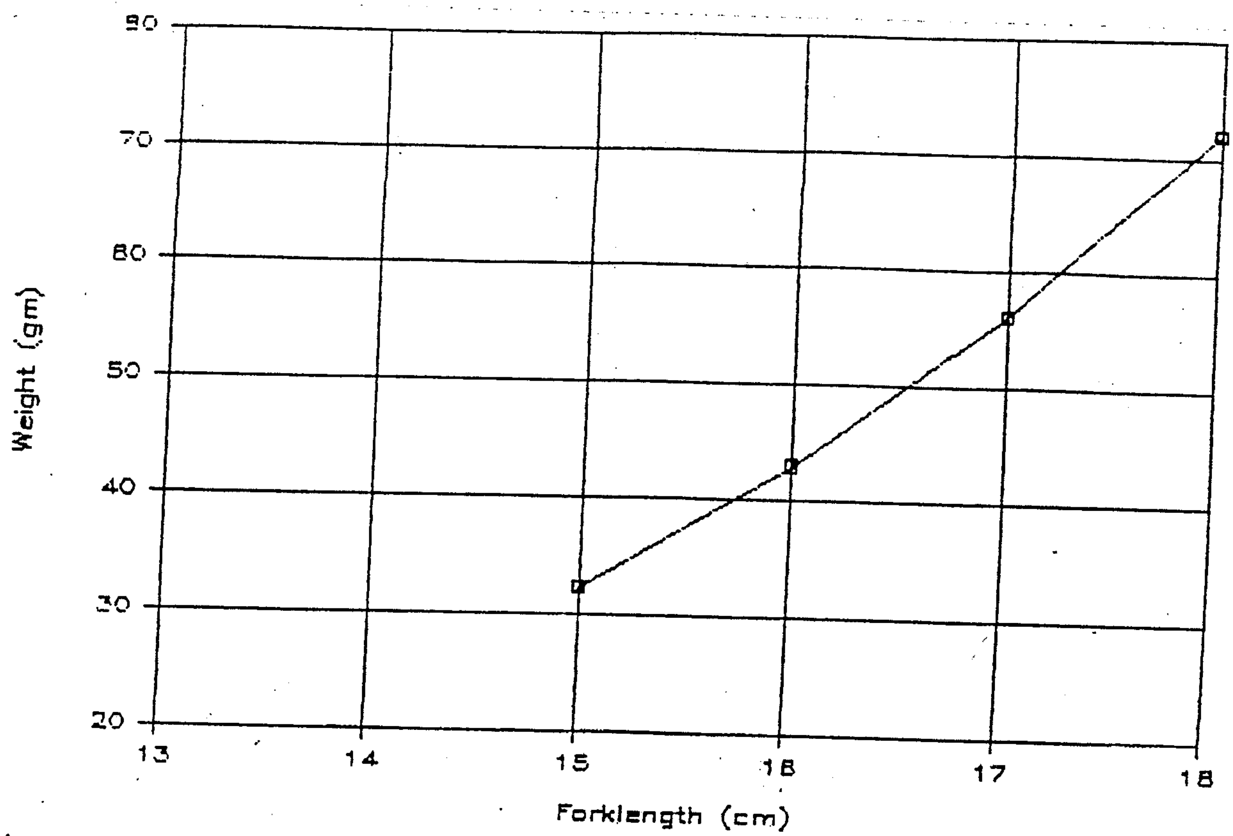



Figure 3.12 Wet Weight vs Fork Length for Female Ciscoes, Elbow Lake.
$Y = aX^b$, a = 0.00, b = 4.42, c (correlation) = 0.98.

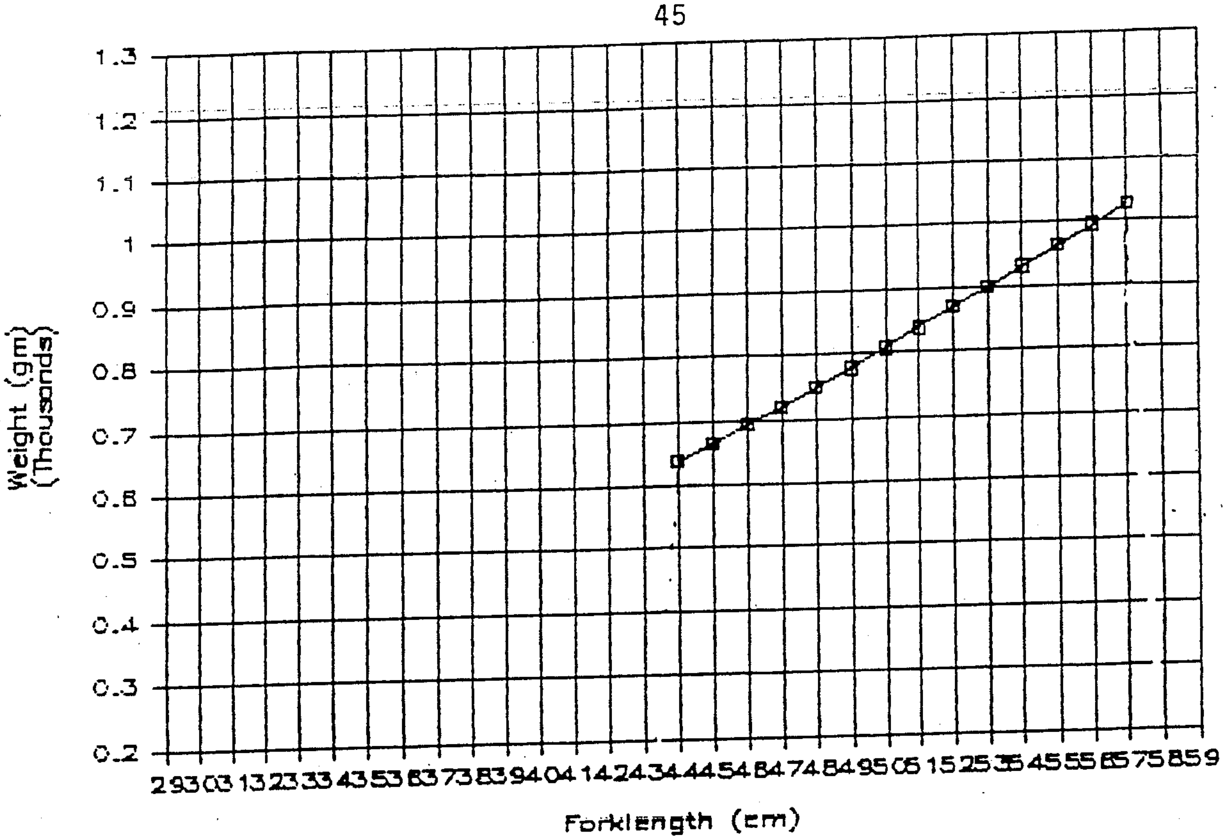



Figure 3.13 Wet Weight vs Fork Length for Female Northern Pike, Thor Lake. $Y = aX^b$, a = 0.60, b = 1.84, c (correlation) = 0.72.

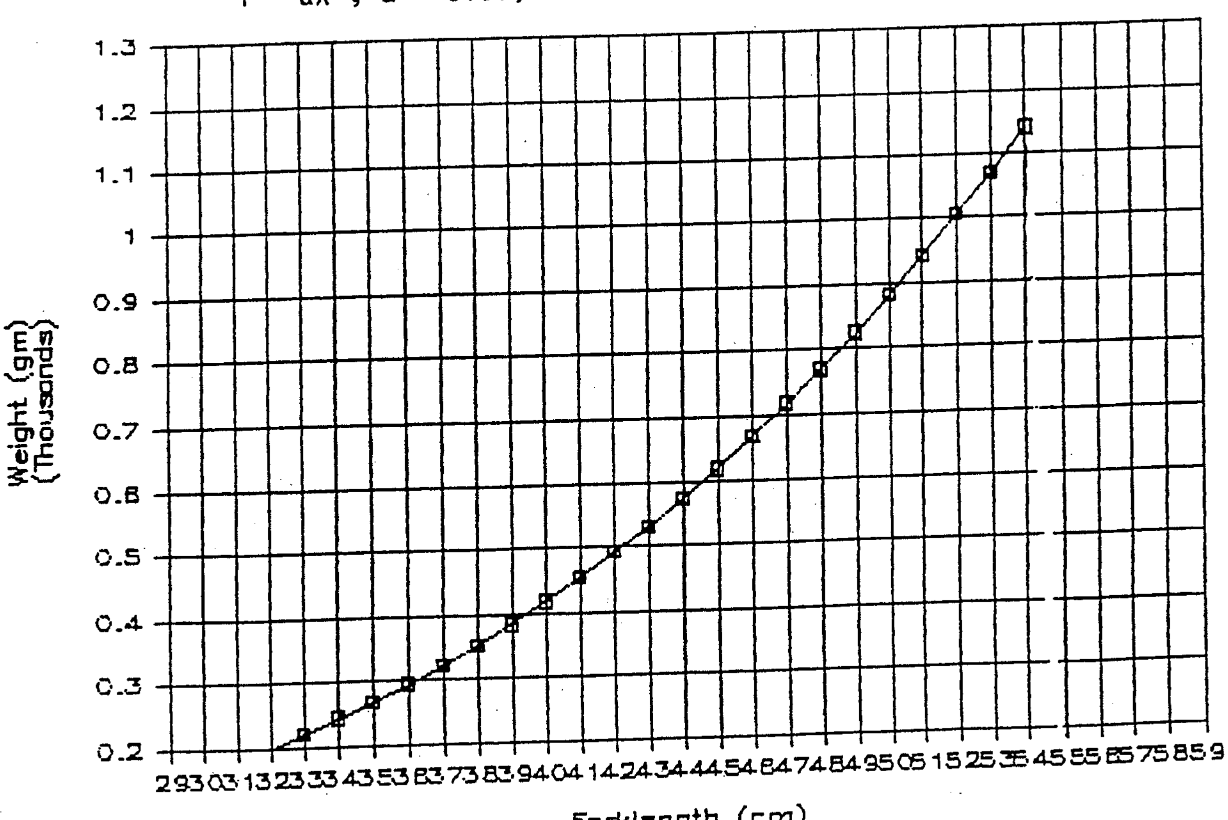



Figure 3.14 Wet Weight vs Fork Length for Male Northern Pike, Thor Lake. $Y = aX^b$, a = 0.00, b = 3.34, c (correlation) = 0.97.

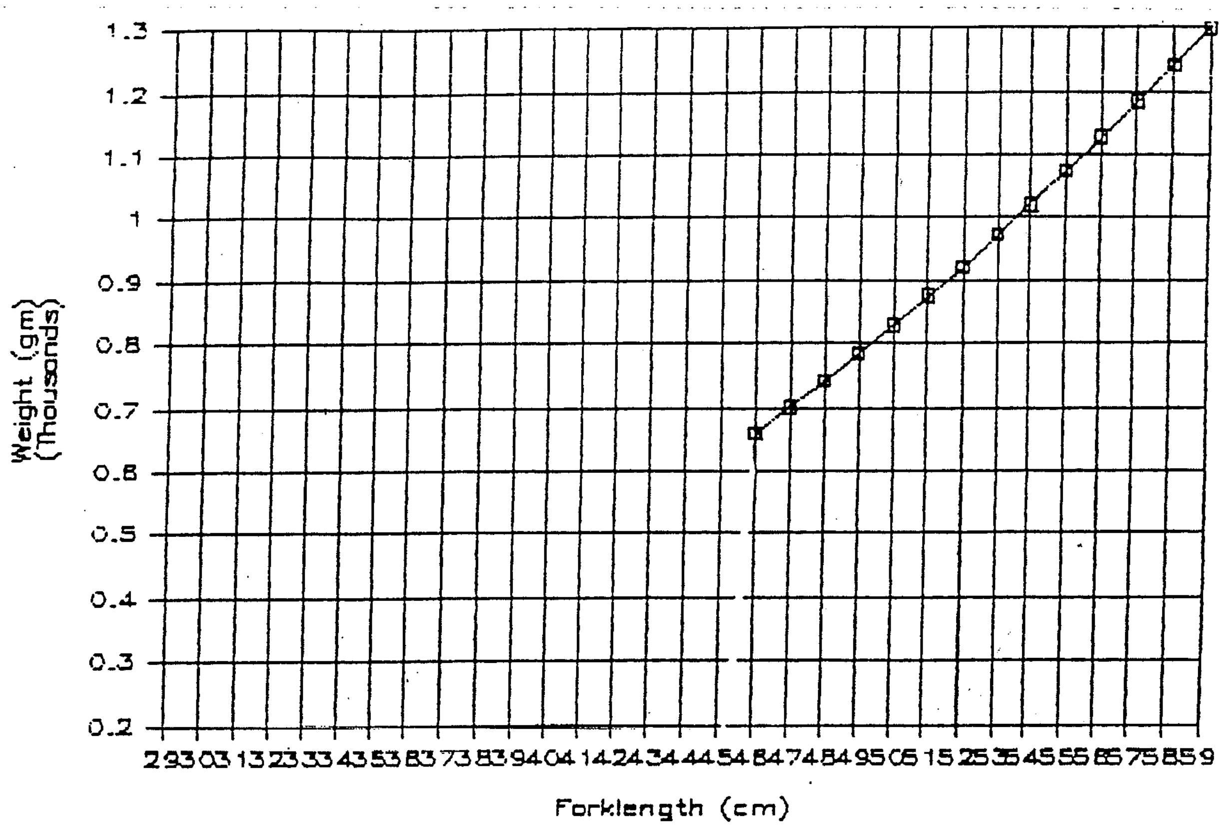



Figure 3.15 Wet Weight vs Fork Length for Female Northern Pike, Elbow Lake.
$Y = aX^b$, a = 0.02, b = 2.71, c (correlation) = 0.90.