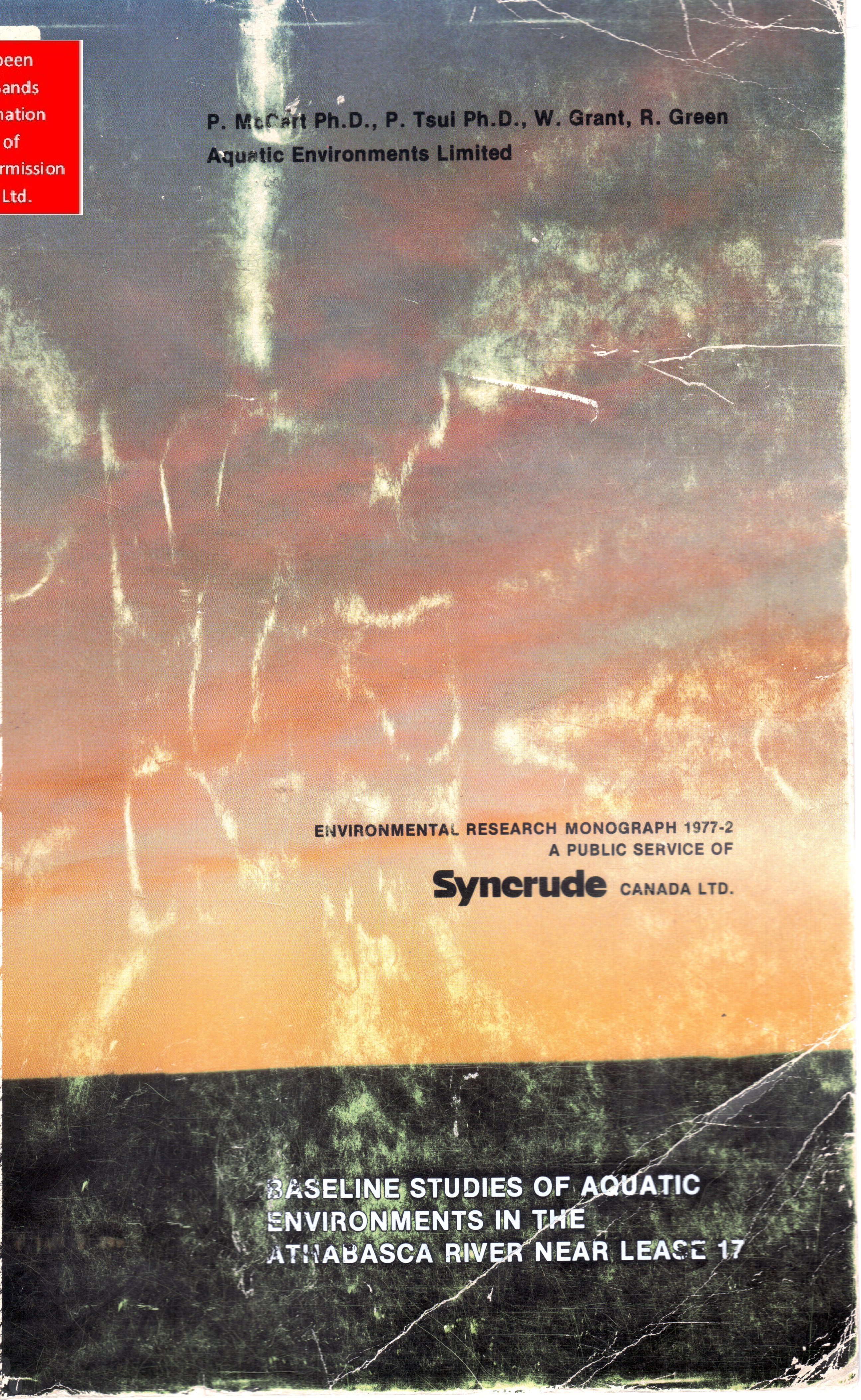

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Aquatic Environments Limited

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BASELINE STUDIES OF AQUATIC ENVIRONMENTS IN THE ATHABASCA RIVER NEAR LEASE 17

Section I

WATER QUALITY

By

Peter McCart, Ph.D.

Section II

PERIPHYTON STUDIES

By

Philip T.P. Tsui, Ph.D.
and
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Section III

BENTHIC MACROINVERTEBRATE STUDIES

By

Philip T.P. Tsui, Ph.D.

Section IV

FISHERIES STUDIES

By

William Grant
and
Peter McCart, Ph.D.

FOREWORD

Syncrude Canada Ltd. commissioned Aquatic Environments Ltd. to survey the Athabasca River near Syncrude's Lease #17. Although Syncrude plans to discharge no process-exposed water from its plant into the river a number of tributary streams have had their flow regimes altered by diversion projects. Future environmental impact assessments will measure changes against the baseline information contained in this report.

It is Syncrude's policy to publish its consultants' final reports as they are received, withholding only proprietary technical information or that of a financial nature. Because we do not necessarily base our decisions on just one consultant's opinion, recommendations found in the text should not be construed as commitments to action by Syncrude.

Syncrude Canada Ltd. welcomes public and scientific interest in its environmental activities. Please address any questions or ocmments to Syncrude Environmental Affairs, 9915 - 108 Street, EDMONTON, Alberta, T5K 2G8

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Baseline Studies

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INTRODUCTION

This is a report of baseline studies of aquatic environments in the Athabasca River. These studies were carried out at the request of Syncrude Canada Limited and were focused in the vicinity of Syncrude's Lease Number 17, which borders the west bank of the Athabasca River north of the town of Ft. McMurray, Alberta (Figure 1). The studies were designed to provide a basis for comparison with changing conditions in the Athabasca River as the Syncrude development proceeds.

The study consisted of three parts:

1) A general reconnaissance early in the study period including a survey of fish species, benthic invertebrates, periphyton (attached algae) and water quality. On the basis of this preliminary survey, permanent sampling stations were identified and particular environmental parameters selected for further study.

2) Detailed studies of selected environmental parameters. Data describing these parameters will form the baseline against which any future changes will be assessed.

3) A survey of the scientific literature relevant to various aspects of the study.

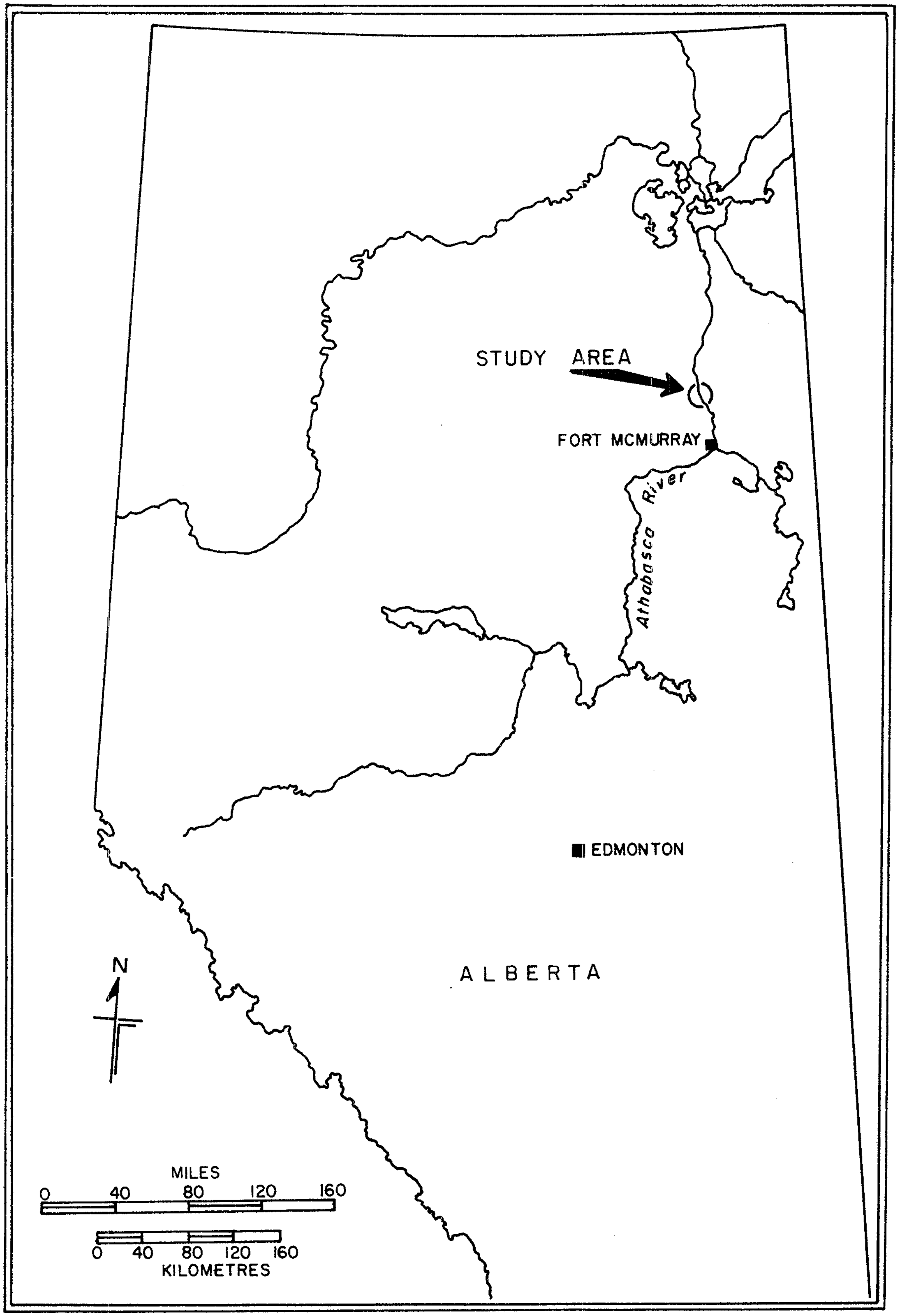

FIGURE 1. Map of the study area.

The area selected for study (Figure 2) extended from a point approximately 2.4 mi upstream of the Great Canadian Oil Sands Pump House to a point approximately 2.8 mi downstream of the McKay River, a total distance of approximately 15.6 mi. The study was confined to the Athabasca River itself and did not include tributaries. Within the study area, the sites of sampling stations were selected in accordance with the following criteria established by Cairns and Dickson (1971), which apply specifically to effluent discharges but are generally applicable to any disturbance:

1. Always have a reference station or stations above all possible discharge points. Because the usual purpose of a survey is to determine the damage that pollution causes to aquatic life, there must be some basis for comparison between areas above and below the point or points of discharge. In practice, it is usually advisable to have at least two reference stations. One should be well upstream from the discharge and one directly above the effluent discharge, but out of any possible influence from the discharge.

2. Have a station directly below each discharge.

3. If the discharge does not completely mix on entering the waterway but channels on one side, stations must be subdivided into left-bank, midchannel and right-bank sub-stations. All data collected--biological, chemical, and physical--should be kept separate by substations.

4. Have stations at various distances downstream from the last discharge to determine the linear extent of damage to the river.

5. All sampling stations must be ecologically similar before the bottom fauna communities found at each station can be compared. For example, the stations should be similar with respect to bottom substrate (sand, gravel, rock or mud), depth, presence of riffles and pools, stream width, flow velocity, and bank cover.

6. Biological sampling stations should be located close to those sampling stations selected for chemical and physical analyses to assure the correlation of findings.

7. Sampling stations for bottom fauna organisms should be located in an area of the stream that is not influenced by atypical habitats, such as those created by road bridges.

8. In order to make comparisons among sampling stations, it is essential that all stations be sampled approximately at the same time. Not more than two weeks should lapse between sampling at the first and last stations.

Obviously, such general criteria must be tailored to fit specific situations. In a large river such as the Athabasca, sites have to be chosen to minimize losses due to flooding, ice movements, river traffic, tampering etc. Despite precautions, losses occur and there are, consequently, some gaps in the resultant data.

The physical, chemical and biological parameters which were selected as representative of conditions in the study area met the following general criteria:

1) they reflect important environmental changes,

2) they are easily measured with a high reproducibility,

3) a statistically significant sample is easily obtained with a minimum of effort and expense.

Further information on these parameters is included in the relevant sections of the report.

As indicated, the purpose of these studies was to provide baseline data for a program of continuous monitoring as the Syncrude development proceeds. In the final section of this report, we have outlined such a program with suggestions regarding the location of sample sites and the environmental parameters which should be measured.

LITERATURE CITED

Cairns, J. Jr., and K.L. Dickson. 1971. A simple method for the biological assessment of the effects of waste discharges on aquatic bottom dwelling organisms. J. Water Pollut. Contr. Fed. 43(5), 755-772.

Section I

WATER QUALITY

by

P. McCart, Ph.D.

MATERIALS AND METHODS

Rationale

Effluent discharge from the Syncrude development could affect water quality in the Athabasca River in a variety of ways: through increases in dissolved solids content and organic loading (principally hydrocarbons), or through changes in nutrient levels, temperature regime, sediment loads, etc. Major changes in water quality could have measureable effects on aquatic ecosystems in the Athabasca River. For this reason, AEL carried out detailed studies of various aspects of water quality in the Athabasca River. The overall objective of these studies was to obtain sufficient data on geographic and seasonal variation in various parameters that the resultant data could serve as a basis for monitoring any changes which occur as the Syncrude development proceeds.

Sample Collection and Analysis

Figure 2 illustrates the location of permanent water quality sampling sites on the Athabasca River. Fewer stations were sampled during the winter than during the summer. At each site, three water samples were collected in 1 litre glass bottles submerged to a depth of 0.5 m with the aid of a weighted bottle holder. Two of these samples were filtered through Whatman GF/C filter discs; the third sample remained unfiltered. One litre of the filtrate was preserved with 5 ml 4NHCl for total dissolved nitrogen, phosphorous and metal ion determinations while the second litre of filtrate was preserved with 2.5 ml $CHCl_3$ (chloroform) for reactive silicate and major anion analyses. The unfiltered sample was treated with 2 ml of 0.4% copper sulphate and retained for turbidity and suspended sediment determinations.

Methods used in the routine analysis of water samples are summarized in Table 1.

In addition to the water samples collected at permanent stations, two special series of samples were obtained. On October 24, 1974, a series of samples was collected at 12 transect sites distributed through the study area. At each

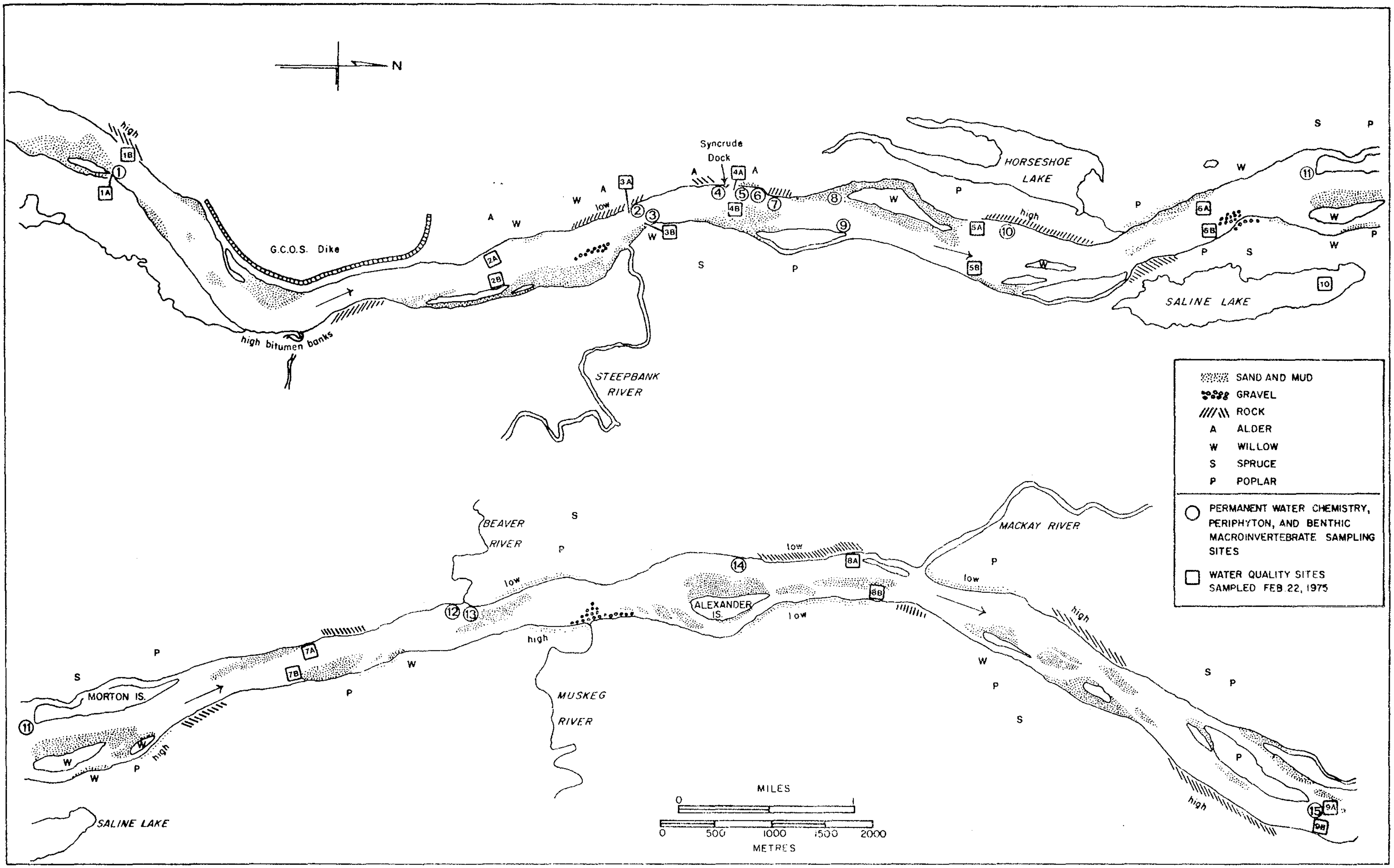

FIGURE 2. Detailed map of study area showing locations of water chemistry, periphyton, and benthic macroinvertebrate sample sites.

TABLE 1. Description of instruments, units and accuracy of techniques used to measure various physical and chemical parameters. *Standard Methods* refer to procedures outlined in Standard Methods for the Examination of Water and Wastewater 13th, ed. (1971).

Parameter measured	Technique or Instrument used	Measurement Unit	Lower limit of Accuracy
Temperature	Mercury pocket thermometer	° Centigrade	± 0.5°C
Conductivity	Beckman RB3 solubridge	μmhos/cm@25°C	± 5 μmhos/cm
Salinity	YS1-33 Salinity/conductivity meter	parts per thousand ‰	± 0.9 ‰ above 4°C ± 1.1 ‰ below 4°C
pH	Radiometer pH meter Type 296 combined Electrode, type Radiometer GK 2311 C.	pH units	± 0.1 pH units
Dissolved Oxygen	Standard Methods: azide modification	mg/1	± 0.1 mg/1
Suspended Sediments	Standard Methods	mg/1	± 0.5 mg/1
Turbidity	Hach Model 2100A turbidimeter	Formazin Turbidity units (F.T.U.)	± 2% of full scale
Chloride ion	Standard Methods: Argentometric titration	mg/1	± 0.5 mg/1
Sulphate ion	Standard Methods: Turbidimetric method	mg/1	1.0 mg ± 10% @ lower limit of detection

(Continued)

TABLE 1. Continued.

Parameter measured	Technique or Instrument used	Measurement Unit	Lower limit of Accuracy
Total Dissolved Phosphorous (TDP)	Standard Methods: 1) Sulphuric acid-perchlorate digestion method 2) Phosphate detection by ascorbic acid reduction method	µg/1	+ 5 µg/1
Total Dissolved Nitrogen (TDN)	1) U.V. irradiation (Strickland and Parsons, 1968) 2) Cadmium reduction to nitrites-Standard Methods 3) Nitrite analysis (Strickland and Parsons, 1968)	µg/1	+ 5 µg/1
Reactive silicates	Standard Methods: Heteropoly blue	µg/1	± 100 µg/1
Na^+, K^+, Mg^+ and Ca^{++}	Atomic absorbtion Instrumentation Laboratories Model 151 aa/ae spectrophotometer	mg/1	± 1.0 mg/1 for all ions
Alkalinity system	Standard Methods: acid titration	mg/1	± 1.0 mg/1
Total carbon	Beckman 915A Total Carbon Analyzer	ppm	± 1.0 ppm

transect site, 5 samples were taken at points approximately equidistant across the river. The samples (1 litre/site) were analysed within 24 hours by personnel of the Syncrude Environmental Laboratory using a Beckman 915A Total Carbon Analyser.

On February 22, 1975, a comparison was made of water quality conditions along the east and west banks of the Athabasca River. This series included some sites other than the permanent sites. The sites sampled in the east/west comparison are indicated separately in Figure 2 .

RESULTS AND DISCUSSION

Complete data for water quality samples taken at permanent stations are presented in Appendix I . In addition, the report includes a summary of data for all samples taken at permanent stations during the regular monthly sampling periods (Table 2). In what follows, each of the major water quality parameters is described in detail.

Physical Parameters

Discharge

Data showing the seasonal pattern of discharge in 1974 and the first nine months of 1975 are presented in Figure 3. During the winter, flows ranged from 6,500 to 10,000 cfs. In both years, the spring freshet began in mid-April and peaked within a few weeks, April 30 (97,600 cfs) in 1974 and May 14 (40,500 cfs) in 1975. Also, in both years, flows declined after the initial surge but reached a second, greater peak in July. In 1974, the July peak occurred on the 17th (105,000 cfs maximum daily discharge) and in 1975 it occurred on July 2 (86,800 cfs maximum daily discharge).

TABLE 2. Summary of water quality data, Athabasca River. Mean values calculated for all samples taken within the study area on various dates. Also mean values for all samples taken in 1974 and 1975. Unless otherwise indicated, values are mg/l. Sulphate data for October 29, 1975 are calculated rather than observed values.

Date	September 3, 1974				October 25, 1974			
	$\bar{x}$	Range	S.E.	N	$\bar{x}$	Range	S.E.	N
PHYSICAL CHARACTERISTICS								
Temperature °C	15.0	14-16	0.26	6	4.7	4-5	0.33	3
Conductivity μmhos/cm	187.0	175-200	4.20	6	155.0	145-162	5.40	3
pH Units	8.1	8.0-8.3	0.06	6	-	-	-	-
Turbidity (Shaken) FTU	14.0	9.7-17	1.20	6	8.1	7.4-8.7	0.70	2
(Settled) FTU	1.5	1.3-1.6	0.04	7	1.5	1.5-1.6	0.05	2
Suspended Solids	25.7	16.8-33.6	2.80	6	21.0	18.4-23.6	2.60	2
Dissolved Oxygen	13.3	13-14	0.21	6	12.2	12.0-12.7	0.23	3
MAJOR IONS								
Ca	-	-	-	-	-	-	-	-
Mg	-	-	-	-	-	-	-	-
Na	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-
Cl	5.2	1.5-8.0	1.1	6	-	-	-	-
SO_4	-	-	-	-	-	-	-	-
HCO_3	91.8	85-100	2.6	6	-	-	-	-
SUM CATIONS	-	-	-	-	-	-	-	-
SUM ANIONS	-	-	-	-	-	-	-	-
MEAN	-	-	-	-	-	-	-	-
% ERROR	-	-	-	-	-	-	-	-
MACRONUTRIENTS								
TDN μg/l	372.0	303-620	50.0	6	-	-	-	-
TDP μg/l	6.5	3-11	1.5	6	-	-	-	-
REACTIVE Si μg/l	1953	1450-2265	145	6	-	-	-	-

(Continued)

TABLE 2. Continued.

Date	December 14, 1974				January 17, 1975			
	$\bar{x}$	Range	S.E.	N	$\bar{x}$	Range	S.E.	N
PHYSICAL CHARACTERISTICS								
Temperature °C	0.0	0-0	0.0	8	0.0	0-0	0.0	9
Conductivity µmhos/cm	316.0	235-360	15.50	8	355.0	318-380	8.50	9
pH Units	8.0	7.6-8.1	0.06	7	-	-	-	-
Turbidity (Shaken) FTU	6.6	4.6-8.2	0.46	7	5.6	4.1-12.4	0.86	9
(Settled) FTU	0.0	0-0	0.0	0	0.0	0-0	0.0	0
Suspended Solids	3.4	1.8-5.6	0.45	7	3.1	1.6-4.5	0.28	9
Dissolved Oxygen	12.3	8.0-13.3	0.72	7	12.5	12.3-12.8	0.06	9
MAJOR IONS								
Ca	35.2	21.5-42.0	4.10	5	-	-	-	-
Mg	9.8	6.6-12.1	1.10	6	-	-	-	-
Na	21.2	11.6-36.5	3.60	6	-	-	-	-
K	2.2	1.6-2.6	0.18	6	-	-	-	-
Cl	14.8	7.5-36.0	4.10	7	18.5	10.5-45.0	3.80	9
SO_4	26.8	9.8-40.0	4.60	7	18.7	7.2-35.6	2.90	9
HCO_3	122.0	77-144	11.20	7	146.0	143-149	1.20	5
SUM CATIONS	3.44	2.64-3.90	0.24	6	25.4	1.5-82.0	8.20	9
SUM ANIONS	3.39	2.59-3.86	0.23	6	-	-	-	-
MEAN	3.41	2.62-3.85	0.23	6	-	-	-	-
% ERROR	1.92	0.66-3.13	0.42	6	-	-	-	-
MACRONUTRIENTS								
TDN µg/l	-	-	-	-	-	-	-	-
TDP µg/l	19.5	14-24	1.7	6	25.4	1.5-82.0	8.20	9
REACTIVE Si µg/l	4190	3340-5125	334	7	3296	2875-4450	207	9

(Continued)

TABLE 2. Continued.

Date	February 22, 1975				March 20, 1975			
	$\bar{x}$	Range	S.E.	N	$\bar{x}$	Range	S.E.	N
PHYSICAL CHARACTERISTICS								
Temperature °C	0.0	0-0	0.0	8	0.0	0-0	0.0	9
Conductivity μmhos/cm	366.0	330-380	5.50	9	363.0	270-420	14.40	9
pH Units	7.8	7.4-8.0	0.04	9	8.1	7.9-8.2	0.04	9
Turbidity (Shaken) FTU	4.7	3.5-7.2	0.36	9	3.7	3.1-4.2	0.17	9
(Settled) FTU	2.1	1.9-2.7	0.08	9	2.0	1.7-2.6	0.09	9
Suspended Solids	11.1	5.2-29.6	2.60	9	4.1	2.8-6.6	0.41	9
Dissolved Oxygen	11.5	11.2-12.0	0.09	9	11.9	11.7-12.2	0.05	9
MAJOR IONS								
Ca	40.7	30-45	2.70	5	-	-	-	-
Mg	11.4	8.4-12.5	0.70	5	-	-	-	-
Na	19.8	16-29.2	2.4	5	-	-	-	-
K	2.2	1.6-2.6	0.17	5	-	-	-	-
Cl	25.5	20.5-45.0	2.8	9	23.6	16-44	3.90	9
SO_4	30.3	15.1-37.2	2.7	9	-	-	-	-
HCO_3	130.0	88-142	5.4	9	128.0	86-138	5.40	9
SUM CATIONS	3.89	3.5-4.12	0.11	5	-	-	-	-
SUM ANIONS	3.91	3.34-4.23	0.15	5	-	-	-	-
MEAN	3.9	3.42-4.10	0.13	5	-	-	-	-
% ERROR	1.96	0.77-3.42	0.46	5	-	-	-	-
MACRONUTRIENTS								
TDN μg/l	-	-	-	-	-	-	-	-
TDP μg/l	16.3	0-33	4.40	9	22.6	17-26	1.10	9
REACTIVE Si μg/l	794	546-1650	113	9	3680	2850-5530	286	9

(Continued)

TABLE 2. Continued.

Date	April 9, 1975				June 2, 1975			
	$\bar{x}$	Range	S.E.	N	$\bar{x}$	Range	S.E.	N
PHYSICAL CHARACTERISTICS								
Temperature °C	0.5	0-1	0.16	8	16.4	16.0-17.2	0.11	15
Conductivity μmhos/cm	349.0	320-395	8.10	8	202.0	160-215	5.20	15
pH Units	7.5	7.1-7.8	0.05	8	8.0	7.8-8.1	0.02	15
Turbidity (Shaken) FTU	4.2	3.3-6.1	0.32	8	40.3	20-53	2.40	15
(Settled) FTU	2.3	2.0-2.6	0.08	8	11.2	7.4-13.0	0.53	15
Suspended Solids	4.7	2.9-10.5	0.91	8	129.0	71-205	11.00	15
Dissolved Oxygen	12.5	12.0-12.9	0.11	8	9.0	8.9-9.3	0.03	15
MAJOR IONS								
Ca	-	-	-	-	-	-	-	-
Mg	-	-	-	-	-	-	-	-
Na	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-
Cl	22.9	15-44	3.60	8	1.8	0.0-10.3	0.87	15
SO_4	-	-	-	-	-	-	-	-
HCO_3	130.0	89-141	6.00	8	80.9	59-91	2.80	15
SUM CATIONS								
SUM ANIONS	-	-	-	-	-	-	-	-
MEAN	-	-	-	-	-	-	-	-
% ERROR	-	-	-	-	-	-	-	-
MACRONUTRIENTS								
TDN μg/l	286.0	0-0	0.0	1	-	-	-	-
TDP μg/l	19.4	10-48	4.4	8	44.1	32-58	1.80	15
REACTIVE Si μg/l	3003	2350-4990	351	8	1616	1510-2060	37	15

(Continued)

TABLE 2. Continued.

Date	June 28, 1975				July 27, 1975			
	$\bar{x}$	Range	S.E.	N	$\bar{x}$	Range	S.E.	N
PHYSICAL CHARACTERISTICS								
Temperature °C	17.0	15.5-17.5	0.15	15	19.7	18-20	0.16	15
Conductivity µmhos/cm	211.0	160-240	5.50	15	209.0	160-290	0.10	15
pH Units	7.8	7.4-8.0	0.05	15	7.8	7.6-8.0	0.02	15
Turbidity (Shaken) FTU	48.3	31-97	3.90	15	47.1	3.9-58.0	4.20	13
(Settled) FTU	8.7	5.9-14.0	0.53	15	14.0	8.6-17.0	0.56	15
Suspended Solids	224.0	117.0-579.5	0.28	15	107.0	26.0-155.6	7.40	15
Dissolved Oxygen	8.39	7.9-8.8	0.07	15	7.68	7-8	0.07	15
MAJOR IONS								
Ca	-	-	-	-	26.8	18.2-31.6	1.10	15
Mg	-	-	-	-	6.9	5.0-11.1	0.41	15
Na	-	-	-	-	7.1	4.5-15.7	0.71	15
K	-	-	-	-	1.1	0.8-1.4	0.04	15
Cl	2.0	0-12	0.92	15	2.8	0.0-22.8	1.60	15
SO_4	-	-	-	-	15.3	3.8-23.2	1.50	15
HCO_3	89.2	66.5-114.0	3.20	15	81.7	62-109	2.80	15
SUM CATIONS	-	-	-	-	2.24	1.78-3.1	0.08	15
SUM ANIONS	-	-	-	-	2.03	1.59-2.86	0.07	15
MEAN	-	-	-	-	2.14	1.69-2.98	0.07	15
% ERROR	-	-	-	-	5.11	0.5-8.37	0.61	15
MACRONUTRIENTS								
TDN µg/l	-	-	-	-	423.0	360-597	16.00	15
TDP µg/l	80.7	55-164	6.60	15	75.2	60-104	3.30	15
REACTIVE Si µg/l	1802	1536-2356	70	15	2607	2415-3144	60	15

(Continued)

TABLE 2. Continued.

Date	August 27, 1975				September 23, 1975			
	$\bar{x}$	Range	S.E.	N	$\bar{x}$	Range	S.E.	N
PHYSICAL CHARACTERISTICS								
Temperature °C	14.7	13-15	0.15	15	12.3	11-14	0.21	15
Conductivity µmhos/cm	227.0	160-430	16.00	15	222.0	180-340	8.90	15
pH Units	7.8	7.4-8.2	0.05	15	7.9	7.6-8.1	0.03	15
Turbidity (Shaken) FTU	22.8	4.3-30.0	2.10	15	14.6	7-20	0.72	15
(Settled) FTU	3.7	2.6-4.6	0.14	15	3.6	2.4-7.4	0.32	15
Suspended Solids	76.8	34.4-184.4	9.70	15	31.5	9.5-63.6	3.20	15
Dissolved Oxygen	9.0	8.7-9.4	0.05	15	9.9	9.5-10.0	0.03	15
MAJOR IONS								
Ca	-	-	-	-	-	-	-	-
Mg	-	-	-	-	-	-	-	-
Na	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-
Cl	5.1	1.3-33.5	2.10	15	4.9	0.5-26.3	1.80	15
SO_4	-	-	-	-	-	-	-	-
HCO_3	90.4	65-152	5.10	15	90.3	72-128	3.20	15
SUM CATIONS	-	-	-	-	-	-	-	-
SUM ANIONS	-	-	-	-	-	-	-	-
MEAN	-	-	-	-	-	-	-	-
% ERROR	-	-	-	-	-	-	-	-
MACRONUTRIENTS								
TDN µg/l	399.0	335-580	18.0	15	467.0	415-660	16.50	15
TDP µg/l	58.1	37-105	4.9	15	39.0	15-113	7.00	15
REACTIVE Si µg/l	3208	2750-3906	78	15	2544	1530-3720	166	15

(Continued)

TABLE 2. Continued.

Date	October 29, 1975				All Observations			
	$\bar{x}$	Range	S.E.	N	$\bar{x}$	Range	S.E.	N
PHYSICAL CHARACTERISTICS								
Temperature °C	0.5	0-0	0.0	15	9.28	0.0-20.0	0.67	142
Conductivity µmhos/cm	210	190-260	3.80	15	253.0	145-430	6.20	142
pH Units	7.8	7.5-8.2	0.04	15	7.9	7.1-8.3	0.06	129
Turbidity (Shaken) FTU	8.6	4.7-11.0	0.42	14	22.0	3.1-97.9	1.62	140
(Settled) FTU	2.7	1.6-3.3	0.10	15	5.9	1.5-17.0	0.41	124
Suspended Solids	18.5	6.5-36.8	1.80	15	65.9	1.6-179.5	6.86	140
Dissolved Oxygen	13.7	13.2-14.1	0.07	15	10.6	7.0-14.0	0.18	141
% Saturation	-	-	-	-	29.3	18.2-45.0	1.07	41
MAJOR IONS								
Ca	26.7	21.8-29.4	0.60	15	29.3	18.2-45.0	1.07	41
Mg	8.1	7.0-8.8	0.14	15	8.3	5.0-12.5	0.33	41
Na	12.0	10.5-18.5	0.49	15	12.5	4.5-36.5	1.05	41
K	1.3	1.0-1.4	0.03	15	1.5	0.80-2.6	0.08	41
Cl	7.5	4.5-14.8	0.67	15	9.3	00-45	0.93	138
SO_4	22.6	16.0-27.4	0.91	15	21.8	3.8-40.0	1.19	55
HCO_3	93.9	81.5-103.0	1.80	15	99.9	59-152	2.08	134
SUM CATIONS	-	-	-	-	2.8	1.78-4.12	0.158	26
SUM ANIONS	-	-	-	-	2.7	1.59-4.23	0.175	26
MEAN	-	-	-	-	2.8	1.69-4.1	0.166	26
% ERROR	-	-	-	-	3.8	0.05-8.37	0.484	26
MACRONUTRIENTS								
TDN µg/l	432.0	380-495	8.50	15	424.8	286-660	8.73	66
TDP µg/l	26.5	15-58	3.4	15	41.9	00-164	2.43	137
REACTIVE Si µg/l	2639	2120-3180	82	15	2545	546-5530	82.20	138

(Continued)

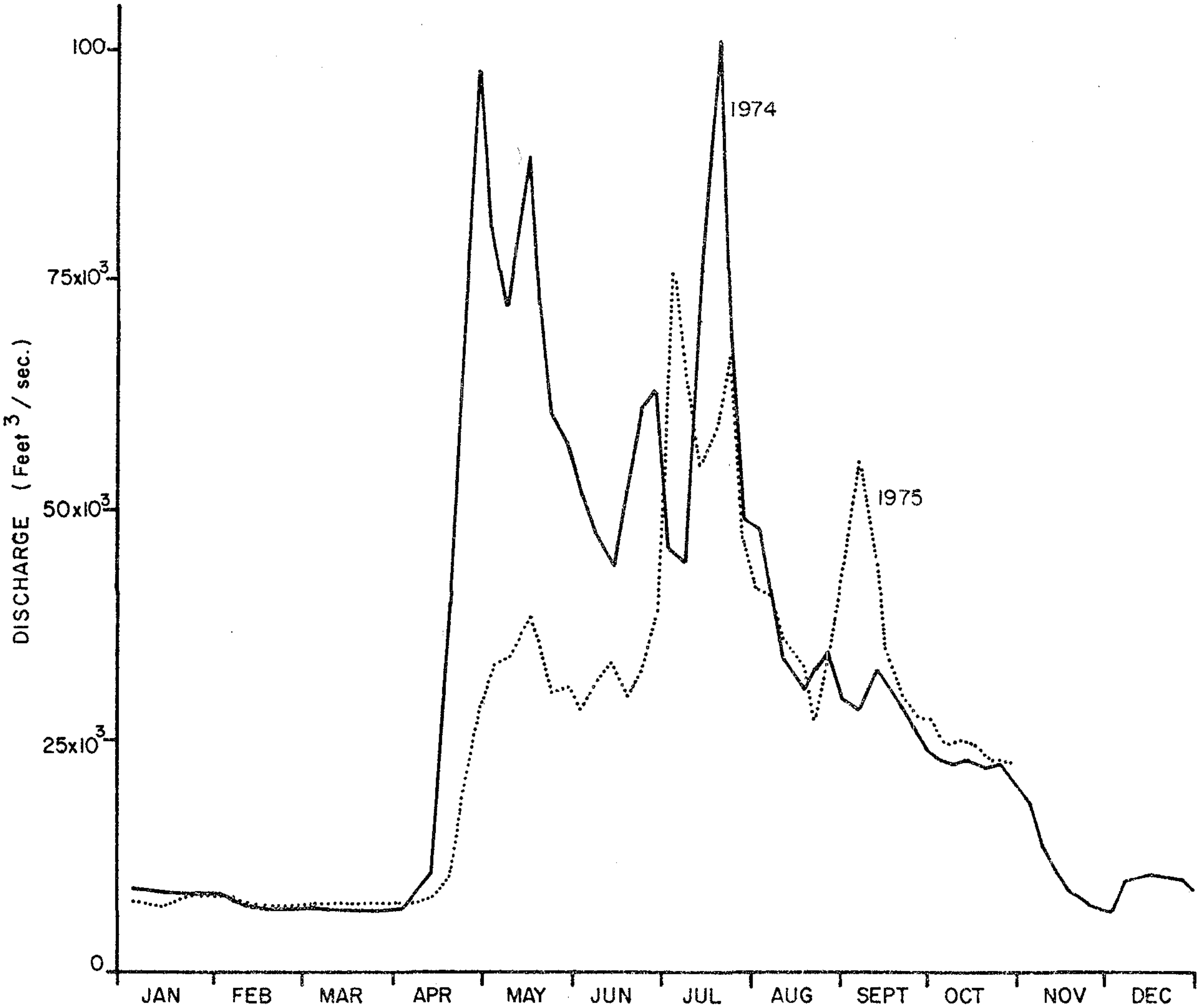

FIGURE 3. Seasonal pattern of discharge of the Athabasca River, 1974 and 1975. Points plotted are weekly mean discharges. Data were supplied by Water Survey of Canada for station "Athabasca River below McMurray."

In both years, discharges declined after the July peak but in 1975 there was an additional peak in September (58,200 cfs, September 4). The early April-May peak is primarily the result of melting of snow and ice, but midsummer and autumn peaks are apparently the result of surface runoff related to rainfall.

Water Temperature

Mean water temperatures recorded during regular sampling periods ranged from 0 C during the December to March period to 19.7 C during the July 27, 1975 sampling. The highest individual temperature recorded for the Athabasca River during the study was 20 C on July 27, 1975. Even higher temperatures may have occurred during the intervals between sampling periods. Temperatures declined rapidly through September and October reaching 0.5 C by the end of October.

Specific Conductance (Conductivity)

The specific conductance (conductivity) of a water sample is a measure of its capacity to convey an electric current. Values for this parameter are affected both by the concentration of ionized substances in the water and the water temperature. The higher the ionic concentration and the higher the temperature, the higher will be the value of specific conductance. Normally, values are adjusted to a standard temperature of 25 C.

The mean conductance values of monthly samples taken during the ice-free period in 1974 (September and October) and 1975 (June through October) ranged from 155 to 227 μmhos (Figure 4 and Table 2). During the five month period from mid-December, 1974 to mid-April, 1975, the mean values for the five monthly sampling periods ranged from 316 to 366, approximately 75% greater than those taken during the ice-free season. This presumably reflects the greater relative contribution of high conductance groundwater and the reduced contribution of low conductance surface runoff during the winter.

pH

All of the pH values recorded during the study were slightly alkaline, between 7.1 and 8.4 for values at individual stations, with mean values for monthly sampling periods ranging from 7.5 to 8.1 (Figure 4 and Table 2). The highest mean value (8.1) was recorded for samples taken September, 1974, and the lowest mean value (7.5) for samples taken April, 1975. There is no clearly discernible seasonal trend.

Turbidity and Suspended Sediment Loads

The seasonal patterns of variation in turbidity (both shaken and settled) and suspended sediments are presented in Figure 5 (data from Table 2). The data indicate that, as might be expected, levels for all three parameters are

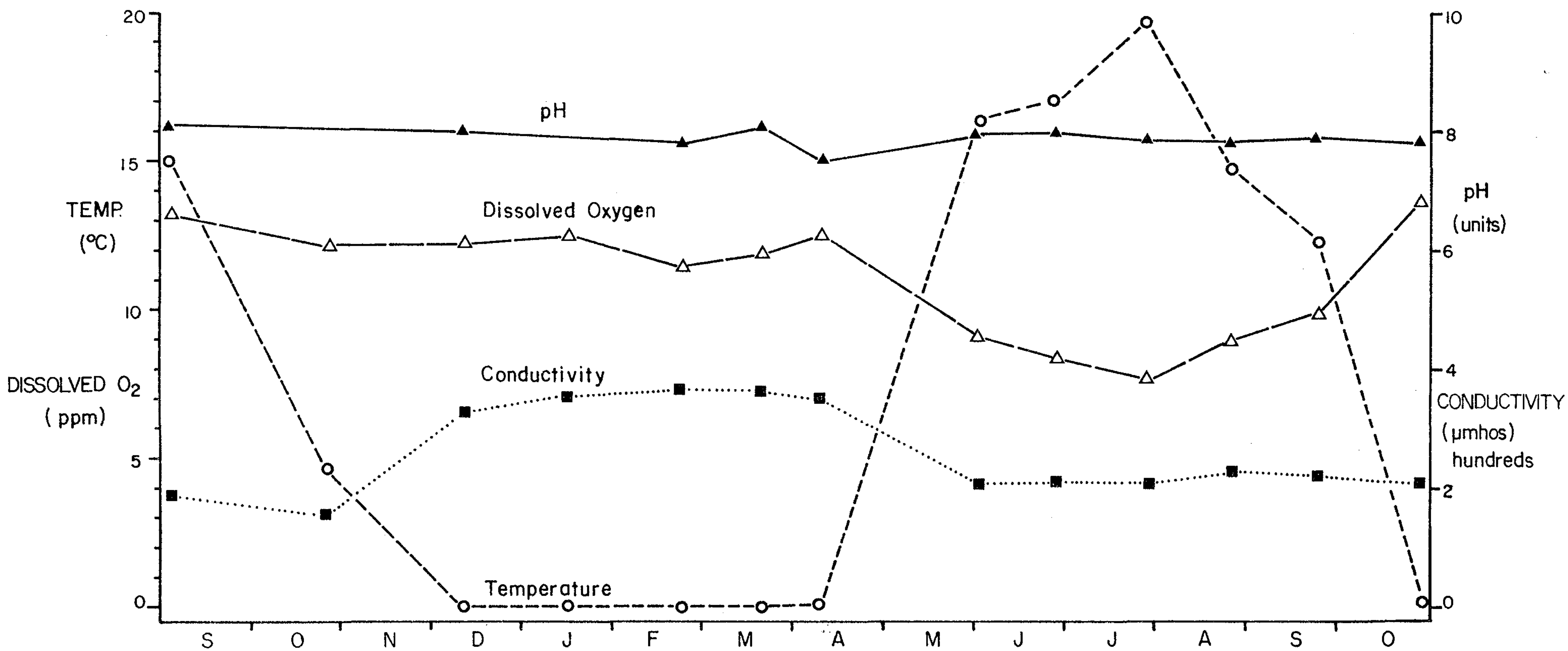

FIGURE 4. Seasonal variation in mean values for pH, dissolved oxygen, conductivity, and temperature in study area, Athabasca River, 1974 and 1975. Data from Table 2.

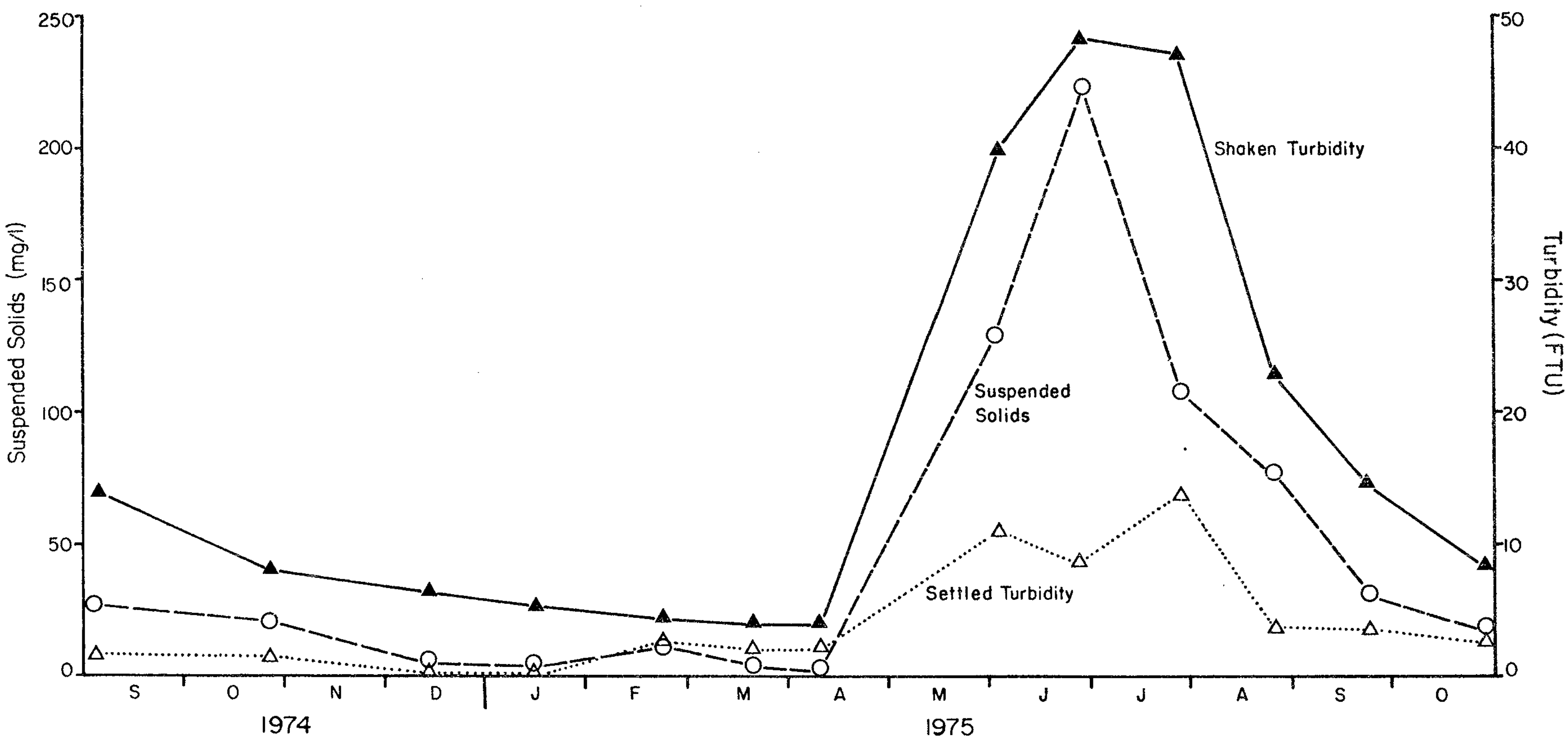

FIGURE 5. Seasonal variation in mean values for turbidity (shaken and settled) and suspended sediments within the study area, Athabasca River, 1974 and 1975. Data from Table 2.

highest during the period May through September when stream discharges are at a maximum. The Athabasca River is generally turbid and the values for all three parameters are relatively high. Suspended sediments, for example, are present in measurable quantities even during mid-winter. In many streams, suspended sediment loads are undetectable during winter with the methods employed during this study.

Much of the turbidity present during the winter is the result of the presence of fine particles which are not readily settleable. Settled turbidities are measured on samples which have been allowed to remain undisturbed for at least 20 hours. In this time, particles down to 0.001 mm (i.e., bacterial size) will normally sink to the bottom of the bottles used. Particles of the next order of magnitude smaller (0.0001 mm) are clays, and would require between 100 and 200 days to settle out. In February, March and April, 1975, the mean settled turbidities ranged from 45 to 56% of the mean values for shaken turbidity. In samples taken in June through October, 1975, these values ranged from 13 to 29%. This difference is probably related to the fact that at higher discharges and higher velocities a high proportion of larger particles is kept in suspension. Overall, settled turbidity averaged approximately 27% of the shaken value.

Suspended sediment concentration is a measure of the weight of particulate matter present per unit volume of water while turbidity is a measure of the impedence of light passing through water. The two parameters are usually, though not necessarily, related. However, a comparison of mean values obtained during monthly sampling (data from Table 2) indicates that, for the Athabasca River, suspended sediment concentrations and shaken turbidities are highly correlated (r=0.94).

Dissolved Oxygen

Dissolved oxygen concentrations were relatively high throughout the year and exceeded 80% saturation at all times, even under winter ice. The low absolute values recorded during the summer of 1975 reflect the fact that the solubility of oxygen is indirectly correlated with temperature, i.e., as temperatures rise, the solubility of oxygen declines.

Chemical Parameters

Major Ions

Figure 6 illustrates seasonal variation in the proportions of major ions in samples of water from the Athabasca River. The July samples are typical of water of the calcium carbonate type with relatively low proportions of sodium, chloride, and sulphate ions. The October and December samples, however, demonstrate increasing proportions of these ions and, by

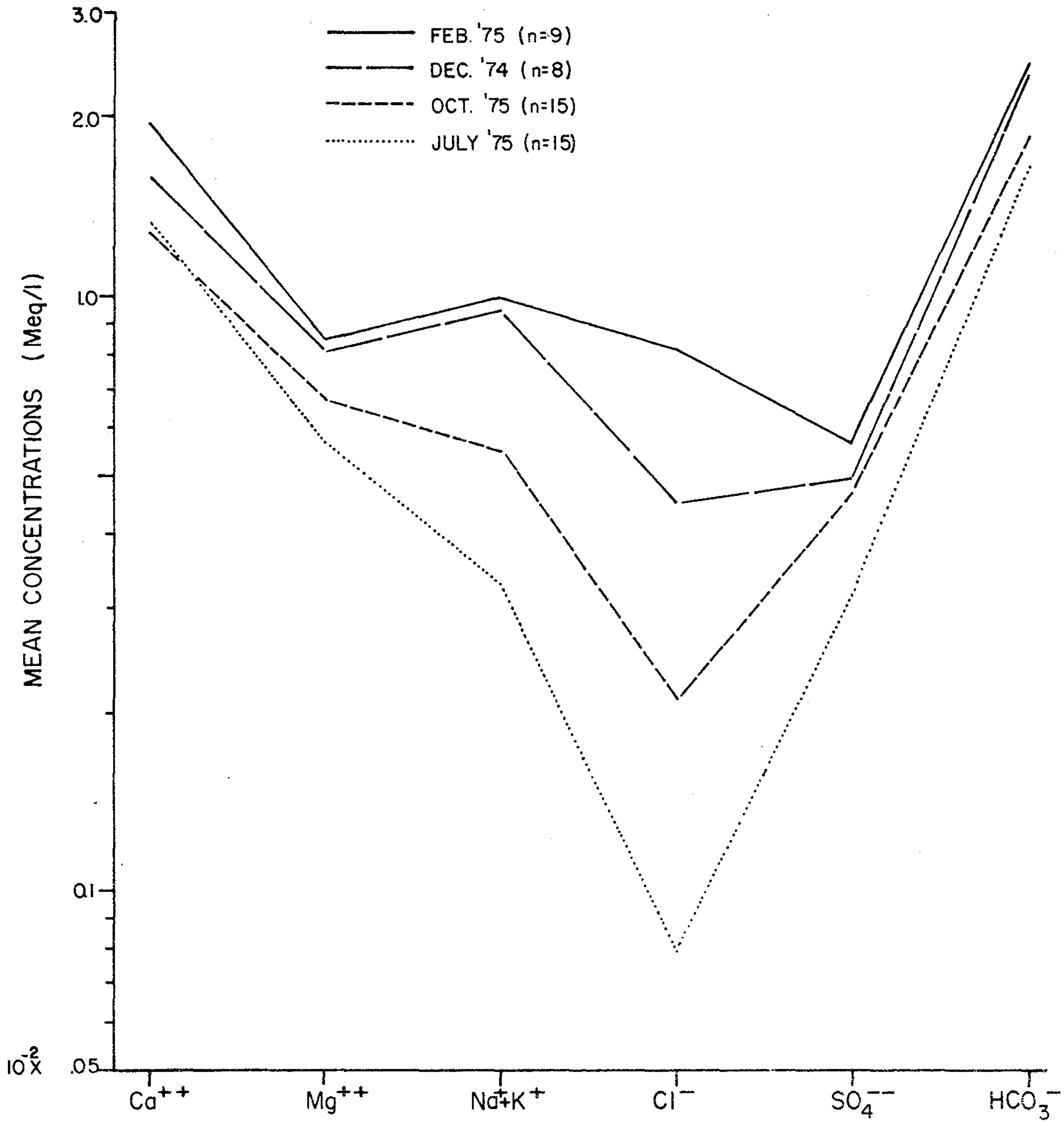

FIGURE 6. Proportions of major ios in water samples taken from the Athabasca River on various dates.

February, the water is definitely of the sodium chloride type. This trend suggests that a major source of discharge during the winter is saline groundwater. During the ice-free season, however, the influence of this groundwater flow would be masked by the much larger contribution from surface runoff of the calcium carbonate type. A change in ionic concentrations is also reflected in the increased values for specific conductance which occur during the winter, from values generally less than 250 to values exceeding 300 μmhos/cm (Figure 4).

Some of the data indicate that there are major sources of groundwater in the vicinity of the study area. A comparison (Figure 7) of the mean proportions of major ions in samples taken February 22, 1975, along the east and west banks of the river indicates a greater proportion of sodium and chloride ions in samples taken along the former. Some other differences are indicated in Table 3 . These include:

1) significantly ($p<0.01$) *higher* values for two selected ion ratios, HCO_3/Cl and Na/Cl,

2) significantly ($p<0.01$) *lower* values for specific conductance.

These data suggest that there are groundwater sources either within or upstream of the study area which differentially affect water quality along the east and west

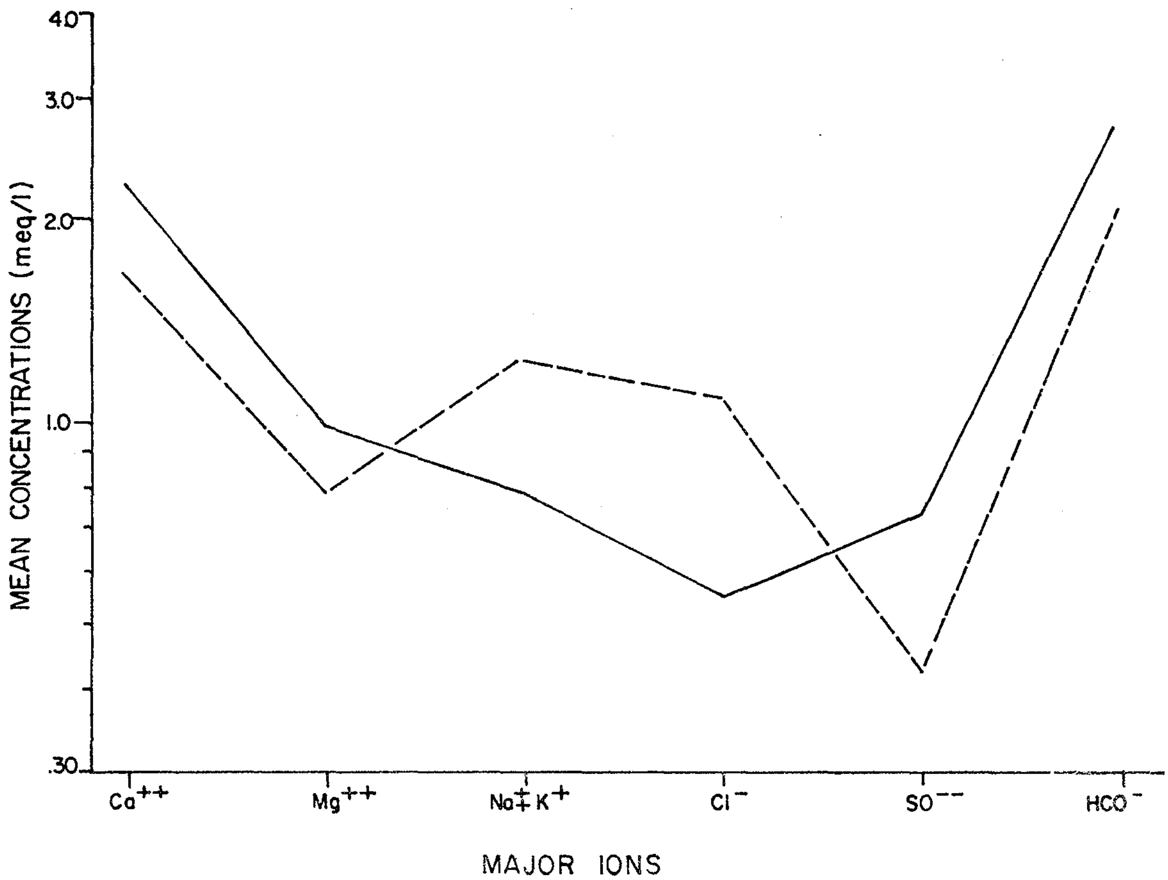

FIGURE 7. Mean values for major ions from four sites along the east (dashed line) and west (solid line) banks of the Athabasca River, February 22, 1975.

TABLE 3. Comparison of specific conductivity, chloride/alkalinity ratio and sodium/chloride ratio for samples taken along the east and west banks of Athabasca River, February 22, 1975. Locations of sample sites are indicated in Figure 10.

WEST BANK				EAST BANK			
Site Number	Conductivity	Chloride/Alkalinity ratio	Na/Cl	Site Number	Conductivity	Chloride/Alkalinity ratio	Na/Cl
1A	360	0.096	1.02	1B	330	0.511	0.65
2A	380	0.166	-	2B	370	0.401	-
3A	360	0.150	-	3B	360	0.261	-
4A	380	0.151	-	4B	370	0.263	-
5A	380	0.156	0.76	5B	320	0.354	0.69
6A	360	0.162	-	6B	300	0.346	-
7A	380	0.158	0.79	7B	300	0.368	0.67
8A	365	0.167	0.87	8B	330	0.282	0.75
9A	380	0.162	-	9B	340	0.284	-
Means	371	0.152	0.860		335	0.341	0.690
S.E.	3.34	0.008	0.058		8.99	0.027	0.022

t (cond. E x Cond. W) = 3.7653 ($p<0.01$)

t (C/A E x C/A W) = 6.6820 ($p<0.01$)

t (Na/Cl E x Na/Cl W) = 2.7244 ($p<0.05$)

banks of the river. There are major aquifers in the Fort McMurray area which bear saline water. Figure 8 compares groundwater from two different sources, springs in the vicinity of Saline Lake and groundwater from a well (4800 East, 2600 South) on Syncrude Lease 17. Both waters are saline but the well water is more dilute and differs in having a proportionately lower sulphate but higher bicarbonate content.

Macronutrients

Macronutrients are plant nutrients which are important in determining the primary productivity of lakes and streams. They include nitrogen, phosphorous, and silica compounds. The first two are important to all plants, the latter is especially important to diatoms which are among the most numerous algae in aquatic ecosystems and which are enclosed within siliceous frustules. In this study, macronutrient levels have been measured as total dissolved nitrogen (TDN), total dissolved phosphorous (TDP), and reactive silica (SiO_2).

The mean value of total nitrogen for all samples (Table 2) was 424.8 μg (range 286 to 660 μg), the mean total phosphorous value was 41.9 μg (range 0-164 μg), and the mean reactive silica value was 2545 μg (range 546 to 5530 μg). All of these values fall within the normal range of variation for streams in Alberta.

Seasonal trends in the concentrations of macronutrients

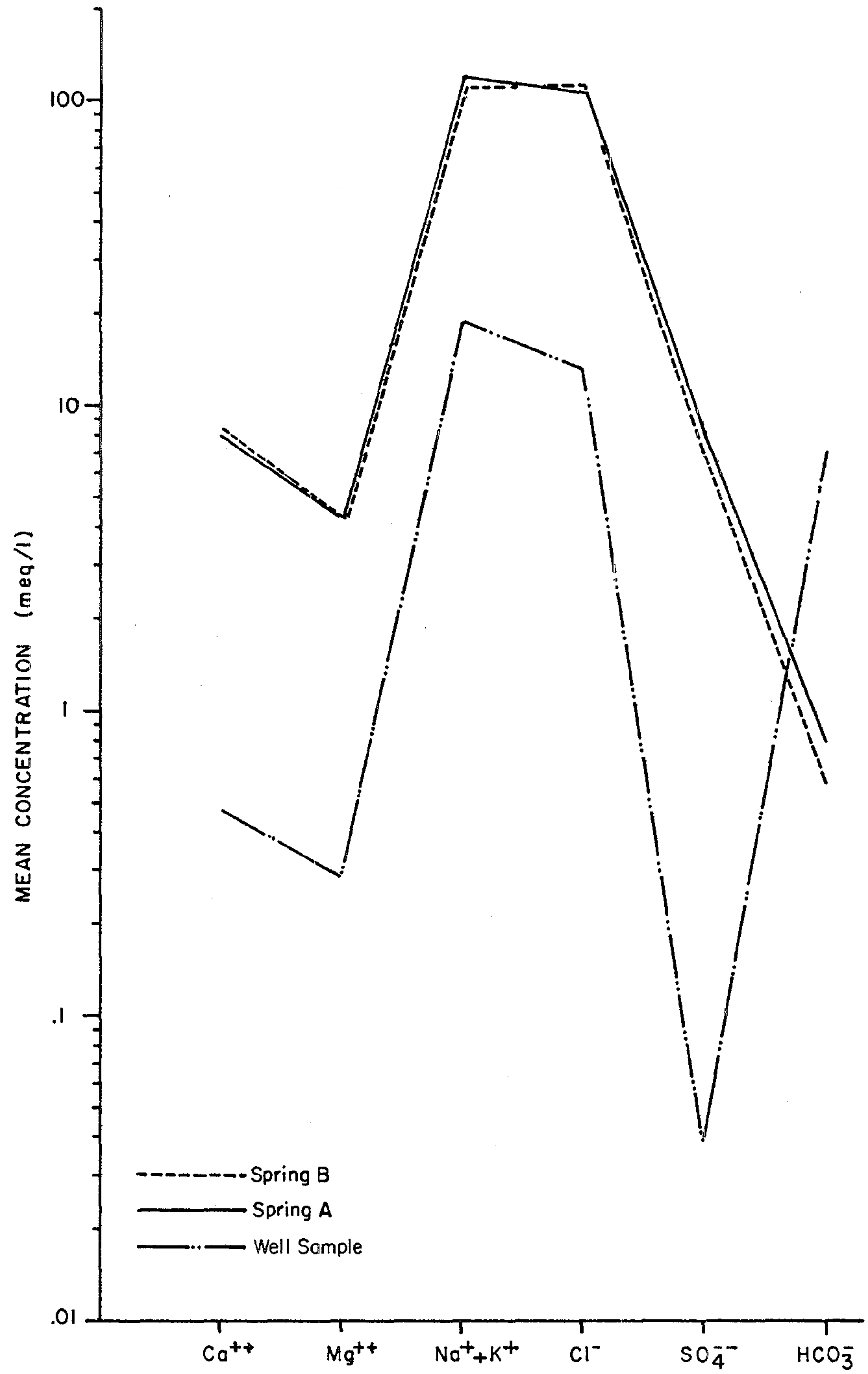

FIGURE 8. Comparison of major ions in samples of groundwater from springs in the vicinity of Saline Lake and from a well (4800 east, 2600 south) on Syncrude Lease 17.

are presented in Figure 9 . The most distinct seasonal pattern is in total dissolved phosphorous (TDP) which showed a distinct peak during the high water period in June and July and lows during the fall and winter period of reduced discharge.

Concentrations of reactive silica were generally higher in samples taken during the winter than those taken in summer suggesting that this parameter tends to be inversely correlated with discharge. It is noteworthy, however, that the lowest mean value for this parameter was recorded during February. There is no obvious explanation for this mid-winter low.

Data for total dissolved nitrogen are too few to reach any definite conclusions regarding patterns of seasonal variation. There does, however, appear to be a tendency for concentrations to increase from early to late summer.

Total Carbon

On October 24, 1974, there was an intensive water sampling effort on the Athabasca River, from a point approximately one mile upstream of the Great Canadian Oil Sands pumping plant to a point approximately 14.8 miles downstream, to determine the variability in values for total carbon within the study area. Samples were taken at five locations along each of twelve transects. The resultant data (Figure 10) indicate a relatively high background level (17 to 18 ppm)

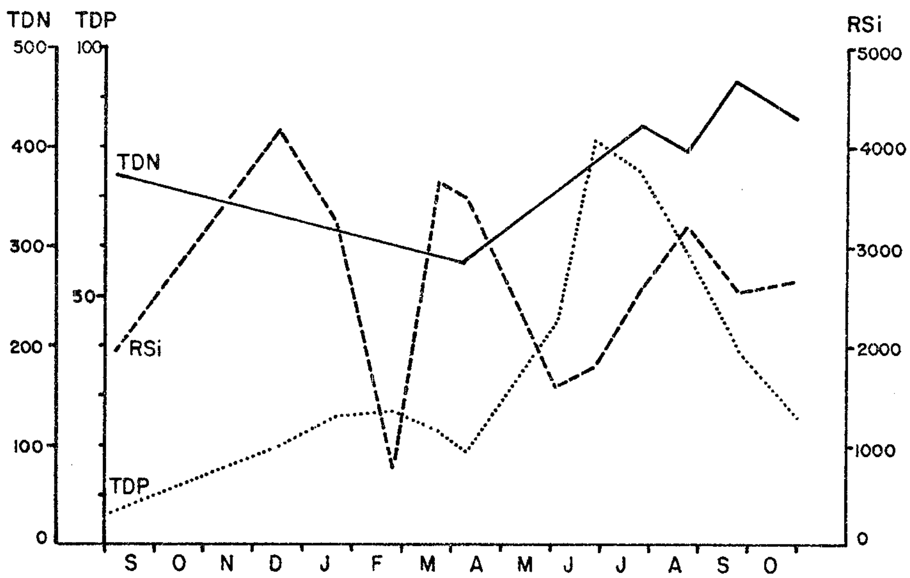

FIGURE 9. Seasonal trends in concentrations of macronutrients in water samples from the study area on the Athabasca River

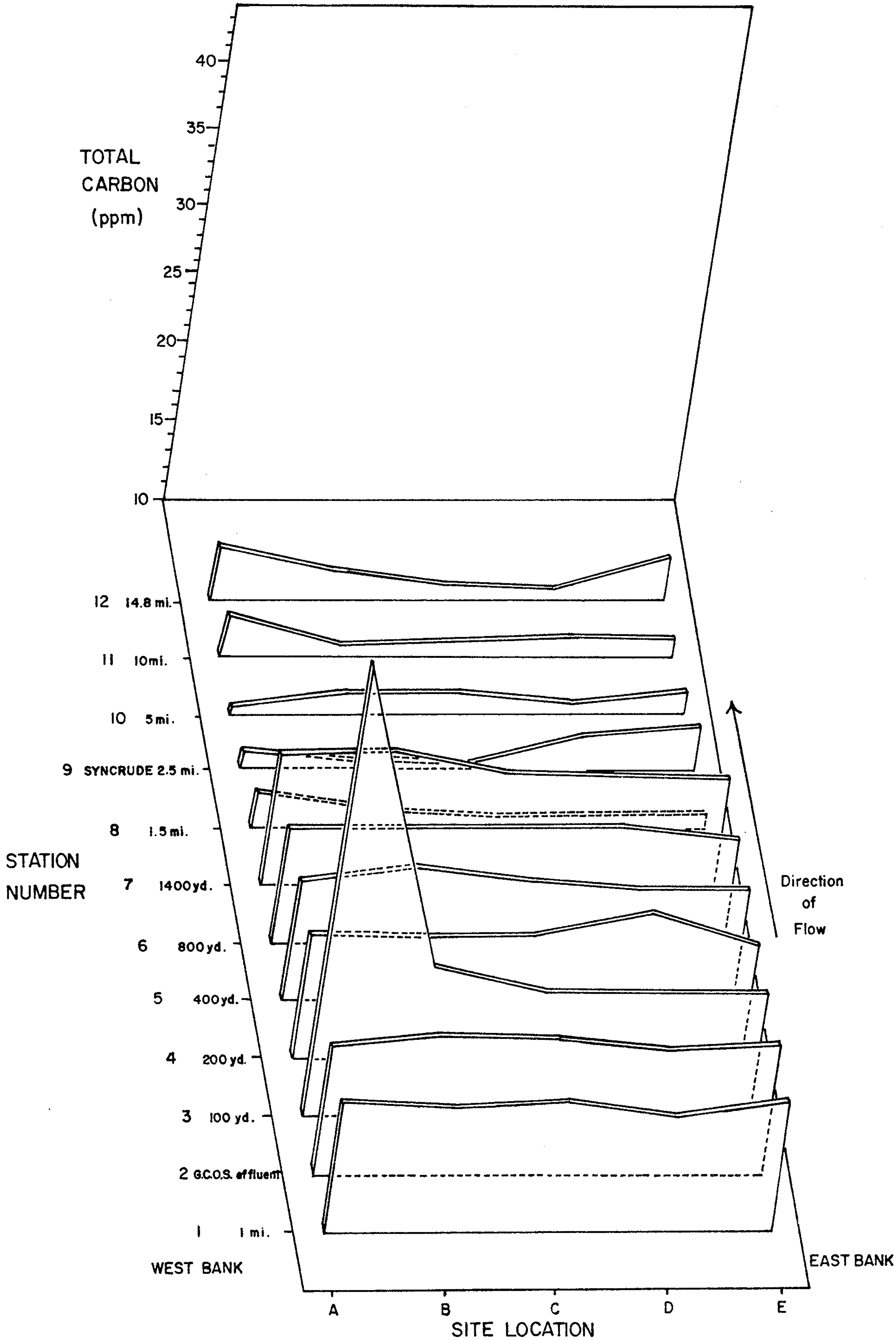

FIGURE 10. Variability in total carbon concentration in water samples taken in study area on October 24, 1974. Further explanation in text.

across the entire transect at the upstream station. These relatively high levels persisted to a point approximately 1400 yards downstream of the GCOS pumping plant then abruptly declined to levels of 11 to 15 ppm, possibly as the result of dilution by waters from the Steepbank River. These lower concentrations persisted as far downstream as Transect 12. In general, values along transects were uniform with no consistent difference between the east and west sides of the river. The only unique reading was one for a sample taken near the west bank of the river, just downstream of the GCOS pumphouse. This was apparently a local concentration, possibly related to GCOS operations, and did not persist downstream.

CONCLUSIONS

Within the study area, one of the most important aspects of water quality from the point of view of the Syncrude development is the relatively high salinity of the discharge during the winter period, apparently the result of a high proportion of groundwater. Obviously, the organisms which now inhabit the river during the winter are tolerant of this naturally occurring seasonal increase. However, any additional increase in salinity (e.g. from the discharge of saline water produced during the dewatering of mining areas) could affect communities of organisms downstream of the discharge point. A continuing monitoring program would determine whether changes in community structure do in fact occur and if so, the nature and extent of such changes.

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Section II

PERIPHYTON STUDIES

by

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and

Roderick Green

MATERIALS AND METHODS

Rationale

The periphyton or attached algae are the principal primary producers in waterways such as the Athabasca River. They form the base of many food chains in river ecosystems and are also an important source of oxygen (Blum, 1956; Clark, 1975). The periphyton community is an excellent indicator of water quality and is used extensively in the classification and monitoring of water quality (Kolkwitz and Marsson, 1908, 1909; Patrick, 1949, 1973; Palmer, 1962; Cairns, 1965). Baseline information concerning the periphyton community of the Athabasca River in the vicinity of the Syncrude development is extremely valuable in establishing baseline population levels for future comparisons.

Specifically the objectives for this study were to determine:

1. periphytic algal species composition and diversity in the Athabasca River in the vicinity of the Syncrude development,

2. seasonal distribution and relative abundance of the major algal taxa,

3. seasonal variation in the standing crop of the periphyton community.

Sample Collection

Periphyton samples were collected in the Athabasca River at monthly intervals from December, 1974 to October, 1975 using glass microscope slides (25 mm x 75 mm) as artificial substrates. The glass slides were held in plexiglas racks, modified from the design of Hansmann (1969), with dimensions 33 x 8 x 9 cm. Each rack held 36 microscope slides. The racks were suspended 0.5 m beneath the ice in winter, and 0.5 m below the water surface in summer (Figures 11 and 12). The locations and site designations of the periphyton samples are illustrated in Figure 2.

Sample Analysis

For each sample, periphyton densities and accumulated biomass were assessed in the following manner. Slides were replaced at monthly intervals. Three sets of 10 exposed slides were preserved in 2% formalin for biomass analysis. The remaining set of 6 slides was preserved in Lugol's

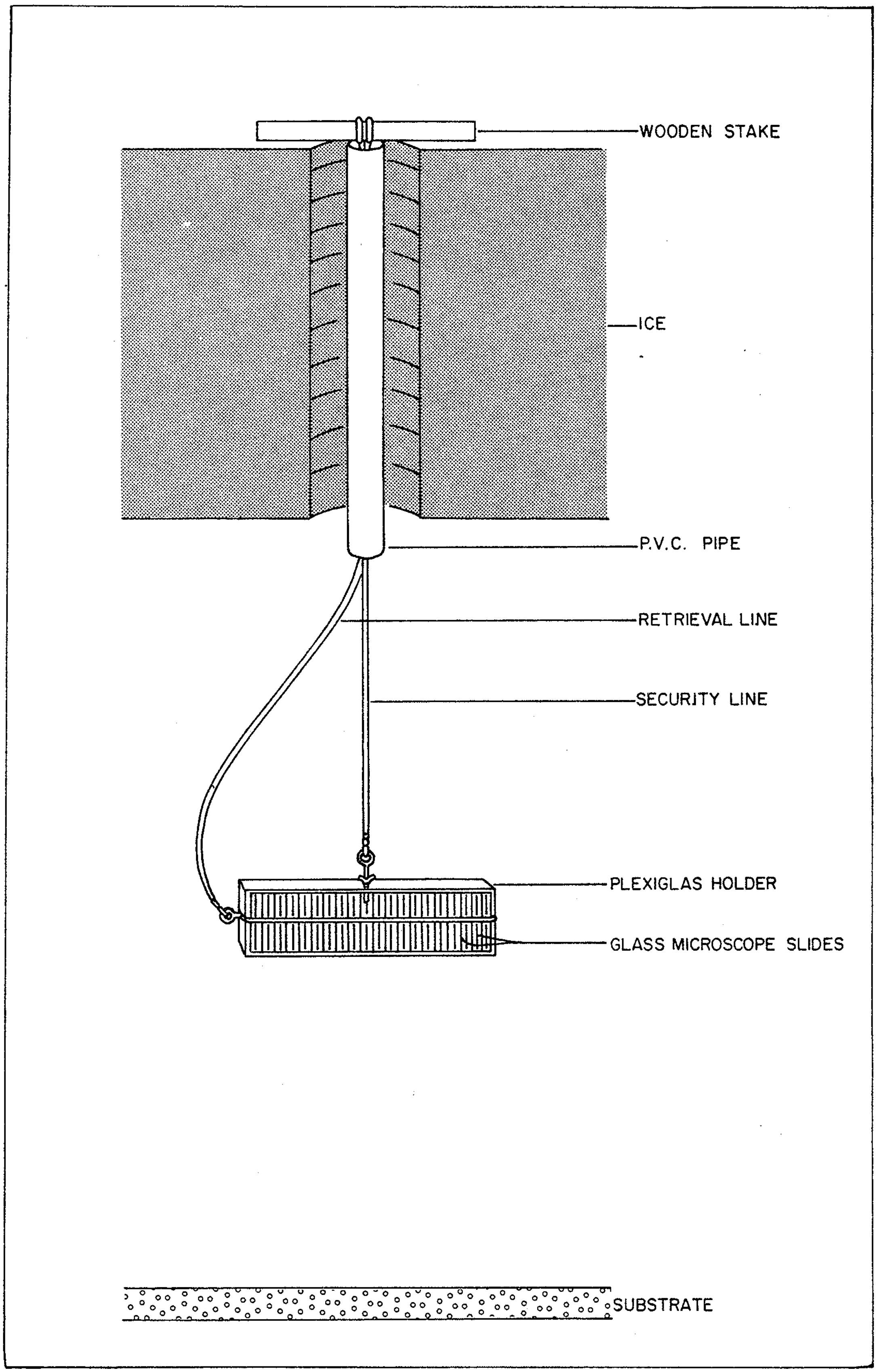

FIGURE 11. Method used in suspending artificial substrate samplers for collecting periphyton during winter studies.

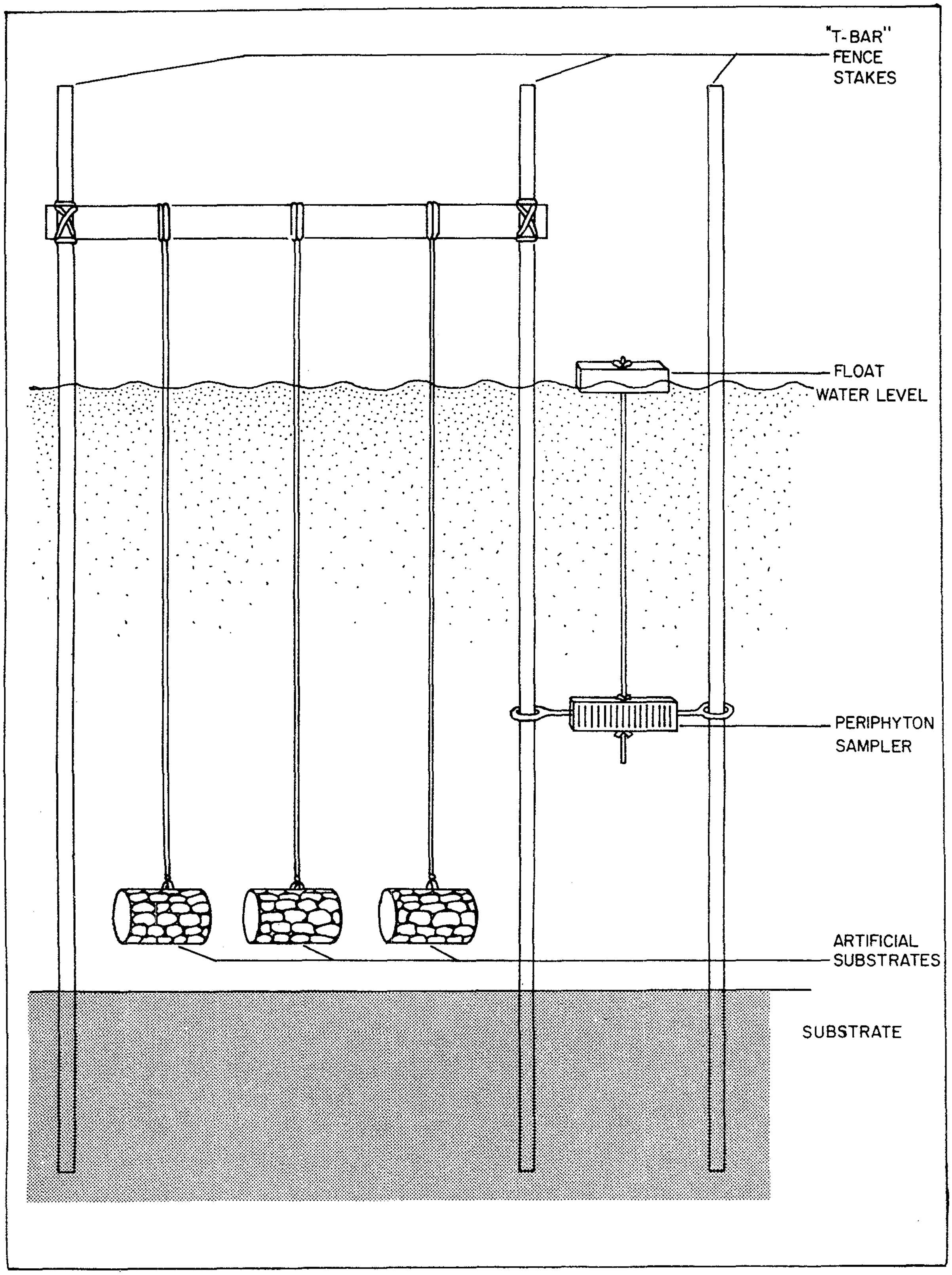

FIGURE 12. Method used in suspending artificial substrate samplers for collecting benthic macroinvertebrates and periphyton during the open water season.

solution for identification and enumeration. Methods used in determining the accumulated biomass of periphyton are those of Stockner and Armstrong (1971) and Standard Methods for the Examination of Water and Wastewater (1971). Periphyton was removed from each set of slides with a razor blade and placed in its original bottle of preservative. The material was filtered on a preweighed Whatman No. 40 filter disc (0.022 mg maximum ash weight per disc), oven dried to a constant weight at 105°C and ashed in a muffle furnace at 500°C for one hour. All weights are accurate to ±0.1 mg. Periphyton biomass was estimated for each replicate as the loss of organic matter on ignition and converted to mg organic matter/m^2, as follows:

$$\underset{\text{(biomass)}}{\text{mg organic matter/m}^2} = \frac{\text{total amount of organic matter lost on ignition (mg)}}{\text{total area of slides (m}^2\text{)}}$$

The methods used for the analysis of periphyton samples are those of Utermöhl (1958), Margalet (1974), and Zoto et al. (1973).

The samples for identification were thoroughly agitated and subsamples were pipetted to settling chambers. The volume of the subsamples depended upon the density of the original sample (i.e., amount of silt, detritus, etc.). Settling time was based upon a standard rate of three hours per centimetre of chamber height.

For organisms other than diatoms, a settling chamber was set up and the subsample was allowed to settle out and examined whole, using a Wild M 40 Inverted Microscope.

For the identification and enumeration of diatoms, the upper portion of the subsample was removed after settling, leaving a film of liquid and the settled organisms. The remaining 2 ml were then evaporated at a temperature below 38°C. The coverslips with the organisms were then ashed in a muffle furnace (560°C ± 10°C for 15 min) to remove all debris and extraneous organic matter. The cleared diatoms were then mounted in Piccolyte and examined under a Wild M 40 Inverted Microscope. Enumeration of the species present was at 750X, with the samples quantified as cells/cm^2. The algae were identified to the species level where possible, with identifications carried out at up to 1750X.

Taxonomic literature used for the identification of algae include: Bourrelly (1968), Cleve-Euler (1951-1955), Desikachary (1959), Hillard (1966, 1967), Patrick and Reimer (1966), Prescott (1962), Skuja (1948, 1964), Smith (1950), Sreenivasa and Duthie (1973), Tiffany and Britton (1951), and Tilden (1910).

RESULTS AND DISCUSSION

Species Composition and Diversity of the Periphyton Community

Species Composition

In total, 191 algal taxa (mostly species) were identified in the periphyton communities from artificial substrates (Table 4). Of these, 117 (61.3%) were diatoms (Bacillariophyceae), 34 (17.8%) were green algae (Chlorophyta), 21 (11.0%) were blue-green (Cyanophyta), 17 (8.9%) were non-diatom Chrysophyta, and 2 (1.0%) were unicellular flagellates (Cryptophyta). Obviously, the periphytic species were dominated by the diatoms. Monthly information on the kinds and number of algae collected between January and October, 1975 (except May) from the study area is given in Appendix II. Among the diatoms, the most common and abundant species encountered were: *Diatoma* spp. (mainly *D. tenue* and *D. vulgare)*, *Fragilaria* spp., *Gomphonema* spp. (mainly *G. intricatum, G. olivaceum,* and *G. parvulum)*, *Navicula* spp. (mainly *N. cryptocephalea, N. tripunctata,* and *N. viridula)*, and *Nitzschia* spp. (mainly *N. acicularis* and *N. dissipata).* Because of their abundance, diatoms are potentially the most

TABLE 4 . Periphytic algae collected from the Athabasca River, in the vicinity of the Syncrude development, between December 1974 to October 1975.

Chlorophyta
- Euchlorophyceae
  - Volvocales
    - Chlamydomonadaceae
      - Chlamydomonas sp.
  - Tetrasporales
    - Palmellaceae
      - Gloeocystis vesiculosa Naegeli
      - Sphaerocystis schroeteri Chodat
  - Chlorococcales
    - Characiaceae
      - Characium Pringsheimii A. Braun
    - Hydrodictyaceae
      - Pediastrum Boryanum (Turp.) Meneghini
      - P. Kawraiskyi Schmidle
    - Oocystaceae
      - Ankistrodesmus falcatus (Corda) Ralfs
      - A. falcatus var. acicularis (A. Braun) G.S. West
      - Cerasterias staurastroides West & West
      - Dictyosphaerium Ehrenbergianum Naegeli
      - Lagerheimia quadriseta (Lemm.) Smith
      - Oocystis pyriformis Prescott
      - Schroederia setigera (Schroed.) Lemmermann
      - Tetraedon caudatum (Corda) Hansgirg
      - T. minimum (A. Braun) Hansgirg
    - Scenedesmaceae
      - Crucigenia quadrata Morren
      - C. tetrapedia (Kirch.) West & West
      - Scenedesmus abundans (Kirch.) Chodat
      - S. armatus (Chodat) G.M. Smith
      - S. dimorphus (Turp.) Kutzing
      - S. longus Meyen
      - S. nr. acutiformis
      - S. obliquus (Turp.) Kutzing
      - S. quadricauda (Turp.) de Brébisson
      - S. quadricauda var. Westii G.M. Smith
      - S. spp.
  - Conjugales
    - Desmidiaceae
      - Closterium leibleinii Kutzing
      - C. parvulum Naegeli
      - C. venus Kutz. var. ?
      - C. spp.
      - Cosmarium subcrenatum Hantzsch
      - C. Meneghini forma α Croasdale
      - C. spp.
      - Staurastrum sp.

TABLE 4 . Continued

Cyanophyta
- Myxophyceae
  - Chroococcales
    - Chroococcaceae
      - Chrococcus minor (Kutz.) Naegeli
      - Coelosphaerium Naegelianum Unger
  - Hormogonales
    - Oscillatoriaceae
      - Lyngbya contorta Lemmermann
      - L. Diguetii Gomont
      - L. limnetica Lemmermann
      - L. nr. perelegans var. angusta
      - L. spp.
      - Oscillatoria acutissima Kufferath
      - O. Agardhii Gomont
      - O. amphibia C.A. Agardh.
      - O. angusta Koppe
      - O. limnetica Lemmermann
      - O. limnosa (Roth) C.A. Agardh
      - O. prolifica (Grev.) Gomont
      - O. subbrevis Schmidle
      - O. tenuis C.A. Agardh
      - O. spp.
      - Phormidium tenue (Menegh.) Gomont
      - P. sp.?
    - Nostocaceae
      - Anabaena sp.
    - Stigonemataceae
      - Hapalosiphon sp.?

Cryptophyta
- Cryptophyceae
  - Cryptomonadales
    - Cryptomonadaceae
      - Cryptomonas sp.
      - Rhodomonas minuta Skuja

Chrysophyta
- Xanthophyceae
  - Heterococcales
    - Chlorotheciaceae
      - Ophiocytium cochleare (Eichw.) A. Braun
- Chrysophyceae
  - Chromulinales
    - Euchromulinaceae
      - Chrysococcus sp.
      - C. nr. rufescens
      - Kephyrion littorale Lund
      - K. obliquum Hilliard
      - K. spirale (Lack.) Conrad
      - K. spp.

TABLE 4. Continued.

Kephyriopsis nr. limnetica
K. spp.
Isochrysidales
Isochrysidaceae
Dinobryon bavaricum Imhof
D. borgei Lemmermann
D. divergens Imhof
D. sociale Ehrenberg
D. sociale var. americanum (Brunn.) Bach.
D. suecicum Lemmermann
D. sp.
Epipyxis gracilis Hilliard and Asmund
Bacillariophyceae
Centrales
Coscinodisceae
Cyclotella comta (Ehr.) Grunow
C. meneghiniana Kutzing
C. nr. kuetzingianum
C. ocellata Pantocsek
C. stelligera Cl. and Grunow
C. spp.
Melosira italica var. subarctica O. Müeller
M. varians Agardh
M. spp.
Stephanodiscus niagarae Ehrenberg
Rhizosoleniaceae
Rhizosolenia eriensis H.L. Smith
Pennales
Fragilariaceae
Asterionella formosa Hassall
Diatoma tenue Agardh
D. tenue var. elongatus Lyngbya
D. vulgare Bory
D. spp.
Fragilaria brevistriata Grunow
F. capucina var. mesolepta Rabenhorst
F. capucina Desmarziers
F. construens (Ehr.) Grunow
F. crotonensis Kitton
F. pinnata Ehrenberg
F. vaucheriae (Kutz.) Peters
F. spp.
Hannea arcus (Ehr.) Patrick
Synedra acus Kutzing
S. amphicephala Kutzing
S. amphicephala var. austriaca (Grun.) Hustedt
S. cyclopum Brutschy
S. delicatissima Wm. Smith
S. nr. goulardi
S. radians Kutzing
S. rumpens var. meneghiniana Grunow

TABLE 4 . Continued.

S. ulna (Nitzsch.) Ehrenberg
S. ulna var. contracta Oestrup
S. ulna var. danica (Kutz.) van Huerck
S. spp.
Tabellaria fenestrata (Lyngb.) Kutzing
T. flocculosa (Roth) Kutzing

Eunotiaceae

Eunotia pectinalis (O.F. Mull.) Rabenhorst

Achnanthaceae

Achnanthes clevei var. rostellata Husted
A. delicatula (Kutz.) Grunow
A. exigua Grunow
A. flexella (Kutz.) Brun.
A. hauckiana var. rostrata Schulz
Achnanthes lanceolata (Breb.) Grunow
A. lanceolata var. dubia Grunow
A. lanceolata var. elliptica Cleve
A. lanceolata var. minor Schulz
A. lanceolata var. omissa Reim
A. linearis var. curta H.L. Smith
A. microcephala (Kutz.) Grunow
A. minutissima Kutzing
A. spp.
Cocconeis disculus var. minor Font
C. pediculus Ehrenberg
C. placentula var. euglypta (Ehr.) Cleve
C. placentula var. lineata (Ehr.) van Huerck
C. thumensis May
C. spp.
Rhoicosphenia curvata (Kutz.) Grunow

Naviculaceae

Amphipleura pellucida Kutzing
Anomoeoneis vitrea (Grun.) Ross
Caloneis amphisbaena (Bory) Cleve
C. bacillum (Grun.) Cleve
C. spp.
Gyrosigma acuminatum (Kutz.) Cleve
G. scalproides (Rabh.) Cleve
Navicula angusta Grunow
N. canalis Patrick
N. capitata Ehrenberg
N. cincta Ralfs
N. cryptocephala Kutzing
N. cryptocephala var. veneta Kutzing
N. elginensis (Greg.) Ralfs
N. graciloides A. Mayer
N. heufleri Grunow
N. lanceolata (Ag.) Kutzing
N. menisculus var. upsaliensis (Grun.) Grunow
N. notha Wallace

TABLE 4. Continued.

N. nr. similis
N. pupula Kutzing
N. pupula var. rectangularis (Greg.) Grunow
N. radiosa Kutzing
N. rhyncocephala Kutzing
N. salinarum var. intermedia (Grun.) Cleve
N. tripunctata (O.F. Mull.) Bory
N. viridula (Kutz.) Kutzing
N. viridula var. avenacea (Breb. ex Grun.) van Huerck
N. viridula var. rostellata (Kutz.) Cleve
N. vulpina Kutzing
N. spp.
Pinnularia biceps Gregory
P. borealis Ehrenberg
P. globiceps var. krookii (Grun.) Cleve
P. mesolepta (Ehr.) W. Smith
P. nodosa (Cl.) Wm. Smith
P. sp.

Gomphonemaceae
Gomphonema acuminatum var. genuinum (Ehr.) Wm. Smith
G. acuminatum var. brebissonii Kutzing
G. angustatum var. genuinum May
G. angustatum var. obtusatum Kutzing
G. constrictum var. clavata Ehrenberg
G. constrictum Ehrenberg
G. gracile Ehrenberg
G. gracile var. lanceolatum (Kutz.) Cleve
G. intricatum Kutzing
G. lanceolatum Ehrenberg
G. olivaceum (Lyng.) Kutzing
G. olivaceum var. balticum A. Cleve
G. olivaceum var. genuinum Mayer
G. parvulum Kutzing
G. parvulum var. subellipticum A. Cleve
G. spp.

Cymbellaceae
Amphora ovalis Kutzing
Cymbella affinis Kutzing
C. amphicephala Naeg. ex Kutz. Husted
C. aspera (E.) Cleve
C. caespitosa (Kutz.) Brun.
C. cuspidata Kutzing
C. microcephala Grunow
C. perpusilla A. Cleve
C. prostrata (Berk.) Cleve
C. sinuata Gregory
C. ventricosa Kutzing
C. spp.

TABLE 4 . Continued.

Epithemiaceae
- Epithemia sorex Kutzing
- E. turgida (Ehr.) Kutzing
- E. spp.
- Rhopalodia gibba (Ehr.) Muller
- R. gibba var. ventricosa (Ehr.) Grunow
- R. spp.

Nitzchiaceae
- Nitzschia acicularis (Kutz.) Wm. Smith
- N. calida Grunow
- N. capitellata Husted
- N. dissipata var. genuina (Kutz.) Grunow
- N. dissipata var. media (Htz.) Grunow
- N. dissipata var. acula (Htz.) Grunow
- N. fonticola Grunow
- N. palea (Kutz.) Wm. Smith
- N. sigma Wm. Smith
- N. sigmoidea (Ehr.) Wm. Smith
- N. suecica (Grun.) A. Cleve
- N. thermalis (Kutz.) Grunow
- N. vermicularis (Kutz.) Cleve
- N. spp.

Surirellaceae
- Cymatopleura solea (Breb.) Wm. Smith
- Surirella angustata Kutzing
- S. ovata Kutzing
- S. ovata var. minuta Brebisson
- S. spp.

Euglenophyta
- Euglenophyceae
  - Euglenales
    - Euglenaceae
      - Euglena gracilis Klebs

reliable and useful indicator species for the biomonitoring of water quality (Williams, 1963). Species that occur in low densities and frequencies are unreliable for monitoring purposes since they may represent organisms washed in from other minor waterbodies, or from tributaries with a different chemical and physical background.

Species Diversity

The structure of the periphyton community (i.e., the number and relative abundance of species) is sensitive to environmental change, since many of the vital functions such as growth and reproduction that govern community dynamics are in turn influenced by external conditions such as temperature, salinity, pollutants, etc. (Patrick, 1973). In the process of gathering baseline information for this study, seasonal variations in the community structure of the periphyton were monitored, the diatoms in particular, to obtain an indication of the response of the community to naturally occurring environmental variation. Two kinds of numerical indices were used to determine the diversity of the periphyton community: the Shannon-Weaver Species Diversity Index ($\bar{d}$)(Shannon and Weaver, 1949), and the related Equitability Index (e)(Lloyd and Ghelardi, 1964).

Margalef (1956) was the first to use diversity indices to indicate variation in structure of phytoplankton communities. He compared the sensitivity of various indices, and established the applicability of the information theory of Shannon and Weaver (1949) in studying algal communities. The machine formula of the Shannon-Weaver Species Diversity Index presented by Lloyd et al. (1968) is:

$$\bar{d} = \frac{C}{N} (N \log_{10} N - \Sigma\, ni \log_{10} ni)$$

where C= 3.321928, N= total number of individuals, and ni= total number of individuals in the i^{th} species. The calculated $\bar{d}$ value is therefore affected by both species richness and by the distribution of individuals among the species. This method of recording and studying algal community diversity has been successfully used by other researchers, e.g., Patten (1962) in his study of Chesapeake Bay.

To determine the component of diversity due to species evenness in the community, the calculated $\bar{d}$ value can be compared to a hypothetical maximum based on MacArthur's (1957) broken stick model. This model depicts a community, frequently observed in nature, where there are a few dominant species and an increasing number of species with fewer individuals. The formula for "equitability" is

$$e = \frac{S'}{S}$$

where S= number of taxa in the sample, and S'= number of taxa expected from a community that conforms to the MacArthur model. Values for S' are obtained from a table devised by Lloyd and Ghelardi (1964).

Biologists with the Environmental Protection Agency in the United States have found that equitability (e) is very sensitive to environmental degradation. Polluted waterways usually have e values between 0.0 and 0.3, whereas values of 0.6 to 0.8 are characteristic of unpolluted streams (Weber, 1973).

The seasonal variation in the $\bar{d}$ and e values for the periphyton and diatom communities at various stations have been listed in Appendix II. Figures 13 and 14 graphically illustrate the seasonal variations in the structure of the periphyton and diatom communities for Stations 1 and 3. It can be seen that, in general, community structure, as determined by $\bar{d}$, was different at the two stations. However, since the diatoms were the dominant species in the community, their $\bar{d}$ and e values closely approximated those for the entire periphyton community. These observations suggest that future biomonitoring effort could be confined to the diatoms since their community dynamics apparently parallel those of the periphyton community as a whole.

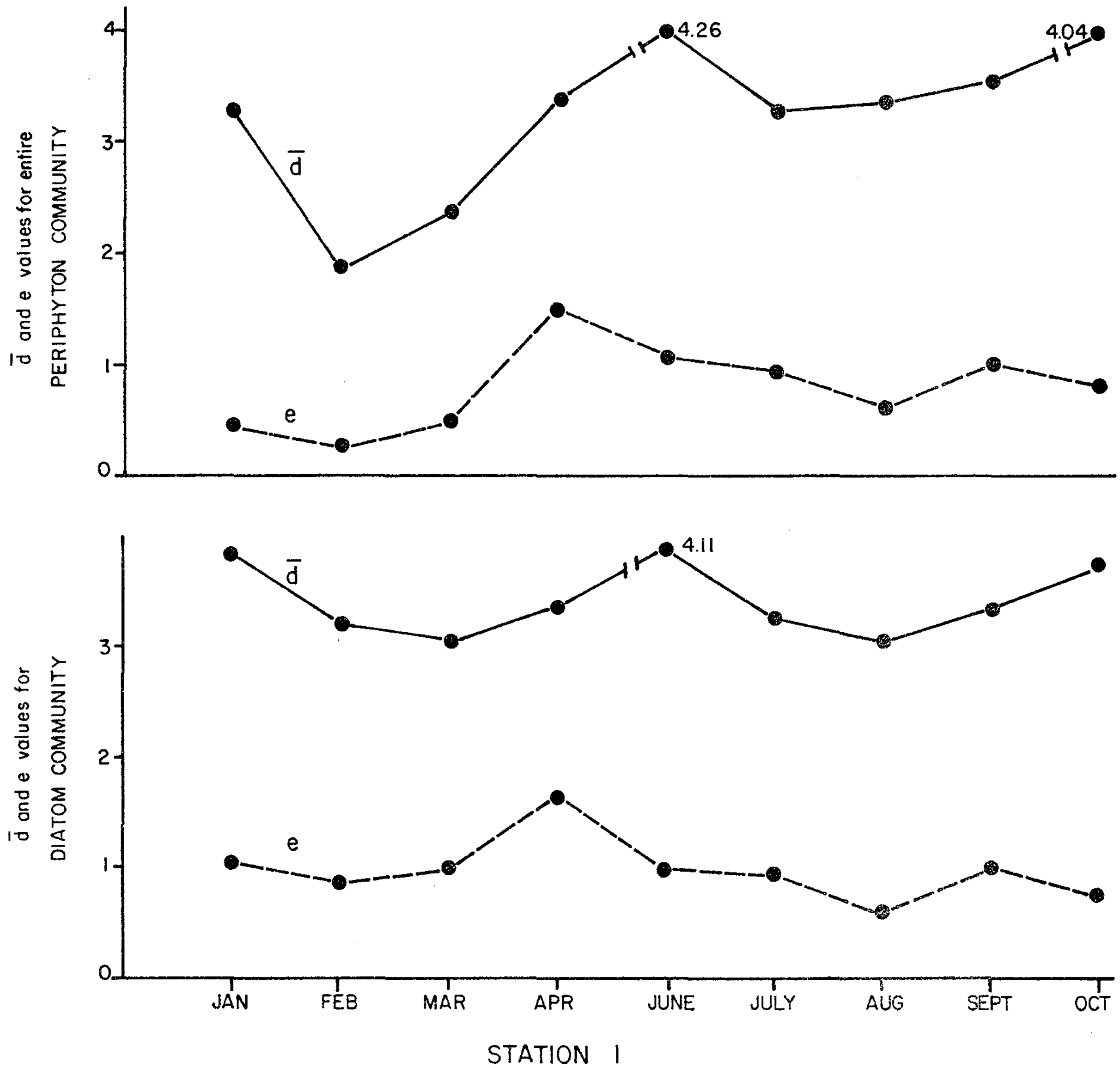

FIGURE 13. Seasonal variation in the diversity of the periphyton and diatom communities at Station 1.

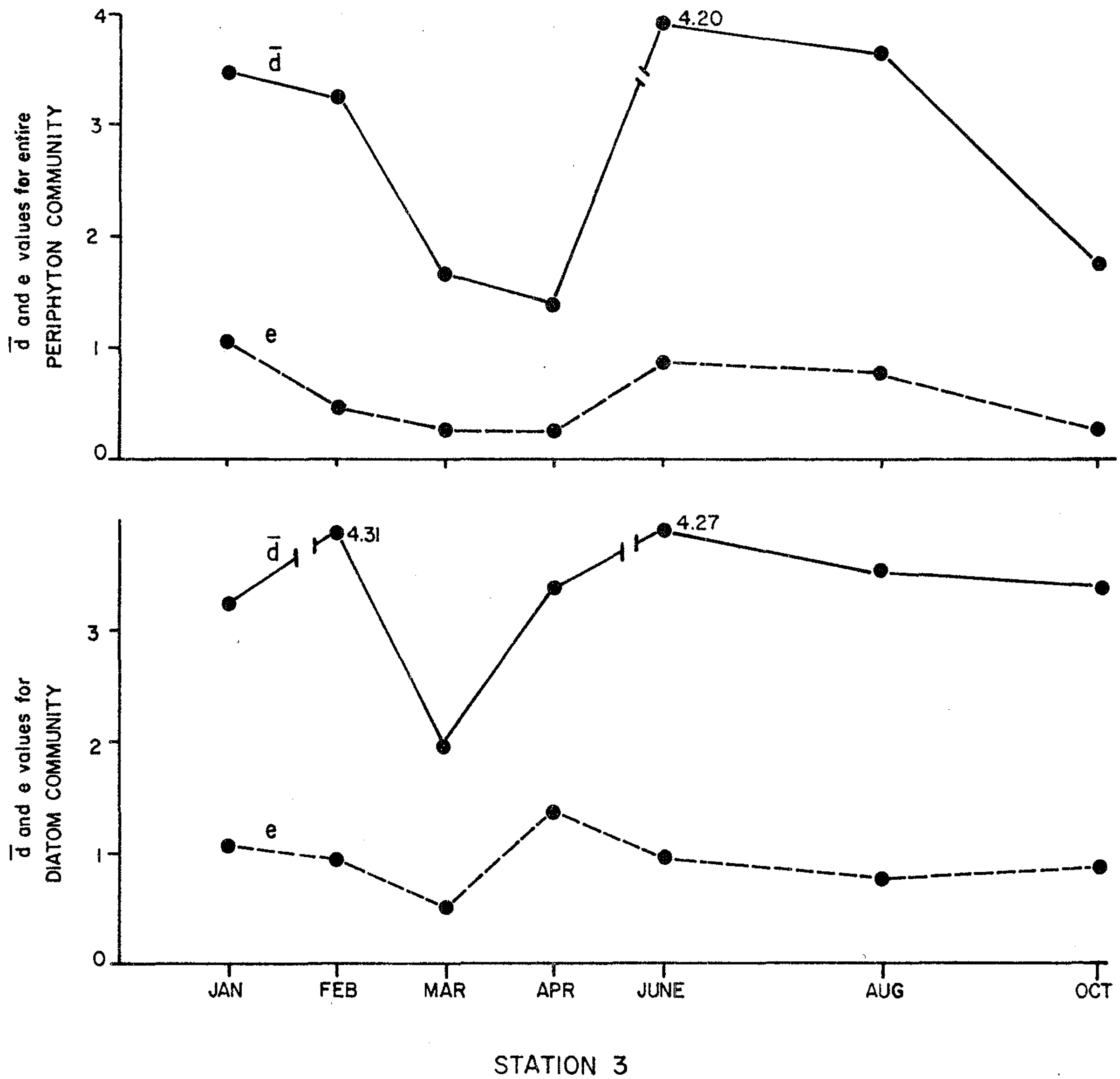

FIGURE 14. Seasonal variation in the diversity of the periphyton and diatom communities at Station 3.

Seasonal Distribution and Relative Abundance

Seasonal distribution and relative abundance (per cent composition) of the three major periphytic algal taxa (Chlorophyta, Cyanophyta, and Chrysophyta) are shown in Figure 15.

Seasonal patterns illustrate that, during the period of ice-cover (January-April), the periphyton community was dominated by the Cyanophyta (blue-green algae), with scattered occurrences of Chrysophyta (diatoms). The principal blue-green algae present during this period of ice cover, low water levels, and decreased river velocity were filamentous forms: *Phormidium* app., *Oscillatoria* spp., and *Lyngbya* spp. The physical characteristics of the Athabasca River during this winter period were undoubtedly advantageous to these types of algae. The few dominating occurrences of Chrysophyta during January-April (January, site 3; March, site 10) were the result of the development of winter-spring species (see Hynes, 1970): *Diatoma* spp., *Gomphonema* spp., and *Navicula* spp. With the onset of the April breakup, scouring effectively removes the periphyton which have developed during the period of ice cover. Douglas (1958) noted the same events in her study of an English stream.

The June-August summer period in the Athabasca River is characterized by high rates of discharge resulting in high water levels and increased river velocity. These factors

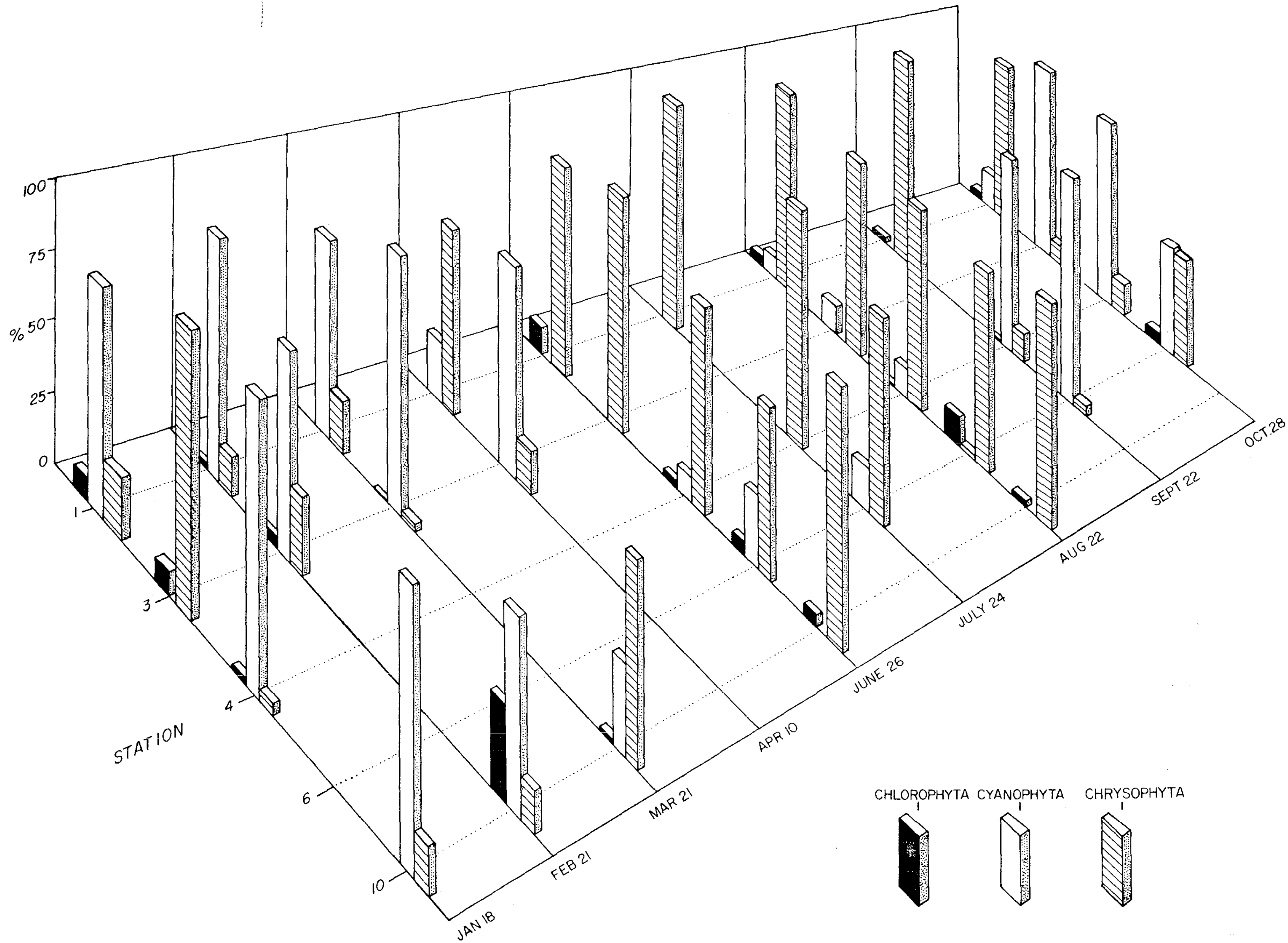

FIGURE 15. Seasonal distribution and relative abundance of three major periphytic algal taxa at the Athabasca River, Syncrude facility.

coincide with the sudden dominance of the Chrysophyta at all stations (Figure 15). Seasonal fluctuations observed in the five dominant periphytic diatom genera from the study area are summarized in Figure 16. Of the five genera illustrated, *Navicula* spp. was the most abundant diatom during the June-August period. Gumtow (1955) described a similar development of *Navicula* spp. during his study of the West Gallatin River, Montana. Numerous Chrysophyta which Blum (1956) has identified as planktonic (i.e., *Asterionella formosa, Synedra* spp., *Fragilaria* spp., *Melosira* spp., *Stephanodiscus* spp., and *Tabellaria fenestrata*) were observed in the June and August samples. All of these species possess either a spring or fall pulse in lake environments (Patrick and Reimer, 1966). Although it is possible for the Athabasca River to develop its own planktonic algae community in sections of slow water, it is more likely that these species were carried into the river by tributaries draining lakes and potholes. These planktonic diatoms settle to the bottom and become short-lived members of the periphyton community. The scattered occurrences of the Chlorophyta are also probably the remnants of phytoplankton populations carried into the river by tributaries.

During the mid-summer (July) period, when river velocities were high, periphytic diatoms dominated the community. Epiphytic diatoms (*Achnanthes* spp., *Coccoheis* spp., *Gomphonema* spp.) dominate as do bottom forms (*Navicula* spp., and *Nitzschia*). Patrick and Reimer (1966) have described the difference between epiphytic and bottom forms.

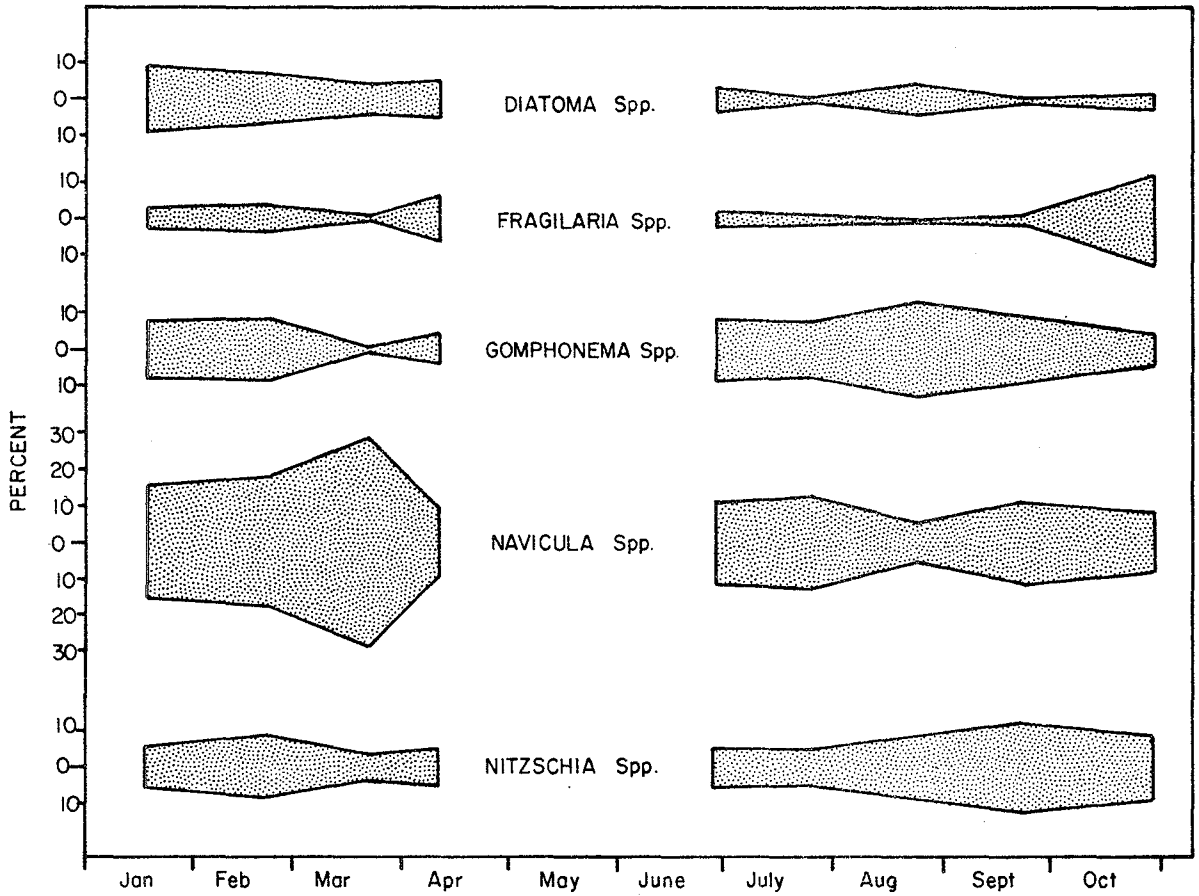

FIGURE 16. Seasonal distributgion and percent composition of five dominant periphytic diatoms of the Athabasca River, in the vicinity of the Syncrude development, between January - October, 1975.

The former are attached to the substrate by a gelatinous secretion, the latter, while they live on the bottom, are not attached and are mobile.

With the slow currents, low water levels, and higher temperatures of the late summer and early fall (August - September), there is a change in the periphyton community. The summer dominants, primarily Chrysophyta, are replaced by a fall community dominated by filamentous Cyanophyta (blue-green) including *Hapalosiphon* spp., *Oscillatoria* spp., and *Lyngbya* spp. The January samples indicate a similar dominance by filamentous blue-green algae suggesting that this community persists and makes up a large portion of the winter periphytic community, as do many of the winter species of diatoms, i.e., *Diatoma* spp. and *Gomphonema* spp.

Seasonal Variation of the Periphyton Standing Crop

Standing crops, expressed in cells/cm^2 and mg of organic matter/m^2, were determined for Stations 1, 3, 4, 6, and 10 (Tables 5 and 6). Based on these data, it appears that there were three peaks of algal "productivity" during the study period, in January, June, and September-October (Figure 17). Cyanophyta (blue-green algae) were probably responsible for the peaks in January and September-October, whereas the high productivity in June was largely a result of the high density of diatoms. Low productivity periods in Spring and Summer e.g. April and July, seemed to coincide with the ice breakup and summer flood respectively. Primary production in the Athabasca River may therefore be a function of current velocity. Similar observations have been discussed in McIntire (1966).

TABLE 5. Seasonal variation in the standing crop (as mg organic matter/m^2) of the periphyton community at the Athabasca River, Syncrude facility, between January - October, 1975.

Station	STANDING CROP (mg organic matter/m^2)								
	January	February	March	April	June	July	August	September	October
1	854.8	206.5	92.4	356.0	777.7	186.7	319.1	498.0	571.0
3	405.9	85.0	106.4	194.0	664.0	-	-	-	196.0
4	-	-	-	-	729.8	271.1	675.6	-	856.9
6	-	-	-	-	605.5	85.0	344.0	596.0	1409.6
10	273.4	47.6	75.6	-	965.4	-	331.5	-	-

TABLE 6. Seasonal variation in the standing crop (as cells/cm^2) of the periphyton community at the Athabasca River, Syncrude facility, between January - October, 1975.

Date	Site Number	TOTAL COUNTS (cells/cm^2) Chlorophyta	Cyanophyta	Cryptophyta	Chrysophyta*	Total
1975						
Jan. 17	1	210	1,895	0	420	2,525
Feb. 21	1	1	327	0	46	374
Mar. 21	1	0	283	0	71	354
Apr. 10	1	0	7	0	23	30
June 27	1	142	0	0	1,286	1,428
July 24	1	0	0	0	10,507	10,507
Aug. 23	1	379	1,210	0	18,231	19,820
Sept.22	1	32	0	0	1,612	1,644
Oct. 28	1	882	3,782	0	23,568	28,232
Jan. 18	3	4	0	0	84	88
Feb. 21	3	20	694	0	216	930
Mar. 21	3	2	653	0	34	689
Apr. 10	3	0	103	0	16	119
June 27	3	0	0	0	23,393	23,393
Aug. 22	3	0	1,532	0	12,931	14,463
Oct. 28	3	0	299,986	0	13,107	313,093

*The division Chrysophyta contains the three classes, Xanthophyceae, Chrysophyceae and Bacillariophyceae.

(Continued)

TABLE 6. Continued.

DATE	Site Number	TOTAL COUNTS (cells/cm^2) Chlorophyta	Cyanophyta	Cryptophyta	Chrysophyta*	Total
1975						
Jan. 18	4	13	6,463	0	261	6,737
June 26	4	738	1,985	0	17,698	20,421
July 24	4	0	0	0	946	946
Aug. 22	4	471	5,129	0	55,325	60,925
Sept. 22	4	1,229	623,353	0	38,858	663,440
Oct. 28	4	0	219,240	0	20,746	239,986
June 26	6	378	1,568	0	4,433	6,379
July 24	6	0	947	0	6,481	7,428
Aug. 22	6	2,206	315	0	22,684	25,205
Sept. 22	6	0	538,184	0	5,298	543,482
Oct. 28	6	1,134	25,083	0	24,700	50,917
Jan. 18	10	0	227	0	28	255
Feb. 21	10	71	176	0	34	281
Mar. 21	10	2	45	0	114	161
June 25	10	1,260	0	0	20,166	21,426
Aug. 22	10	476	0	0	28,178	28,654

*The division Chrysophyta contains the three classes, Xanthophyceae, Chrysophyceae and Bacillariophyceae.

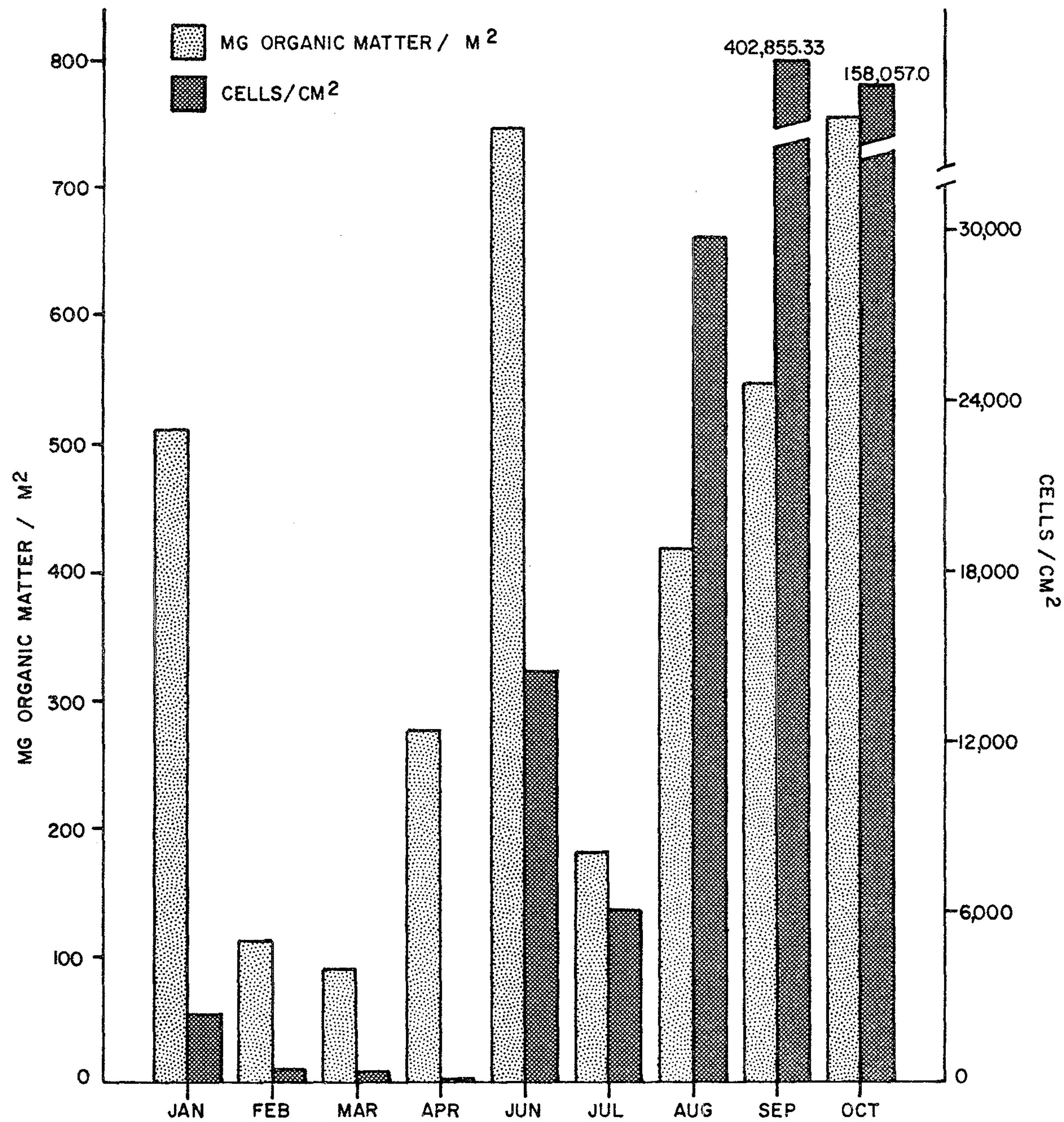

FIGURE 17. Seasonal variation in the mean standing crop (as mg organic matter/m^2 and cells/cm^2(of the periphyton community at the Athabasca River, Syncrude facility, in 1975.

CONCLUSIONS

The periphyton community of the Athabasca River does not appear to be unusual for large turbid rivers. The ecology of the community seems to be a function of river discharge, velocity and related parameters (e.g. turbidity, energy and nutrient flux) rather than any presently occurring industrial activity.

Zimmerman (quoted in Hynes, 1970) concluded that, with respect to periphyton communities, the effect of current is often of greater importance than that of the quality of the water. In the Athabasca River the definite seasonal patterns in the species composition and standing crop of the periphyton community were apparently the result of large seasonal differences in river velocity, and water levels. Similar observations on the effects of current on periphyton community structure and productivity have been documented in McIntire (1966), Odum (1956), Whiteford (1960), Whitford and Schumacher (1961, 1964).

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Section III

BENTHIC MACROINVERTEBRATE STUDIES

by

Philip T.P. Tsui, Ph.D

MATERIALS AND METHODS

Rationale

The specific objectives of this study were to:

1) describe the species composition and diversity of the benthic animal communities at selected stations upstream and downstream from the proposed point of effluent discharge;

2) describe the quantities of animals (standing crop) inhabiting the river bottom at the selected stations;

3) test and select an optimal method of sampling benthic macroinvertebrates from the study area for the purpose of monitoring future water quality.

To achieve these objectives, Aquatic Environments Limited approached the study in two phases: 1) a preliminary reconnaissance of the study area, and 2) detailed and intensive sampling of 15 selected stations during the June to October period in 1975.

The reconnaissance study was performed in order to 1) locate suitable sampling stations for the detailed study,

2) determine the appropriate sampling equipment to be used, 3) determine the distribution of various substrate-types, and 4) assess the diversity and density of the benthic macroinvertebrates within the study area. The reconnaissance consisted of two field surveys (September and October, 1974). Results of these surveys formed the basis of the Athabasca River Study - Progress Report (AEL, 1975) and will not be further discussed in the present report.

For the detailed study, 15 permanent monitoring stations were established in the study area (Figure 2). Criteria for the selection of stations included: spatial relation to the proposed effluent site, current velocity, substrate type, and accessibility.

Sample Collection

Two methods of invertebrate sampling were used at each site. Three artificial substrate samplers, each consisting of an "Easy-Way Bar-B-Q Tumble Basket" (16.8 cm diameter by 26 cm length) filled with crushed quarry rock (approximately 10 cm diameter), were suspended 15 cm above the substrate (Figure 12) and exposed for 30 days. On each field trip the baskets were retrieved and placed in a plastic 2.5 gallon bucket partially filled with water. All invertebrates and accumulated debris were brushed into the bucket. After careful inspection of the rocks for any remaining invertebrates, the basket was refilled and placed back in position. The contents of the bucket were then washed through a seive bucket (425 μ mesh opening). The retained material was then stored in a "Whirlpak" plastic bag and further preserved in 10% formalin for later identification and enumeration.

Aquatic invertebrates were also sampled with a modified Ekman-type grab (Burton and Flannagan, 1973). Three replicate grab samples were taken at each site except for Stations 2 and 6 where only artificial substrate samples were taken. The samples were washed through sieve buckets (425 μ mesh opening) and preserved in 10% formalin for later analysis.

Table 7 is a summary of the benthic macroinvertebrate sampling program at the Athabasca River, Syncrude facility.

Sample Analysis

In the laboratory, samples were washed in a sieve (U.S. Standard No. 30) and spread in a Petri dish. Organisms were removed and examined with the aid of a stereoscopic dissecting microscope. Organisms in each major taxonomic group (Family, Order, or Class) were counted and further preserved in 75% isopropol alcohol.

The major taxonomic references used include Allen and Edmunds (1961a, 1961b, 1965), Jensen (1966), Jewett (1959),

TABLE 7. Summary of the benthic marcoinvertebrate sampling program at the Athabasca River, Syncrude facility.

Month	STATION 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
June,1975	AEE	A	AEE	AEE	AEE	A	EE	AEE	AEE	AEE	AEE	AEE	AEE	AEE	EE
July,1975	E	-	-	E	AE	-	A	E	E	AE	E	AE	E	E	E
Aug.,1975	E	-	E	AE	AE	A	AE	A	E	AE	E	AE	AE	E	-
Sept.1975	E	-	-	AE	AE	A	AE	A	E	AE	E	AE	AE	E	E
Oct.,1975	E	-	-	AE	AE	A	AE	A	E	A	E	AE	E	-	E

A = Three rock basket samplers exposed for 30 days.

E = Three Ekman grab samples.

Needham et al. (1935), Pennak (1953), Ricker (1943, 1964), Usinger (1963), and Ward and Whipple (1959). The Chironomidae were identified according to the provisional key by Hamilton and Saether[1].

[1]Unpublished key, Environment Canada, Freshwater Institute. Winnipeg.

RESULTS AND DISCUSSION

Species Composition and Diversity of the Benthic Animal Community

Species Composition

For each of the 15 stations sampled, a list was made of the benthic macroinvertebrate species or taxa collected (Tables 8 to 22). Baseline information included: 1) species or taxa present, 2) total number of individuals collected in the open-water period, 3) their relative abundance, and 4) seasonal distribution of taxa. Based on the percentage composition of the standing crop (from Tables 8 to 22), species (or taxa) were classified with respect to their dominance in the community. Such an analysis is useful in gaining an overall impression of the benthic community composition in the study area (Ulfstrand, 1968). Five categories of abundance were designated on the basis of the percentage composition of the total standing crop at a particular station during the study period.

1) Dominant taxon (D) - at least 25%.
2) Subdominant taxon (S) - at least 10%, but less than

TABLE 8. Benthic marcoinvertebrates collected from Station 1.

Taxa	Total No. Collected	Percentage Composition	Month of Occurrence
Trichoptera	1	0.22	
Cheumatopsyche sp.	1	0.22	A
Ephemeroptera	83	18.10	
Baetis sp. A	35	7.63	J
Brachycerus sp.	1	0.22	J
Ephemerella sp.	1	0.22	J
Heptagenia sp.	40	8.71	J
Leptophlebia sp.	1	0.22	J
Pseudocloeon sp.	4	0.87	J
Siphloplecton sp.	1	0.22	J
Plecoptera	45	9.80	
Isogenus sp.	45		J,O
Diptera	320	69.72	
Ceratopogonidae	4	0.87	J
Chironomidae	307	66.88	J,Ju,S,O
Empididae	2	0.44	J,O
Simuliidae	1	0.22	A
Unident. dipteran	6	1.31	
Oligochaeta	10	2.18	J
Total No. Collected	459		
Total Taxa Collected	15		

J=June, Ju=July, A=August, S=September, O=October

TABLE 9. Benthic macroinvertebrates collected from Station 2.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	9		3.78		
Brachycentrus sp.		7		2.94	J
Hydropsyche sp.		2		0.84	J
Ephemeroptera	37		15.54		
Baetis sp. A		23		9.66	J
Ephemerella sp.		7		2.94	J
Heptagenia sp.		7		2.94	J
Plecoptera	107		44.95		
Isogenus sp.		107		44.95	J
Diptera	78		32.77		
Chironomidae (total)		70		29.41	J
Ablabesmyia sp.		20		8.40	J
Polypedilum sp.		1		0.42	J
Heterotrissocladius sp.		16		6.72	J
Simuliidae		1		0.42	J
Unident. dipteran		7		2.94	J
Odonata	3		1.26		
Ophiogomphus sp.		3		1.26	J
Oligochaeta	4		1.68		J
Total No. Collected	238				
Total Taxa Collected	13				

J=June

TABLE 10. Benthic macroinvertebrates collected from Station 3.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	8		2.19		
Brachycentrus sp.		1		0.27	J
Hydropsyche sp.		6		1.64	J,A
Unident. trichopteran		1		0.27	
Ephemeroptera	72		19.72		
Baetis sp. A		9		2.46	J
Baetis sp. B		12		3.28	J
Epeorus sp.		1		0.27	J
Ephemerella sp.		14		3.83	J,A
Heptagenia sp.		30		8.21	J,A
Pseudocloeon sp.		1		0.27	J
Rhithrogena sp.		5		1.36	J
Plecoptera	27		7.39		
Isogenus sp.		25		6.84	J,A
Perlodidae sp.		1		0.27	J
Pteronarcys sp.		1		0.27	A
Odonata	1		0.27		
Ophiogomphus sp.		1		0.27	J
Diptera	203		55.61		
Ceratopogonidae		2		0.54	J
Chironomidae		78		21.36	J,A
Empididae		4		1.09	J
Simuliidae		114		31.23	J
Unident. dipteran		5		1.36	
Oligochaeta	54		14.79		J,A
Total No. Collected	365				
Total Taxa Collected	20				

J=June, A=August

TABLE 11. Benthic macroinvertebrates collected from Station 4.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	27		1.96		
Brachycentrus sp.		1		0.70	O
Hydropsyche sp.		24		1.74	J,A,S
Oxyethira sp.		2		0.14	J
Ephemeroptera	61		4.43		
Baetis sp. A		30		2.18	J,A,O
Ephemerella sp.		13		0.94	J,O
Heptagenia sp.		18		0.13	J,A,S,O
Plecoptera	271		19.69		
Alloperla sp.		1		0.07	A
Brachyptera sp.		1		0.07	A
Isogenus sp.		255		18.53	J,A,S,O
Pteronarcys sp.		14		1.01	A,O
Odonata	5		0.36		
Gomphus sp.		3		0.21	Ju,S
Ophiogomphus sp.		2		0.14	J
Diptera		485	35.31		
Ceratopogonidae		9		0.65	J,A,S,O
Chironomidae (total)		443		32.19	
Ablabesmyia sp.		63		4.57	J,A,S,O
Chironomus sp.		30		2.18	J
Demicryptochironomus sp.		7		0.51	J,A
Heterotrissocladius sp.		10		0.72	J,A,O
Cryptochironomus sp.		20		1.45	A,S,O
Orthocladiinae		2		0.14	J
Chironomidae		299		21.72	J,Ju,A,S,O
Procladius sp.		1		0.07	J
Polypedilum sp.		11		0.79	J,Ju,O
Empididae		6		0.43	A,S,O
Rhagionidae (total)		1		0.07	
Atherix sp.		1		0.07	A
Simuliidae		18		1.30	J,A
Tipulidae		1		0.07	J
Unident. dipteran		7		0.51	
Oligochaeta	523		38.0		J,Ju,A,S,O
Nematoda	4		0.28		Ju,S
Total No. Collected	1375				
Total Taxa Collected	29				

J=June, Ju=July, A=August, S=September, O=October

TABLE 12. Benthic macroinvertebrates collected from Station 5.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	25		2.91		
Brachycentrus sp.		2		0.23	J
Cheumatopsyche sp.		7		0.81	J,Ju,S
Hydropsyche sp.		16		1.86	Ju,A,S
Ephemeroptera	105		12.23		
Ametropus sp.		3		0.34	J,S,O
Baetis sp. A		13		1.51	J,A
Epeorus sp.		1		0.11	A
Ephemerella sp.		28		3.26	J,A,S
Heptagenia sp.		50		5.82	J,Ju,A,S
Pseudocloeon sp.		1		0.11	J
Rhithrogena sp.		9		1.04	S
Plecoptera	280		32.63		
Brachyptera sp.		5		0.58	S
Isogenus sp.		263		30.65	J,A,S
Pteronarcys sp.		11		1.28	Ju,S
Unident. plecopteran		1		0.11	
Odonata	5		0.58		
Gomphus sp.		2		0.23	S,O
Ophiogomphus sp.		3		0.34	J,Ju,A
Diptera	57		6.64		
Ceratopogonidae		7		0.81	J,S,O
Chironomidae (total)		42		4.89	
Ablabesmyia sp.		11		1.28	J,Ju,O
Cryptochironomus sp.		7		0.81	A,S,O
Demicryptochironomus sp.		5		0.58	J,O
Heterotrissocladius sp.		5		0.58	Ju,S,O
Orthocladiinae		5		0.58	J,S
Paratendipes sp.		1		0.11	O
Polypedilum sp.		2		0.23	Ju,A
Heterocladius sp.		6		0.69	J
Empididae		4		0.46	S,O
Simuliidae		2		0.23	A
Tipulidae		2		0.23	J
Amphipoda	1		0.11		
Hyalella azteca		1		0.11	S
Oligochaeta	380		44.28		J,Ju,A,S,O
Nematoda	4		0.44		J,Ju,A
Mollusca	1		0.11		
Sphaerium sp.		1		0.11	O
Total No. Collected	858				
Total Taxa Collected	32				

J=June, Ju=July, A=August, S=September, O=October

TABLE 13. Benthic macroinvertebrates collected from Station 6.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	65		8.20		
Brachycentrus sp.		9		1.13	J
Cheumatopsyche sp.		1		0.12	S
Glossosoma sp.		1		0.12	S
Hydropsyche sp.		54		6.81	J,S
Ephemeroptera	115		14.52		
Baetis sp. A		37		4.67	J,A,S,O
Baetis sp. B		6		0.75	J
Ephemerella sp.		45		5.68	J,A
Epeorus (Ironopsis) sp.		1		0.12	J
Heptagenia sp.		12		1.51	J,A,S
Pseudocloeon sp.		5		0.63	J
Rhithrogena sp.		9		1.13	J,S
Plecoptera	507		64.01		
Brachyptera sp.		2		0.25	S
Isogenus sp.		497		62.75	J,A,S,O
Pteronarcys sp.		8		1.01	J,S
Diptera	83		10.47		
Chironomidae		65		8.20	J,A,S,O
Empididae		2		0.25	J,S
Simuliidae		13		1.64	J,A
Undent. dipteran		3		0.37	
Odonata	4		0.50		
Ophiogomphus sp.		4		0.50	J
Oligochaeta	18		2.27		J,A,S,O
Total No. Collected	792				
Total Taxa Collected	20				

J=June, A=August, S=September, O=October

TABLE 14. Benthic macroinvertebrates collected from Station 7.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	3		0.54		
Glossosoma sp.		1		0.18	S
Hydropsyche sp.		2		0.36	A,S
Ephemeroptera	27		4.91		
Ametropus sp.		1		0.18	J
Baetis sp. A		2		0.36	A
Ephemerella sp.		2		0.36	S,O
Heptagenia sp.		22		4.00	Ju,A,S,O
Plecoptera	37		6.73		
Isogenus sp.		36		6.55	Ju,A,S,O
Pteronarcys sp.		1		0.18	O
Diptera	115		20.94		
Ceratopogonidae		13		2.36	J,S,O
Chironomidae		100		18.21	J,A,S,O
Tabanidae		2		0.36	A,S
Odonata	2		0.36		
Ophiogomphus sp.		2		0.36	A
Oligochaeta	363		66.12		J,A,S,O
Nematoda	2		0.36		S
Total No. Collected	549				
Total Taxa Collected	14				

J=June, Ju=July, A=August, S=September, O=October

TABLE 15. Benthic macroinvertebrates collected from Station 8.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	160		19.51		
Brachycentrus sp.		25		3.04	J,Ju,S,O
Cheumatopsyche sp.		27		3.29	J,A,S
Glossosoma sp.		5		0.60	A,O
Hydropsyche sp.		98		11.95	J,A,O
Lepidostoma sp.		1		0.12	J
Limnephilidae		2		0.24	J
Unident. trichopteran		2		0.24	
Ephemeroptera	107		13.04		
Baetis sp. A		8		0.97	J,A
Baetis sp. B		20		2.43	A,O
Ephemerella sp.		55		6.70	J,A,S,O
Heptagenia sp.		20		2.43	J,A,O
Isonychia sp.		1		0.12	A
Paraleptophlebia sp.		1		0.12	A
Rhithrogena sp.		2		0.24	S
Plecoptera	418		50.97		
Acroneuria sp.		1		0.12	J
Isogenus sp.		389		47.43	J,Ju,A,S,O
Perlodidae sp.		1		0.12	J
Pteronarcys sp.		27		3.29	J,A,S,O
Diptera	103		12.56		
Ceratopogonidae		8		0.97	J,Ju,O
Chironomidae		91		11.09	J,Ju,A,S,O
Rhagionidae		1		0.12	J
Simuliidae		1		0.12	J
Tipulidae		2		0.24	J,Ju
Oligochaeta	29		3.53		J,Ju,A,O
Nematoda	3		0.36		Ju
Total No. Collected	820				
Total Taxa Collected	25				

J=June, Ju=July, A=August, S=September, O=October

TABLE 16. Benthic macroinvertebrates collected from Station 9.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	8		1.67		
Brachycentrus sp.		6		1.25	J
Hydropsyche sp.		2		0.41	J
Ephemeroptera	29		6.06		
Ameletus sp.		2		0.41	J
Ametropus sp.		2		0.41	J,Ju
Baetis sp. A		4		0.82	J
Ephemerella sp.		9		1.88	J
Heptagenia sp.		12		2.51	J,S
Plecoptera	43		8.99		
Isogenus sp.		42		8.78	J
Perlodidae		1		0.20	J
Diptera	250		52.3		
Ceratopogonidae		4		0.82	A,S,O
Chironomidae		231		48.32	J,Ju,A,S,O
Empididae		1		0.20	J
Simuliidae		14		2.92	J,O
Odonata	7		1.46		
Gomphus sp.		2		0.41	A
Ophiogomphus sp.		5		1.04	J,Ju,A
Nematoda	6		1.25		J,Ju,S,O
Oligochaeta	127		26.56		J,Ju,A,S,O
Mollusca	8		1.67		
Lymnaea sp.		1		0.20	A
Sphaerium sp.		7		1.46	J,A,S,O
Total No. Collected	478				
Total Taxa Collected	19				

J=June, Ju=July, A=August, S=September, O=October

TABLE 17. Benthic macroinvertebrates collected from Station 10.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	32		10.99		
Brachycentrus sp.		14		4.81	J,S
Cheumatopsyche sp.		1		0.34	J
Hydropsyche sp.		17		5.84	J,A,S
Ephemeroptera	134		46.04		
Ametropus sp.		11		3.78	J,Ju,A
Baetis sp. A		48		16.49	J,A
Epeorus (Ironopsis) sp.		2		0.68	J,A
Ephemerella sp.		5		1.71	J
Heptagenia sp.		67		23.02	J,A,S,O
Pseudocloeon sp.		1		0.34	J
Plecoptera	106		36.42		
Brachyptera sp.		1		0.34	J
Isogenus sp.		100		34.36	J,A,S,O
Pteronarcys sp.		5		1.71	J,A,S
Diptera	16		5.49		
Chironomidae (total)		11		3.78	
Ablabesmyia sp.		5		1.71	J,Ju
Cryptochironomus sp.		1		0.34	S
Demicryptochironomus sp.		1		0.34	J
Heterotrissocladius sp.		1		0.34	J
Orthocladiinae		2		0.68	J
Tanytarsus sp.		1		0.34	A
Empididae		2		0.68	J,O
Simuliidae		3		1.03	Ju,A
Odonata	1		0.34		
Ophiogomphus sp.		1		0.34	J
Oligochaeta	2		0.68		J,S
Total No. Collected	291				
Total Taxa Collected	22				

J=June, Ju=July, A=August, S=September, O=October

TABLE 18. Benthic macroinvertebrates collected from Station 11.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	87		16.05		
Brachycentrus sp.		3		0.55	J,O
Cheumatopsyche sp.		9		1.66	J
Hydropsyche sp.		75		13.83	J
Ephemeroptera	27		4.98		
Baetis sp. A		2		0.36	J
Ephemerella sp.		18		3.32	J,O
Heptagenia sp.		6		1.10	J
Pseudocloeon sp.		1		0.18	J
Plecoptera	109		20.11		
Isogenus sp.		94		17.34	J,O
Pteronarcys sp.		15		2.76	J
Diptera	203		37.45		
Ceratopogonidae		2		0.36	J
Chironomidae		192		35.42	J,Ju,S,O
Empididae		1		0.18	J
Rhagionidae		3		0.55	J
Simuliidae		3		0.55	J
Tipulidae		2		0.36	J
Odonata	2		0.36		
Ophiogomphus sp.		2		0.36	J,O
Oligochaeta	111		20.47		J,A,S,O
Nematoda	2		0.36		O
Hydracarina	1		0.18		J
Total No. Collected	542				
Total Taxa Collected	19				

J=June, Ju=July, A=August, S=September, O=October

TABLE 19. Benthic macroinvertebrates collected from Station 12.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	19		0.80		
Brachycentrus sp.		3		0.12	J,Ju
Cheumatopsyche sp.		3		0.12	Ju,S
Hydropsyche sp.		13		0.55	J,Ju,S
Ephemeroptera	99		4.21		
Ametropus sp.		3		0.12	S,O
Baetis sp. A		6		0.24	J,Ju
Brachycercus sp.		1		0.04	Ju
Ephemerella sp.		4		0.17	S
Heptagenia sp.		83		3.53	J,Ju,A,S,O
Rhithrogena sp.		2		0.08	Ju
Plecoptera	258		1.09		
Isogenus sp.		248		10.55	J,Ju,A,S,O
Pteronarcys sp.		10		0.40	Ju,S
Diptera	14		0.59		
Chironomidae (total)		11		0.46	
Ablabesmyia sp.		1		0.04	Ju
Chironomus sp.		2		0.08	J,Ju
Cryptochironomus sp.		4		0.17	A,S
Demicryptochironomus sp.		1		0.04	O
Heterotrissocladius sp.		2		0.08	J,A
Polypedilum sp.		1		0.04	Ju
Empididae		1		0.04	O
Simuliidae		2		0.08	Ju
Odonata	4		0.17		
Ophiogomphus sp.		4		0.17	J
Oligochaeta	1953		83.10		J,Ju,A,S,O
Nematoda	3		0.12		A,S
Total No. Collected	2350				
Total Taxa Collected	22				

J=June, Ju=July, A=August, S=September, O=October

TABLE 20. Benthic macroinvertebrates collected from Station 13.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	5		0.37		
Brachycentrus sp.		3		0.22	J,S
Hydropsyche sp.		1		0.07	J
Oxyethira sp.		1		0.07	J
Ephemeroptera	41		3.02		
Ametropus sp.		2		0.14	A
Baetis sp. A		2		0.14	J
Ephemerella sp.		22		1.62	A,S
Heptagenia sp.		13		0.95	J,A,S
Hexagenia sp.		1		0.07	J
Pseudocloeon sp.		1		0.07	J
Plecoptera	44		3.24		
Alloperla sp.		2		0.14	J
Isogenus sp.		40		2.95	J,A,S
Pteronarcys sp.		2		0.14	S
Diptera	385		28.41		
Ceratopogonidae		31		2.28	J,Ju,A,S,O
Chironomidae		346		25.53	J,Ju,A,S,O
Empididae		2		0.14	J,S
Simuliidae		4		0.29	J,Ju
Tabanidae		2		0.14	Ju
Odonata	3		0.22		
Ophiogomphus sp.		3		0.22	J,S
Amphipoda	1		0.07		A
Tricladida	1		0.07		J
Hirudinea	1		0.07		J
Oligochaeta	860		63.46		J,Ju,A,S,O
Nematoda	3		0.22		J,Ju
Mollusca	11		0.81		
Sphaerium sp.		11		0.81	J,A,S
Total No. Collected	1355				
Total Taxa Collected	24				

J=June, Ju=July, A=August, S=September, O=October

TABLE 21. Benthic macroinvertebrates collected from Station 14.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	36		12.41		
Brachycentrus sp.		14		4.82	J
Cheumatopsyche sp.		5		1.72	J
Glossosoma sp.		2		0.68	J
Hydropsyche sp.		14		4.82	J
Neureclipsis sp.		1		0.34	J
Ephemeroptera	75		25.86		
Baetis sp. A		39		13.44	J
Cinygmula sp.		2		0.68	J
Epeorus (Ironopsis) sp.		7		2.41	J
Ephemerella sp.		12		4.13	J
Heptagenia sp.		15		5.17	J
Plecoptera	54		18.62		
Isogenus sp.		53		18.27	J
Pteronarcys sp.		1		0.34	J
Diptera	88		30.34		
Ceratopogonidae		5		1.72	J,S
Chironomidae		76		26.20	J,Ju,S
Simuliidae		7		2.41	J
Odonata	1		0.34		
Gomphidae		1		0.34	J
Oligochaeta	35		12.06		J,Ju,A,S
Nematoda	1		0.34		J
Total No. Collected	290				
Total Taxa Collected	18				

J=June, Ju=July, A=August, S=September

TABLE 22. Benthic macroinvertebrates collected from Station 15.

Taxa	Total No. Collected		Percentage Composition		Month of Occurrence
Trichoptera	2		2.98		
Hydropsyche sp.		2		2.98	O
Ephemeroptera	3		4.47		
Ametropus sp.		1		1.49	O
Ephemerella sp.		1		1.49	O
Heptagenia sp.		1		1.49	S
Plecoptera	4		5.97		
Acroneuria sp.		1		1.49	J
Isogenus sp.		3		4.47	O
Diptera	36		53.73		
Ceratopogonidae		3		4.47	J,O
Chironomidae		30		44.70	J,Ju,S,O
Tabanidae		2		2.98	S
Tipulidae		1		1.49	S
Oligochaeta	21		31.34		J,Ju,S,O
Nematoda	1		1.49		S
Total No. Collected	67				
Total Taxa Collected	12				

J=June, Ju=July, S=September, O=October

25%.

3) Common taxon (C) - at least 1%, but less than 10%.

4) Rare taxon (R) - at least 0.1%, but less than 1%.

5) Incidental taxon (I) - less than 0.1%.

To obtain a general impression of the relative dominance of the invertebrates collected, a "dominance index" was calculated for each taxon by assigning an arbitrary numerical value to each of the five categories:

D = 16

S = 8

C = 4

R = 2

I = 1

By adding up the values for each taxon at all the stations, an overall indication of the relative dominance of the taxa can be seen. Based on these values, the invertebrate taxa were grouped into dominance classes (Tables 23 to 25). It can be seen that the section of the Athabasca River near the Syncrude facility is dominated by dipteran or fly larvae, and sludge worms (Oligochaeta). This is probably due to the presence of extensive mud substrates at the sampling station. The Chironomidae (midges) are the dominant dipterans and, of these, *Ablabesmyia* sp. is the most common (Table 24). Further analysis of the stonefly, mayfly, and caddisfly fauna (Table 25) indicated that the common species are

TABLE 23. Grouping of the major benthic macroinvertebrate taxa from the study area in dominance classes based on their dominance index values. See text for further explanation.

Index:	186-154	132-108	68-24	8-1
	Diperta	Ephemeroptera	Odonata	Tricladida
	Oligochaeta	Plecoptera	Trichoptera	Hirudinea
				Amphipoda
				Mollusca

TABLE 24. Grouping of the Chironomidae (Diptera) species in dominance classes based on their dominance index values.

Index:	17	15-5	2-1
	Ablabesmyia sp.	*Chironomus* sp.	*Heterocladius* sp.
		Cryptochironomus sp.	*Paratendipes* sp.
		Demicryptochironomus sp.	*Procladius* sp.
		Heterotrissocladius sp.	*Tanytarsus* sp.
		Polypedilum sp.	

TABLE 25. Grouping of the Plecoptera, Ephemeroptera, and Trichoptera species in dominance classes based on their dominance index values.

Index: 120	58-50	38-36	22-6	3-1
Plecoptera	Ephemeroptera	Plecoptera	Plecoptera	Plecoptera
Isogenus sp.	*Baetis* sp.	*Pteronarcys* sp.	*Acroneuria* sp.	*Alloperla* sp.
	Ephemerella sp.		*Brachyptera* sp.	
	Heptagenia sp.			
	Trichoptera	Trichoptera	Ephemeroptera	Ephemeroptera
	Hydropsyche sp.	*Brachycentrus* sp.	*Ametropus* sp.	*Ameletus* sp.
			Epeorus sp.	*Brachycercus* sp.
			Pseudocloeon sp.	*Cinygmula* sp.
			Rhithrogena sp.	*Hexagenia* sp.
				Isonychia sp.
			Trichoptera	*Leptophlebia* sp.
			Cheumatopsyche sp.	*Paraleptophlebia* sp.
			Glossosoma sp.	*Siphloplecton* sp.
				Trichoptera
				Lepidostoma sp.
				Neureclipsis sp.
				Oxyetheria sp.

Isogenus sp. (stonefly), *Baetis* sp., *Ephemerella* sp., *Heptagenia* sp. (mayflies), and *Hydropsyche* sp. (caddisfly). The species composition of the benthic communities in the study area is comparable to that observed by Flannagan (1975) in a 450 km stretch of the Athabasca River upstream of the Clearwater River, and by Renewable Resources Consulting Services Ltd. (1974) in Beaver River. The latter, however, had a rather large population of riffle beetles (Elmidae) which did not appear in samples from the study area where they were apparently either rare or absent.

Species Diversity

To obtain a general impression of the diversity of the benthic macroinvertebrate communities in the study area, we have assessed the species diversities at several selected stations that were similarly sampled throughout the entire open-water period. For each selected station, a Shannon-Weaver Species Diversity Index (Shannon and Weaver, 1949) was calculated by combining all samples into a single composite sample. The machine formula for the Shannon-Weaver Species Diversity Index (Lloyd et al., 1968) is:

$$\bar{d} = \frac{c}{N}\,(N \log_{10} N - \Sigma\, ni \log_{10} ni)$$

where C = 3.321928; N = total number of individuals; ni = total number of individuals in the i^{th} species. The results are summarized in Table 26, where the value of $\bar{d}$ ranges

TABLE 26. Diversity of the benthic macroinvertebrate communities, as determined by the Shannon-Weaver Species Diversity Index ($\bar{d}$), at selected stations within the study area during the open-water season (June-October, 1975).

Station	$\bar{d}$
1*	1.77
4	2.79
5	2.56
10	2.87
12	0.97
13*	1.63

*All chironomids grouped as 1 taxon.

from 0.97 to 2.87. These values indicate a rather diversified benthic fauna within the study area (Wilhm, 1970).

Species diversity is dependent on the number of species (richness) and the distribution of individuals among the species (evenness). Shannon and Weaver's information-theoretical measure of mean species diversity per individual ($\bar{d}$) is sensitive to, and increases with, both species richness and evenness. The value of $\bar{d}$ is proportional to the uncertainty of identification of an individual selected at random from a multi-species population. In general, $\bar{d}$ values range from zero to any positive number, but are seldom greater than ten. The $\bar{d}$ value is at a minimum when all individuals belong to the same species, whereas $\bar{d}$ is at a maximum value when each species contains the same number of individuals. In natural unstressed streams, $\bar{d}$ values usually vary between 1 and 4, whereas in polluted streams the value of $\bar{d}$ is usually less than 1 (Wilhm, 1970). The low $\bar{d}$ value at Station 12 (Table 26) was not due to a lack in species richness, rather, the large number of oligochaetes (Table 19) collected there had affected the evenness of the samples and hence a low $\bar{d}$ value.

Standing Crop of Benthic Macroinvertebrates

Standing crop represents and measures an instantaneous quantity of organisms and is therefore a relative indication of productivity. However, it does not include the time (rate) factor concerned with the development of the crop. In this study, the standing crop of the major benthic macroinvertebrate taxa at six selected stations (1, 4, 5, 9, 12, and 13) was recorded at monthly intervals throughout the open-water season. These data indicate the relative productivity of the existing benthic ecosystem and form a basis for future comparisons. The results of this investigation are summarized in Tables 27 to 32. Based on these results, the following conclusions can be drawn:

1. At all stations, the main bulk of the standing crop is composed of fly (Diptera) larvae and sludge worms (Oligochaeta) with other aquatic insects such as the mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), and dragonflies (Odonata) forming a smaller portion of the crop. Flannagan (1975) observed a similar pattern in his study areas in the Athabasca River and the Calling River. However, the densities of Diptera and Oligochaeta recorded in this study were much higher than those reported by Flannagan (1975).

2. The short-term flood in late June and early July, 1975 significantly reduced the benthic macroinvertebrate

TABLE 27. Seasonal variation in the standing crop (number m^{-2}) of benthic macroinvertebrates at Station 1.

Month	Major Taxa					Total No.m^{-2}
	Trichoptera	Ephemeroptera	Plecoptera	Diptera	Oligochaeta	
June	-	-	-	2489.76	14.82	2504.58
				2045.16	103.74	2148.90
July	-	-	-	44.46	-	44.46
August	14.82	-	-	14.82	-	29.64
September	-	-	-	14.82	-	14.82
October	-	44.46	29.64	3616.08	-	3690.18

TABLE 28. Seasonal variation in the standing crop (number m^{-2}) of benthic macroinvertebrates at Station 4.

Month	Major Taxa				Total
	Odonata	Diptera	Oligochaeta	Nematoda	$No.m^{-2}$
June	-	3705.00	400.14	-	4105.14
	29.64	5483.40	904.02	-	6417.06
July	59.28	59.28	192.66	44.46	355.68
August	-	133.38	2608.32	-	2741.70
September	14.82	978.12	815.10	14.82	1922.86
October	-	2252.64	2311.92	-	4564.56

TABLE 29. Seasonal variation in the standing crop (number m^{-2}) of benthic macroinvertebrates at Station 5.

Month	Major Taxa						Total No.m^{-2}
	Ephemeroptera	Odonata	Diptera	Oligochaeta	Nematoda	Mollusca	
June	-	-	474.24	44.46	-	-	518.70
	14.82	-	-	207.48	-	-	222.30
July	-	-	29.64	118.56	29.64	-	177.84
August	-	-	829.92	3334.50	14.82	-	4179.24
September	14.82	14.82	266.76	370.50	-	-	666.90
October	14.82	14.82	2015.52	400.14	-	14.82	2460.12

TABLE 30. Seasonal variation in the standing crop (number m^{-2}) of benthic marco-invertebrates at Station 9.

Month	Major Taxa							Total
	Ephemeroptera	Plecoptera	Odonata	Diptera	Oligochaeta	Nematoda	Mollusca	No.m^{-2}
June	29.64	14.82	-	44.46	251.94	-	-	340.86
	-	14.82	-	59.28	14.82	14.82	14.82	118.56
July	14.82	-	14.82	133.38	59.28	44.46	-	266.76
August	-	-	44.46	59.28	948.48	-	59.28	1111.50
September	14.82	-	-	44.46	474.24	14.82	29.64	577.98
October	-	-	-	3023.28	133.38	14.82	14.82	3186.30

TABLE 31. Seasonal variation in the standing crop (number m^{-2}) of benthic macro-invertebrates at Station 12.

Month	Major Taxa					Total No. m^{-2}
	Ephemeroptera	Plecoptera	Diptera	Oligochaeta	Nematoda	
June	-	-	222.3	414.96	-	637.26
	-	-	518.7	148.20	-	666.90
July	-	-	88.92	14.82	-	103.74
August	-	-	118.56	24,038.04	14.82	24,171.42
September	29.64	-	29.64	3,601.26	29.64	3,690.18
October	29.64	29.64	29.64	44.46	-	133.38

TABLE 32. Seasonal variation in the standing crop (number m^{-2}) of benthic macro-invertebrates at Station 13.

Month	Major Taxa						Total No.m^{-2}
	Ephemeroptera	Trichoptera	Diptera	Oligochaeta	Nematoda	Mollusca	
June	14.82	-	2074.80	533.52	-	29.64	2652.78
	-	-	844.74	326.04	-	-	1170.78
July	-	14.82	414.96	222.30	14.82	-	666.90
August	14.82	-	74.10	2148.90	-	74.10	2311.92
September	-	-	296.40	6239.22	-	74.10	6609.72
October	-	-	829.92	2726.88	-	-	3556.80

standing crop at all the stations studied. Similar reductions in benthos densities due to bottom scouring during floods have been reported by Anderson and Lehmkuhl (1968) and Thorup (1970). Based on the August samples, however, it seems that, by that time, the benthic invertebrate populations at most of the stations had recovered from the effects of the flood.

Evaluation of Two Biomonitoring Techniques

Benthic organisms provide a valuable indicator of past and present water quality conditions because of their long life histories and central position in the food chain, as well as their lack of mobility and their sensitivity to physico-chemical stress (Mackenthum, 1969; Cairns and Dickson, 1971). In this study, AEL field-tested several methods of sampling benthic organisms in order to determine an optimum collecting method for use by Syncrude for the purpose of routine biomonitoring of water quality.

Benthic sampling in large rivers like the Athabasca River is difficult due to 1) the variety of natural substrates encountered, 2) stream scour and shifting of substrates, 3) variable or high stream flow, and a host of other physical factors. The samplers tested in this study included a rock-filled barbecue basket type of artificial substrate sampler (Mason et al., 1967), a modified Ekman-type grab

(Burton and Flannagan, 1973), and a Surber sampler. Of the samplers tested, the Surber sampler was found to be unsuitable for the study area because of the lack of shallow riffle areas. Therefore, only the proficiencies of the first two samplers have been evaluated. Parameters evaluated were:

1) the number of taxa and individuals collected,

2) the kinds of taxa collected, and

3) the diversity and community structure of the benthos sampled.

Sampling procedures have been described in the section on "Methods".

Number of Taxa and Individuals

Figure 18 is a comparison of the number of invertebrate taxa and individuals collected by three basket samplers and three Ekman grab samples at six stations during the months of June, August, and September, 1975. It can be seen that the basket samplers consistently collected more different invertebrate taxa than the Ekman grab. However, there was no distinct correlation between the number of individuals collected and the type of sampler used.

Kinds of Taxa

Table 33 is a comparison of the benthic macroinvertebrate

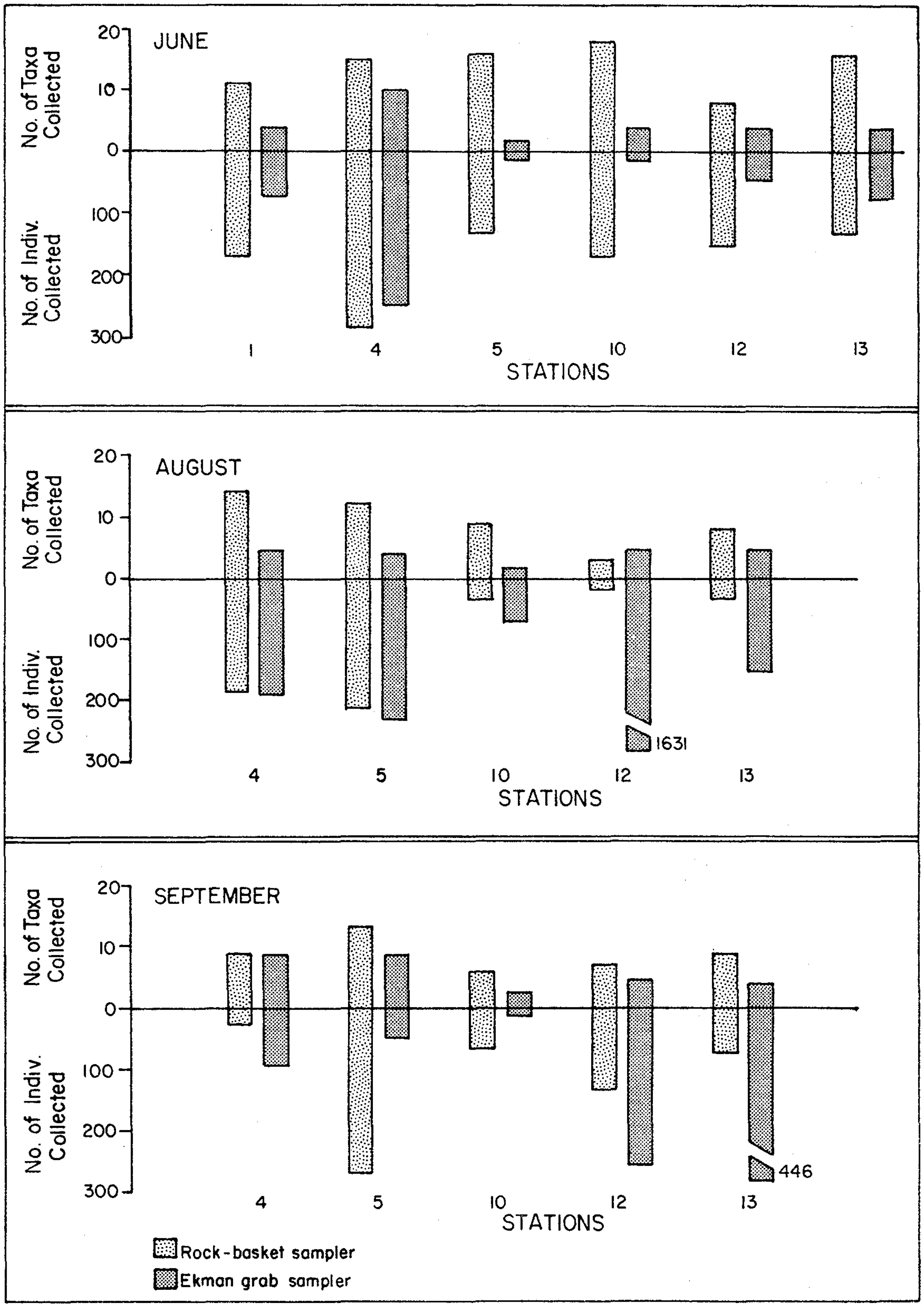

FIGURE 18. Comparison of the number of invertebrate taxa and individuals collected by the rock-basket and Ekman grab samplers.

TABLE 33. A comparison of the benthic macroinvertebrate taxa collected by the rock basket sampler and the Ekman grab from the study area, between June-October, 1975.

Taxa	Rock Basket	Ekman Grab
Trichoptera		
Brachycentrus sp.	+	+
Cheumatopsyche sp.	+	+
Glossosoma sp.	+	-
Hydropsyche sp.	+	+
Lepidostoma sp.	+	-
Limnephilidae	+	-
Neureclipsis sp.	+	-
Oxyethira sp.	+	-
Unidentified tricopteran	+	-
Ephemeroptera		
Ameletus sp.	+	-
Ametropus sp.	+	+
Baetis sp. A	+	-
Baetis sp. B	+	-
Brachycercus sp.	+	-
Cinygmula sp.	+	-
Epeorus (Ironopsis) sp.	+	-
Ephemerella sp.	+	+
Heptagenia sp.	+	+
Hexagenia sp.	-	+
Isonychia sp.	+	-
Leptophlebia sp.	+	+
Paraleptophlebia sp.	+	-
Pseudocloeon sp.	+	-
Rhithrogena sp.	+	-
Siphloplecton sp.	+	-
Plecoptera		
Acroneuria sp.	+	-
Alloperla sp.	+	+
Brachyptera sp.	+	-
Isogenus sp.	+	+
Perlodidae	-	+
Pteronarcys sp.	+	+
Unidentified plecopteran	+	-

(Continued)

TABLE 33. Continued.

Taxa	Rock Basket	Ekman Grab
Diptera		
Ceratopogonidae	+	+
Chironomidae		
Ablabesmyia sp.	+	+
Chironomus sp.	-	+
Cryptochironomus sp.	-	+
Demicryptochironomus sp.	+	+
Heterotissocladius sp.	+	+
Orthocladiinae sp. 1	+	-
Orthocladiinae sp. 2	+	-
Paratendipes sp.	-	+
Polypedilum sp.	+	+
Procladius sp.	-	+
Tanytarsus sp.	+	-
Empididae	+	+
Ragionidae		
Atherix variegata sp.	+	-
Simuliidae	+	+
Tabanidae	-	+
Tipulidae	+	+
Coleoptera		
Gyrinidae	-	-
Hemiptera		
Corixidae	+	+
Oligochaeta	+	+
Nematoda	+	+
Odonata		
Unidentified Gomphidae	+	-
Gomphus sp.	-	+
Ophiogomphus sp.	+	+
Hirudinea	+	-
Amphipoda		
Hyalella sp.	+	-
Hydracarina	-	+
Tricladida	-	+
Mollusca		
Lymnaea sp.	-	+
Sphaerium sp.	-	+
TOTAL No. of Taxa Collected	50	34

taxa collected by the basket sampler and the Ekman grab during the course of the study. It can be seen that the basket sampler collected a significantly larger number of riffle insects such as the caddisfly, mayfly, and stonefly species (Figure 19). However, the Ekman grab collected more substrate-associated and slow water benthic species e.g., the *Hexagenia* burrowing mayfly, the net-spinning *Hydropsyche* caddisfly, the chironomid larvae, and the molluscs. Overall, the basket sampler collected more invertebrate taxa (50) than the Ekman grab (34).

Species Diversity

Figure 20 is a comparison of the species diversity of the benthic samples collected by the basket samplers and by the Ekman grab for six stations during the month of June, August, and September, 1975. The $\bar{d}$ values for the basket samples are consistently higher than those for the grab samples. This indicates that the basket samples were richer in the number of species collected and that there was a more even distribution of individuals among the species collected.

Based on the foregoing comparisons, the basket sampler appears to be a more suitable device for biomonitoring water quality for the following reasons:

1) The basket sampler collects larger number of

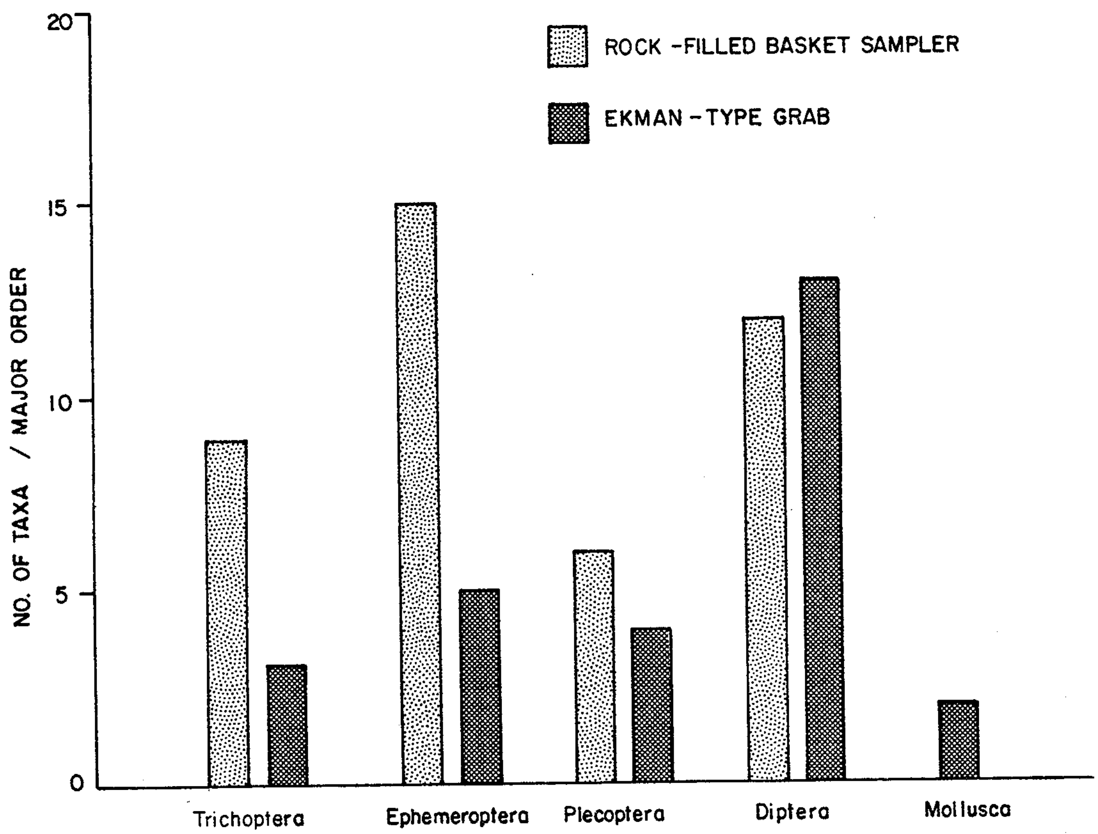

FIGURE 19. Comparison of the number of taxa per major invertebrate group collected by the rock-basket sampler and the Ekman grab.

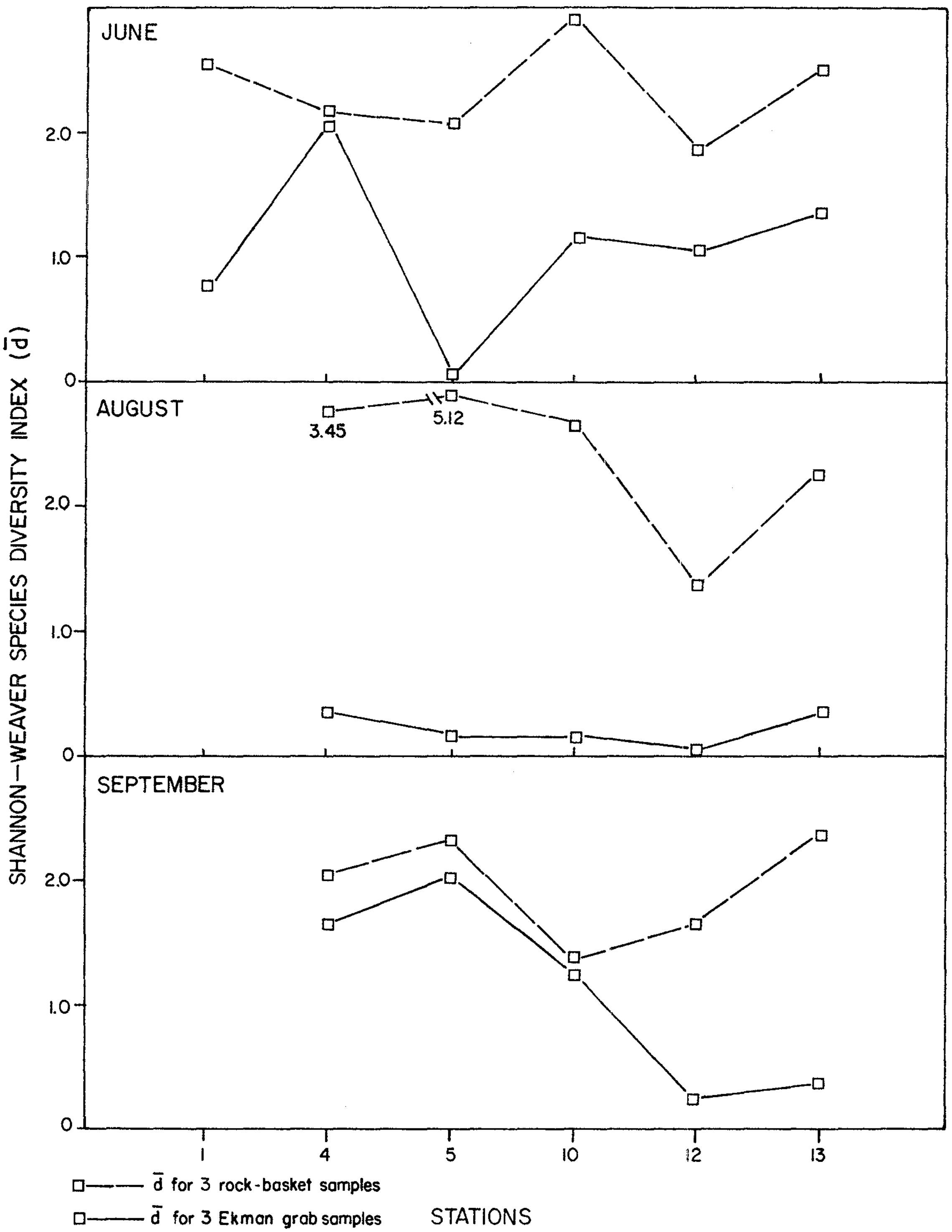

FIGURE 20. Comparison of the species diversity of benthic samples collected by the basket sampler and the Ekman grab.

invertebrate taxa and there is a more even distribution of individuals among the collected species. These characteristics are particularly desirable in water quality monitoring. In comparing the efficiencies of the basket sampler and the Peterson dredge, Anderson and Mason (1968) concluded that in water quality monitoring studies, it is best to have as many different organisms as possible on which to base conclusions. Dickson et al. (1971) also indicated that, in a comparison of biological water quality between selected stations, the number of taxa collected and the community structure of the macroinvertebrates sampled are more reliable indices of water quality than the number of specimens obtained.

2) The basket sampler selectively collects more of the "pollution sensitive" macroinvertebrates such as the nymphs of mayflies and stoneflies. The basket sampler is therefore a more sensitive biomonitoring tool.

3) The basket samplers can remain in the river throughout the study period, and are therefore continuously assessing the biological response of the benthic fauna to water quality.

4) The artificial substrates provided by the basket sampler reduce sample variation due to substrate difference and therefore can collect comparable samples at different times and places (Beak et al., 1973).

5) Because of substrate variability, a large number of bottom grab samples would be needed to give an adequate estimate of the benthic composition. Recent studies (Dickson et al., 1971; Mason et al., 1973) have indicated that a relative small number of basket samplers are needed to obtain reliable quantitative data. For a large river, Mason et al. (1973) demonstrated that three replicate baskets can be expected ($p = 0.95$) to provide an estimate of the true mean number of macroinvertebrates within ±20% of the sample mean.

Based on these considerations, AEL recommends that rock-filled basket artificial substrate samplers be used in routine biological monitoring of the Athabasca River water quality.

CONCLUSIONS

The benthic fauna of the study area exhibits a species composition and standing crop that are typical of large rivers with a predominantly mud substratum. In spite of the occurrence of bitumen in the substrate at some of the sampling stations (e.g., Stations 1, 3, 9, 13, and 15), there was no significant difference in the benthic animal community structure between stations with and without bituminous substrates. Stations with bituminous substrates, however, usually have a higher per cent composition of Chironomidae (midge) larvae and Oligochaeta (sludge worms). In experiments on the effect of crude oil on the colonization of artificial substrates by zoobenthos, Snow and Rosenberg (1975) also found that oil affected total numbers of colonizing individuals rather than species composition (diversity). They also found that dominance patterns were essentially the same on both oil-treated and control substrates.

Benthic populations at the Athabasca River tar sands area are probably hardy elements that, through the process of selection, have become adapted to the bituminous substrates.

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Section IV

FISHERIES STUDIES

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MATERIALS AND METHODS

Rationale

Environmental disturbance associated with the Syncrude development could affect fish populations in the Athabasca River directly or indirectly. Examples of the former might include mortalities associated with the release of toxic substances, explosives used during riverbank construction, the suffocation of eggs in sedimented spawning grounds, reductions in oxygen levels associated with the release of organic compounds, etc. Indirect effects might include changes in either primary (periphyton) or secondary (benthic macroinvertebrate) production which would affect fish dependent on these organisms as sources of food.

As with other aspects of the investigation, the fisheries studies were designed to provide baseline data against which any future changes in fish populations could be gauged. The studies were focused on three areas:

1) the relative abundance of various species,

2) seasonal movements,

3) life histories of major species.

Sample Collection and Analysis

Preliminary surveys to establish suitable collection techniques and locations were conducted from late August through October, 1975. During winter studies (December 1974 - April 1975), attempts were made to locate and identify overwintering fish populations by settling gillnets under the ice. At each of six locations within the study area (Figure 21), a single 15 m x 2.4 m panel of monofilament gillnet, either 5.1 cm (2 in.) or 7.3 cm (3 in.) stretched mesh, was set under the ice for a period of 24 to 72 hours. All fish captured during this portion of the study were frozen for dissection and life history analysis in the Calgary laboratory.

Five locations were chosen for repeated gillnet sampling during the open water season (Figure 21). Of these, three duplicated sites sampled during the winter but two were established at new locations. Gillnet stations were located in quieter water areas (over sand and silt bottoms) associated with the lee of islands (GN 1 and 3) and obstructions (i.e., Syncrude Dock--GN 2), or by shoreline indentations (GN 4 and 5). At each of these five open water sites, a standard gang, two 15 m x 2.4 m panels of monofilament

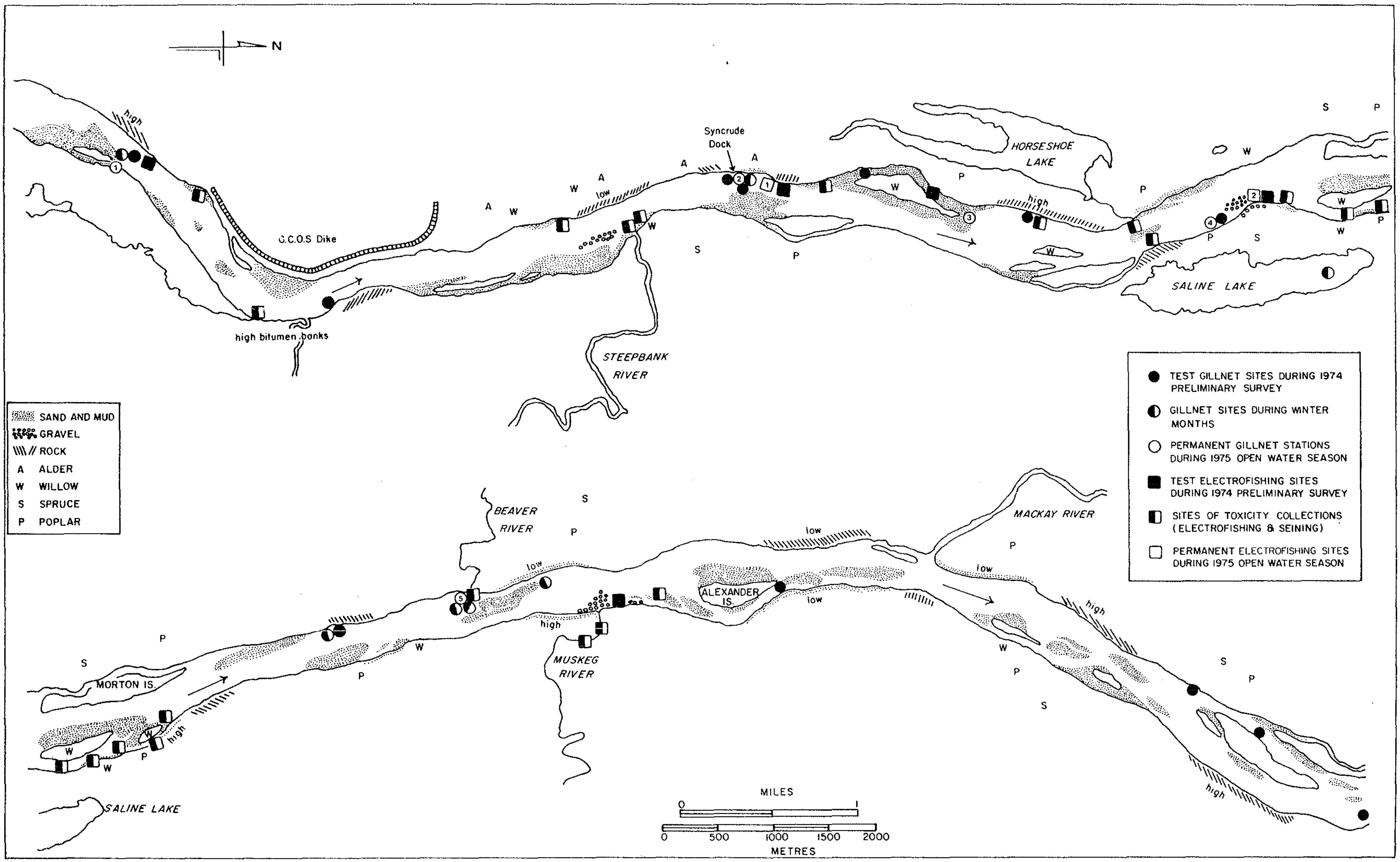

FIGURE 21. Detailed map showing the sample sites fished during 1974 and 1975 within the study area.

gillnet stretched mesh size 6.4 and 8.9 cm (2.5 and 3.5 in.), was set for a minimum total period of 24 hours. However, because of the accumulation of debris, the gillnets were checked and cleaned at 12 hour intervals. Records were kept of gillnetting periods and catches by species. Most of the fish were retained for dissection and life history analysis.

The soft bottom (silt and sand) and the fluctuating water levels characteristic of much of the nearshore areas restricted the number of acceptable inshore sampling (electrofishing and/or seining) locations to two permanent stations (Figure 21). The upstream location, designated EF 1, had a steep drop-off with a rock, boulder substrate, and a moderate current velocity (0.54 m/sec). The lower site was located on the gravel, rock shoreline near Saline Lake. The drop-off of this site was more gradual with a moderate current velocity (0.48 m/sec). These areas were sampled on a monthly basis during the open water season using a Smith-Root Type V Backpack Electrofisher. Records were kept of fishing effort (seconds of electrofisher operation) and of catches by species. Most of the captured fish were retained for dissection and life history analysis.

In addition to the permanent electrofishing stations, inshore habitats were sampled both with the electrofisher and with a nylon marquissette beach seine (6 m x 1.2 m with 0.64 mm mesh) during the collection of live fish for toxicity studies. These collections were made at 19 locations throughout the study area in late July and early August. Records were kept of the approximate numbers of each species captured during these collections and have been used in determining species distribution and in estimating the relative abundance of various species in nearshore habitats. A subsample of the collected fish were retained for toxicity studies and life history analysis, the remainder were released alive.

Most of the fish retained for life history analysis during the ice-free season were dissected fresh in a field laboratory. A few fish, which were difficult to identify in the field, were preserved (10% formalin) and shipped to the Calgary laboratory for identification and detailed analysis. The fish captured during the winter and shipped frozen were thawed before dissection.

During detailed examination, fish were measured to the nearest millimetre fork length, then weighed to the nearest 0.1 g on a triple beam balance. Gonads were examined to determine sex and state of maturity then weighed together on a triple beam balance (to nearest 0.1 g). The classification of state of maturity of fish is as follows.

Fish containing no evidence of having previously spawned (e.g. retained eggs) or of spawning in the coming spawning season were classified as *immature*. Fish that would spawn but were not in spawning condition when collected were classified as *mature green*. Fish in spawning condition (those which exuded sex products [eggs or milt] with application of gentle pressure on the abdomen) were classified as *mature ripe*. Fish which had recently spawned were listed as *mature, spawned-out*. Fish containing evidence of having previously spawned but which would not spawn in the coming season were classified as *mature non-spawners*.

To estimate egg size, ten fresh eggs from the largest size class were removed from the ovaries, placed in line end to end, and measured to the nearest 0.1 mm with Vernier calipers.

Fecundities were estimated by a subsampling procedure similar to that described by McCart et al. (1972). A portion, approximately 10%, of the total volume of the ovaries, was separated, weighed, then placed in 10% formalin until the eggs had hardened. The eggs in the subsample were then counted and an estimated total fecundity calculated by direct proportion.

Depending on the species, otoliths, scales, finrays, or dorsal spines were retained for age and growth determination. For several species, more than one part was retained and the best for aging purposes selected after a preliminary examination. Finrays and dorsal spines were not found to be satisfactory for any species in the study area and therefore, all of the age data presented are based on either scale or otolith examination. Scales were cleaned and dry mounted between glass microscope slides for later projection with a

Bausch and Lomb slide projector. After removal, otoliths were stored in glycerol for later examination under a binocular microscope. Most otoliths were examined whole but those of goldeye were ground on a lapidary wheel (No. 600 sandpaper) prior to aging.

Criteria for the identification of scale annuli are those of Lagler (1956). Criteria for otolith annuli are those of Nordeng (1961).

An examination was made of the stomach contents of most fish subjected to detailed examination. For each stomach, food items were listed without regard to relative abundance or proportionate volume. Such data indicate the frequency of occurrence of various food items and the range of food items utilized.

RESULTS AND DISCUSSION

Species Present and Relative Abundance

During this study, 17 species of fish were captured in the study area (Table 34). Among the larger species, those susceptible to gillnets (Table 35), the most abundant species was the goldeye which constituted 34.9% of the total gillnet sample. Other common species were the walleye (25.6%), longnose suckers (12.0%), and lake whitefish (10.6%). None of the other four species (northern pike, flathead chub, white sucker, and burbot) taken in gillnets exceeded 8% of the total catch.

Among the species taken at the permanent electrofishing sites (EF 1 and EF 2), by far the most abundant was the trout-perch which constituted 72.3% of the total of 382 individuals of 12 species taken at these locations in 1975 (Table 36). Other common species, in descending order, were lake chub (7.3%), walleye (5.5%), emerald shiner (3.9%), flathead chub (3.1%), and longnose sucker (2.9%). Other species were rarely taken. Data obtained during seining and electrofishing for toxicity collections indicate that the relative abundance of species was similar at other nearshore locations (Table 37).

TABLE 34. Fish species captured within the Study Area on the Athabasca River in 1974 and 1975. Methods and locations of capture are indicated. Locations identified as GN are gillnet sites and those identified as EF are electroshocking sites. Relative abundance of species within the Study Area is also indicated: A=abundant, C=common and R=rare.

Family	Common name	Scientific name	Code Name	Methods of Capture and Locations	Relative Abundance
Salmonidae					
Coregoninae	lake whitefish	*Coregonus clupeaformis* (Mitchill)	LKWT	GN-1,2,3,4,5	A
Thymallinae	Arctic grayling	*Thymallus arcticus* (Pallas)	GRAY	GN-2	R
Hiodontidae	goldeye	*Hiodon alosoides* (Rafinesque)	GOLD	GN-1,2,3,4,5	A
Esocidae	northern pike	*Esox lucius* Linnaeus	PIKE	EF-2;GN-1,2,3,4,5	C
Cyprinidae	lake chub	*Couesius plumbeus* (Agassiz)	LKCB	EF-1,2	C
	emerald shiner	*Notropis atheriniodes* Rafinesque	EMSH	EF-1,2	C
	spottail shiner	*Notropis hudsonius* (Clinton)	SPSH	EF-2	C
	flathead chub	*Platygobio gracilis* (Richardson)	FLCB	EF-2;GN-1,2,3,4,5	C
	longnose dace	*Rhinichthys cataractae* (Valenciennes)	LNDC	EF-2	R
Catostomidae	longnose sucker	*Catostomus catostomus* (Forster)	LNSK	EF-1,2;GN-1,2,3,4,5	C
	white sucker	*Catostomus commersonii* (Lacépède)	WTSK	EF-2; GN-1,2,3,4,5	C
Gadidae	burbot	*Lota lota* (Linnaeus)	BURB	EF-1,2;GN-1,2	C
Gasterostidae	brook stickleback	*Culaea inconstans* (Kirtland)	BRST	EF-1	R
Percopsidae	trout-perch	*Percopsis omiscomaycus* (Walbaum)	TRPH	EF-1,2	A
Percidae	yellow perch	*Perca flavescens* (Mitchill)	YWPH	EF-(side channel near Saline L.)	R
	walleye	*Stizostedion vitreum* (Mitchill)	WALL	EF-1,2;GN-1,2,3,4,5	A
Cottidae	slimy sculpin	*Cottus cognatus* Richardson	SLSC	EF-2	R

TABLE 35. Summary of gillnet catches of the five permanent sites on the Athabasca River in 1975, expressed in catch per unit effort (number of fish per hour per standard gang x 1000). Actual numbers of fish collected are presented in brackets.

Location	Gillnet Site 1					
Sample Period	May 31	June 22	July 15	Aug. 24	Sept. 17	Oct. 22
Effort (hours)	27	24	24	24	24	23.5
lake whitefish	-	-	-	42 (1)	83 (2)	43 (1)
goldeye	74 (2)	-	83 (2)	83 (2)	500(12)	-
northern pike	333 (9)	83 (2)	-	42 (1)	-	301 (7)
flathead chub	-	-	-	42 (1)	-	-
longnose sucker	37 (1)	-	-	-	-	-
white sucker	37 (1)	42 (1)	-	-	-	43 (1)
burbot	-	-	-	-	-	-
walleye	37 (1)	125 (3)	-	-	125 (3)	-

(Continued)

TABLE 35. Continued.

Location	Gillnet Site 2					
Sample Period	May 15	May 16	May 27	June 2	June 24	June 25
Effort (hours)	26.5	22.5	24	24	25	24.5
lake whitefish	226 (6)	311 (7)	-	-	-	-
goldeye	-	-	-	880(22)	520(13)	571(14)
northern pike	-	89 (2)	42 (1)	40 (1)	-	82 (2)
flathead chub	76 (2)	89 (2)	125 (3)	80 (2)	-	-
longnose sucker	302 (7)	489(11)	83 (2)	80 (2)	40 (1)	-
white sucker	-	-	42(11)	-	-	82 (2)
burbot	-	-	-	-	-	-
walleye	113 (3)	444(10)	125 (3)	240 (6)	240 (6)	82 (2)
Sample Period	July 15	Aug. 7	Aug. 21	Sept. 16	Oct. 21	
Effort (hours)	24.5	24	24.5	24	24.3	
lake whitefish	41 (1)	-	163 (4)	750(18)	454(11)	
goldeye	286 (7)	511(12)	816(20)	375 (9)	289 (7)	
northern pike	-	-	122 (3)	-	-	
flathead chub	122 (3)	43 (1)	-	-	-	
longnose sucker	122 (3)	-	-	167 (4)	206 (5)	
white sucker	-	43 (1)	-	-	-	
burbot	-	-	-	-	-	
walleye	204 (5)	468(11)	286 (7)	875(21)	784(19)	

(Continued)

TABLE 35. Continued.

Location	Gillnet Site 3							
Sample Period	May 29	June 20	July 17	July 18	July 19	Aug. 21	Sept. 16	Oct. 21
Effort (hours)	24	25	24	24	23.5	24	24.5	24
lake whitefish	-	-	-	-	-	-	82 (2)	42 (1)
goldeye	-	83 (2)	42 (1)	42 (1)	85 (2)	417(10)	694(17)	-
northern pike	42 (1)	-	-	-	-	125 (3)	41 (1)	41 (1)
flathead chub	125 (3)	-	-	42 (1)	-	-	41 (1)	-
longnose sucker	125 (3)	167 (4)	-	167 (4)	-	-	41 (1)	-
white sucker	-	42 (1)	-	-	-	-	-	83 (2)
burbot	-	-	-	-	-	-	-	-
walleye	83 (2)	83 (2)	-	-	-	42 (1)	204 (5)	292 (7)

(Continued)

TABLE 35. Continued.

Location	Gillnet Site 4				
Sample Period	May 28	June 20	Aug. 23	Sept. 18	Oct. 23
Effort (hours)	24	23	24	24	24
lake whitefish	-	-	83 (2)	-	42 (1)
goldeye	41 (1)	-	125 (3)	-	-
northern pike	-	-	-	-	-
flathead chub	83 (2)	-	-	42 (1)	42 (1)
longnose sucker	-	-	42 (1)	42 (1)	208 (5)
white sucker	-	-	125 (3)	-	167 (4)
burbot	-	-	-	-	-
walleye	-	-	42 (1)	-	83 (2)

	Gillnet Site 5					
Sample Period	June 2	June 21	July 17	Aug. 23	Sept. 18	Oct.24
Effort (hours)	24	24	26.5	24	23.5	24
lake whitefish	-	-	-	-	85 (2)	-
goldeye	167 (4)	42 (1)	38 (1)	417(10)	85 (2)	-
northern pike	-	42 (1)	-	125 (3)	-	42 (1)
flathead chub	83 (2)	-	-	-	-	-
longnose sucker	-	-	-	-	43 (1)	208 (5)
white sucker	125 (3)	42 (1)	-	-	-	-
burbot	-	-	-	-	-	42 (1)
walleye	167 (4)	125 (3)	38 (1)	42 (1)	-	42 (1)

(Continued)

TABLE 35. Continued.

Sample Period	Open Water			
Effort (hours)	3248	Combined catch at 5 gillnet sites		
Species		Number	% of Total Catch	Catch per Unit Effort
lake whitefish		54	10.6	16.6
goldeye		177	34.9	54.5
northern pike		39	7.7	12.0
flathead chub		25	4.9	7.7
longnose sucker		61	12.0	18.8
white sucker		21	4.1	6.5
burbot		1	0.2	0.3
walleye		130	25.6	40.0
TOTALS		508	100.0	156.4

TABLE 36. Summary of electroshocking catches at the two permanent sites on the Athabasca River 1975, expressed in catch per unit effort (number of fish captured per shocking second x 1000). Actual numbers of fish collected are presented in brackets.

Location	Electroshocking Site 1				Electroshocking Site 2							Combined Sites	
Date	June 21	Aug. 21	Sept. 20	Oct. 21	May 28	June 19	July 15	July 19	Aug. 25	Sept. 20	Oct. 21		% of Total Catch
Effort (sec. shocked)	527	231	243	187	765	805	1907	263	990	1028	1446	8392	
northern pike	-	-	-	-	-	-	-	-	-	-	0.7 (1)	0.1 (1)	0.3
lake chub	1.9 (1)	-	12.3 (3)	-	2.6 (2)	-	0.5 (1)	-	11.1 (11)	3.9 (4)	4.1 (6)	3.4 (28)	7.3
emerald shiner	1.9 (1)	-	-	-	2.6 (2)	-	3.1 (6)	3.8 (1)	5.1 (5)	-	-	1.8 (15)	3.9
flathead chub	-	-	4.1 (1)	-	5.2 (4)	2.5 (2)	1.0 (2)	-	1.0 (1)	1.9 (2)	-	1.4 (12)	3.1
longnose dace	-	-	-	-	-	-	-	-	-	2.9 (3)	-	0.4 (3)	0.8
longnose sucker	-	-	4.1 (1)	-	5.2 (4)	2.5 (2)	0.5 (1)	-	-	2.9 (3)	-	1.3 (11)	2.9
white sucker	-	-	-	-	2.6 (2)	-	-	-	-	-	-	0.2 (2)	0.5
burbot	5.7 (3)	-	4.1 (1)	5.3 (1)	3.9 (3)	-	-	-	1.0 (1)	-	-	1.1 (9)	2.4

(Continued)

TABLE 36. Continued.

Location	Electroshocking Site 1				Electroshocking Site 2							Combined Sites	
Date	June 21	Aug. 21	Sept. 20	Oct. 21	May 28	June 19	July 15	July 19	Aug. 25	Sept. 20	Oct. 21		% of Total Catch
Effort (sec. shocked)	527	231	243	187	765	805	1907	263	990	1028	1446	8392	
brook stickleback	-	-	-	5.3 (1)	-	-	-	-	-	-	0.7 (1)	0.2 (2)	0.5
trout-perch	-	-	20.6 (5)	5.3 (1)	18.3 (14)	5.0 (4)	73.4 (140)	45.6 (12)	6.1 (6)	26.3 (27)	46.3 (67)	32.9 (276)	72.3
walleye	-	4.3 (1)	-	-	-	1.2 (1)	0.5 (1)	15.2 (4)	8.1 (8)	-	4.1 (6)	2.5 (21)	5.5
slimy sculpin	-	-	-	-	2.6 (2)	-	-	-	-	-	-	0.2 (2)	0.5
TOTAL	9.5 (5)	4.3 (1)	45.3 (11)	16.0 (3)	43.1 (33)	11.2 (9)	79.2 (151)	64.6 (17)	32.3 (32)	37.9 (39)	56.0 (81)	45.5 (382)	100.0

TABLE 37. Summary of data for fish collections from the Athabasca River for toxicity purposes listing species captured, numbers, and percentages of total catches.

Species	Electro-shocking n	Electro-shocking % of Total	Seining n	Seining % of Total	Combined n	Combined % of Total
Arctic grayling	2	1.3	-	-	2	<0.1
northern pike	10	6.5	14	0.5	24	0.9
lake chub	14	9.2	96	3.6	110	3.9
emerald shiner	2	1.3	77	2.9	79	2.8
spottail shiner	-	-	10	0.4	10	0.4
flathead chub	-	-	219	8.3	219	7.8
longnose dace	1	0.7	1	<0.1	2	<0.1
longnose sucker	15	9.9	42	1.6	57	2.0
burbot	1	0.7	6	0.2	7	0.3
trout-perch	71	46.7	1622	61.1	1693	60.4
walleye	36	23.7	558	21.0	594	21.2
slimy sculpin	-	-	8	0.3	8	0.3
TOTALS	152		2653		2805	

The only abundant species was the trout-perch (60.4% overall). The common species were the same as those at the permanent electrofishing stations, though the order of dominance was different: walleye (21.2%), flathead chub (7.8%), lake chub (3.9%), emerald shiner (2.8%), and longnose sucker (2.0%). Two species, the spottail shiner and grayling, were taken during the toxicity collections that were not taken at either of the permanent electrofishing stations. On the other hand, two species, the brook stickleback and white sucker, taken at the permanent stations, were not taken during the toxicity collections.

Life Histories of Fish Species

Lake Whitefish

The lake whitefish is one of a number of closely related, sibling species within the "*Coregonus clupeaformis*" complex (McPhail and Lindsey, 1970). The species complex is widely distributed in Canada and Alaska, absent only from the Atlantic and Pacific coasts, most of the Arctic Islands, and parts of the Missouri Drainage. Adult and large juvenile lake whitefish were taken at all five permanent gillnet stations in the study area (Figure 21) but no young-of-the-year were captured.

Though its numbers have been reduced in many areas, the lake whitefish is still the most valuable commercial freshwater fish in Canada and, in addition, is becoming increasingly popular as a sport fish. Although widely distributed in Alberta, this species is generally limited to the cooler, well-oxygenated areas of lakes, seldom entering rivers (Paetz and Nelson, 1970). The Athabasca River population is unusual in that, not only are they abundant, it is possible that they also spawn in the river.

Lake whitefish were taken at all permanent gillnet stations within the study area (Figure 22). As previously indicated (Table 35), they were one of the more common large species, especially in late summer and fall (Figure 23). A total of 65 lake whitefish was collected during the course of the study. The otoliths of four of these were considered unreadable and were not, therefore, included in analyses of growth and maturation (Table 38). A comparison of the growth of the Athabasca River sample with that of populations in lakes in northern Alberta (Figure 24) indicates a growth rate similar to that in Namur Lake but slower than that in either Gardiner Lake or Pitchimi Lake.

There was no significant difference in the numbers of males (N=29) and females (N=30) in the total sample (aged and unaged). Almost 90% of the males sampled were mature but only 54% of the females (Table 39). Males mature at earlier ages than females. In age groups 4 through 8, 21 of 24 (87.5) of the males sampled were mature but only 7 of 22 (31.8) of the females. This appears to be typical of the

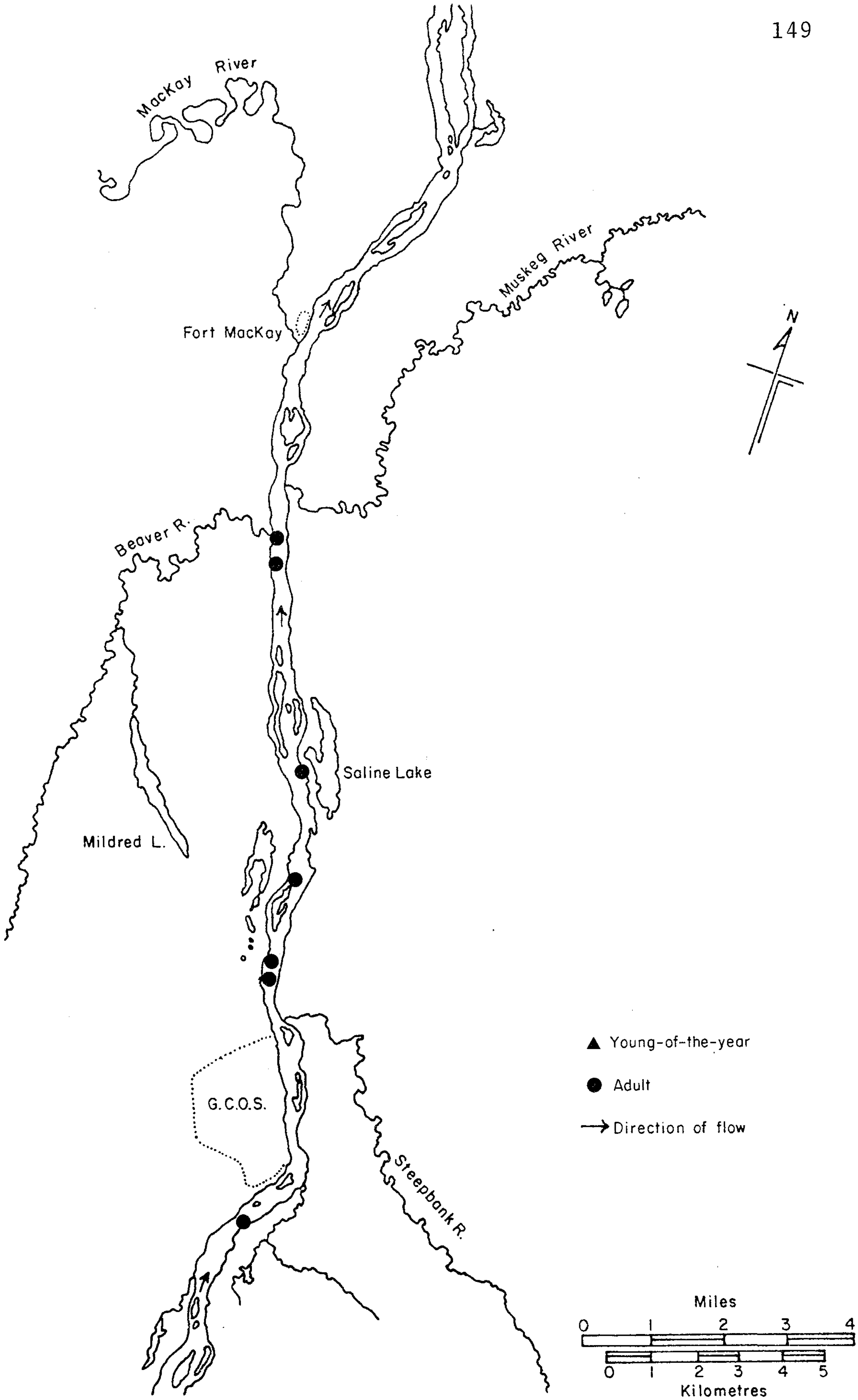

FIGURE 22. Sites of which lake whitefish were captured within the study area, 1974 and 1975.

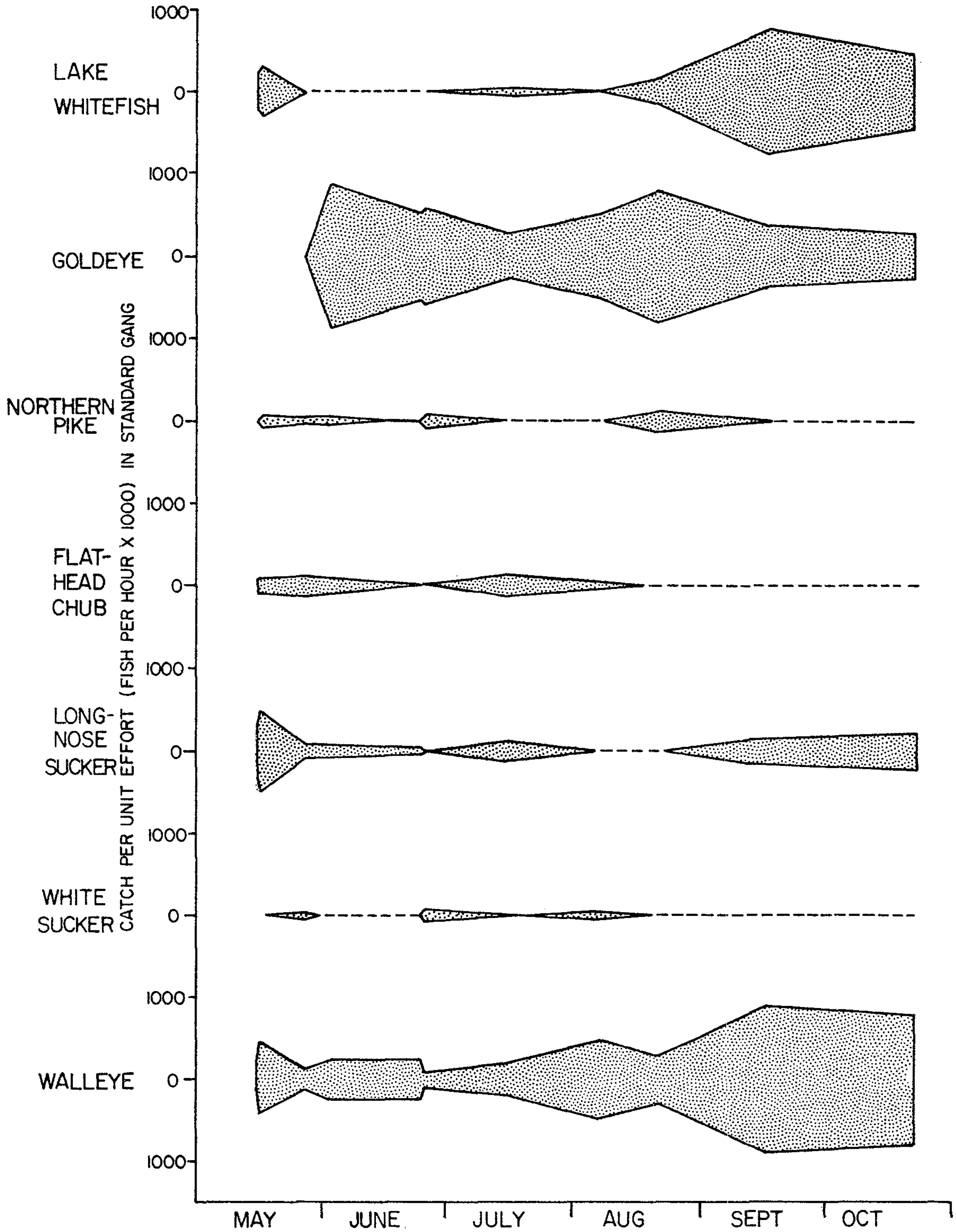

FIGURE 23. Seasonal abundance of seven fish species at GN 2. Catch per unit effort is catch per hour per standard gang x 1000.

TABLE 38. Observed length-age relationships, age specific sex ratios, and age at maturity for lake whitefish collected during the 1974 and 1975 gillnetting of the Athabasca River. Lake whitefish were aged using otoliths. Of the 65 pairs of otoliths examined, 4 pair were unreadable.

Age	Fork Length (mm)			Males			Females			Total
	Mean	S.D.	Range	N	%	% Mature	N	%	% Mature	
0	-	-	-	0	-	-	0	-	-	0
1	-	-	-	0	-	-	0	-	-	0
2	-	-	-	0	-	-	0	-	-	0
3	-	-	-	0	-	-	0	-	-	0
4	321.3	30.7	270-354	4	50.0	100.0	4	50.0	0.0	8
5	331.8	20.7	294-369	4	40.0	75.0	6	60.0	33.3	10
6	340.1	18.1	318-371	5	62.5	80.0	3	37.5	33.3	8
7	365.9	21.1	315-394	7	53.8	85.7	6	46.2	33.3	13
8	373.7	11.8	360-395	4	57.1	100.0	3	42.9	66.6	7
9	389.0	11.3	380-404	0	-	-	5	100.0	100.0	5
10	406.3	7.7	400-415	0	-	-	3	100.0	100.0	3
11	415.0	16.6	398-434	4	80.0	100.0	1	20.0	100.0	5
12	(416.0)	-	-	0	-	-	1	100.0	100.0	1
13	(475.0)	-	-	0	-	-	1	100.0	100.0	1
TOTALS				28	45.9	89.3	33	54.1	54.4	61

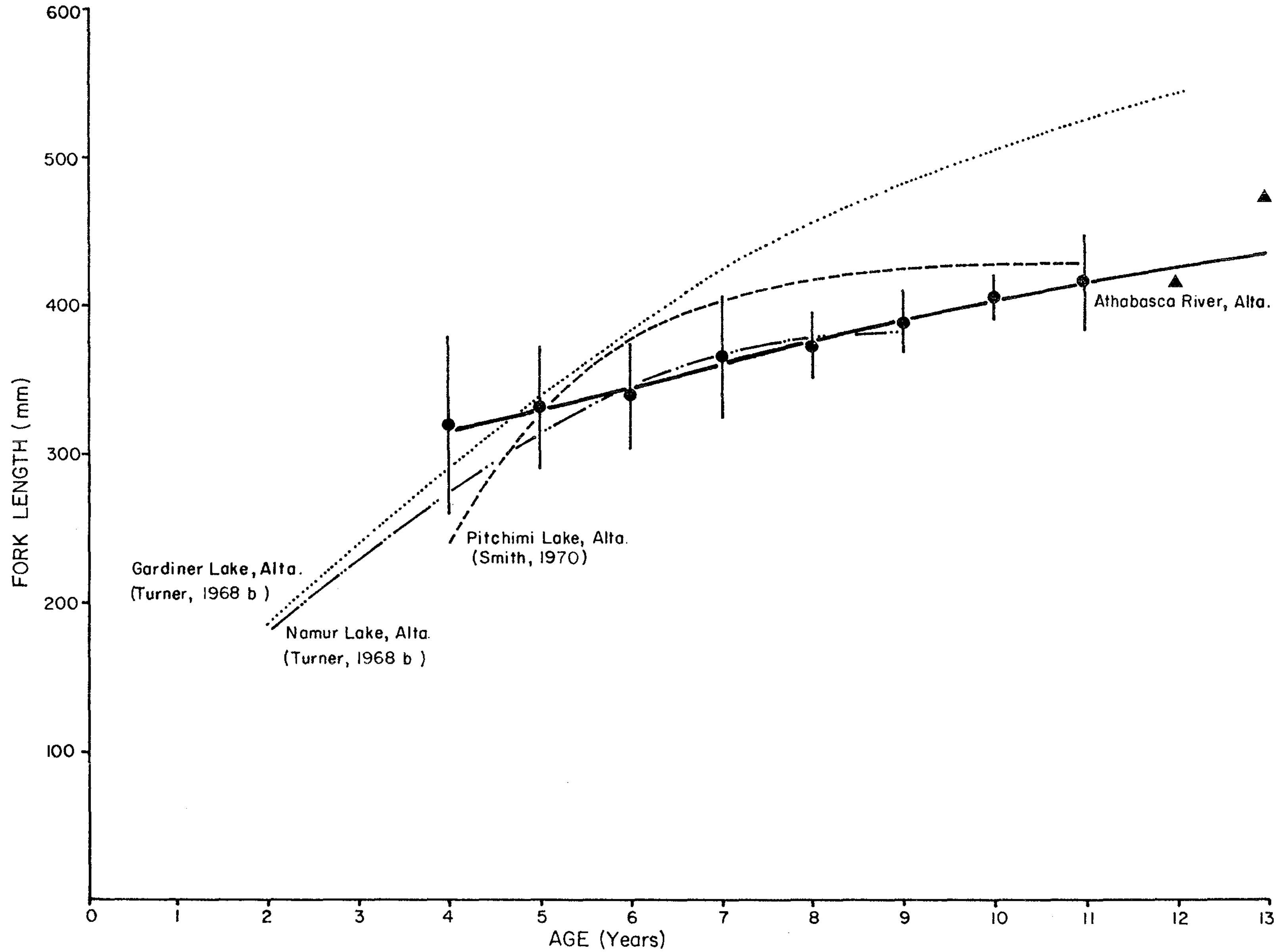

FIGURE 24. Comparison of growth rates of lake whitefish collected during this study on the Athabasca River, Alberta and at three other locations in Alberta. The Athabasca River sample was aged from otoliths, the others from scales. Symbols for the Athabasca River sample are: closed circles, mean fork length; closed triangles, individual fish lengths; vertical lines, 95% confidence limits (calculated for age groups containing five or more fish).

TABLE 39. Summary of sex, maturity, and spawning condition for all lake whitefish collected from the Athabasca River during 1974 and 1975 (includes 4 individuals with unreadable otoliths).

Sample Period	Immature		Mature Green		Mature Ripe		Mature Spawned-out		Mature Non-spawner		Percent Mature	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Oct. 1974	-	-	-	-	-	-	4	2	-	-	100.0	100.0
Jan. 1975	-	2	-	-	-	-	1	-	-	-	100.0	-
May 1975	1	5	5	4	-	-	-	-	-	-	80.0	44.4
July 1975	-	-	-	1	-	-	-	-	-	-	-	100.0
Aug. 1975	-	-	3	2	-	-	-	-	-	-	100.0	100.0
Sept.1975	2	1	-	9	-	-	9	-	-	-	81.8	90.0
Oct. 1975	-	9	-	-	-	-	4	-	-	1	100.0	10.0
TOTALS	3	17	8	16	-	-	18	2	-	1	89.6	52.8

species (Scott and Crossman, 1973).

The spawning season and the spawning grounds of the population of whitefish inhabiting the Athabasca River are not definitely known. In 1974, two spawned-out females and four spawned-out males were captured in late October (Table 39). In 1975, one spawned-out male was captured January 19 and 14 more between September 16 and October 21. Although mature green females (egg diameters to 2.2 mm) were present in the study area from May through August and mid September, only immature females and a single mature non-spawner were captured in October. These data suggest a spawning period beginning in late September and continuing at least into October.

Typically, this species spawns in lakes, however, river spawning populations have been reported (Scott and Crossman, 1973; Jessop et al., 1974). The presence of spawned-out whitefish, early in the fall, far from any suitable lake, suggests that they may be spawning in the river or its tributaries. There are reports of lake whitefish in spawning condition in the vicinity of the series of rapids (Cascade Rapids, etc.) on the Athabasca River approximately 31 km (19.5 mi) upstream of Fort McMurray (Dr. S. Smith, personal communication). No whitefish fry have, however, been taken within the study area.

Fecundities were calculated for 13 mature green females (fork length 366-475 mm). Egg numbers ranged from 12,634 to 34,179 with a mean of 21,223 (standard deviation ± 6,554) per female.

Figure 23 indicates seasonal variation in gillnet catches of lake whitefish at station 2, the most productive gillnet site. The species was present in moderate numbers in May but was scarce thereafter until mid-August when numbers began to increase to a peak in September and October. The late season peak in abundance may be the consequence of movements to and from spawning grounds.

A large portion (60.9%) of 64 lake whitefish stomachs analysed was empty. Corixidae adults (56.0%), Chironomidae larvae (20.0%), and Trichoptera larvae (12.0%) occurred most frequently in the remaining 25 stomachs. Fish eggs, clams (*Sphaerium*), and Coleoptera (Gyrinidae) adults appeared less frequently, (Table 40).

Goldeye

In North America, the main area of distribution of the goldeye is in the Great Plains including the three Prairie Provinces in Canada. In the Mackenzie River Drainage, they extend as far north as Aklavik in the Mackenzie Delta, N.W.T. (Kennedy and Sprules, 1967). Goldeye were taken at all five permanent gillnet stations in the study area (Figure 25) but no young-of-the-year were captured.

Goldeye prefer the quieter, more turbid waters of large rivers, small lakes, and the muddy shallows of larger lakes

TABLE 40. Frequency of occurrence of food items in stomachs of five species of fish examined during studies on the Athabasca River, 1974 and 1975.

	lake whitefish		goldeye		northern pike		flathead chub		walleye	
	N	%	N	%	N	%	N	%	N	%
BENTHOS:										
Ephemeroptera nymphs	-	-	11	9.2	-	-	1	2.7	2	3.7
Odonata nymphs	-	-	2	1.7	1	5.3	1	2.7	-	-
Plecoptera nymphs	-	-	7	5.9	-	-	2	5.4	2	3.7
Trichoptera larvae	3	12.0	1	0.8	-	-	2	5.4	-	-
Chironomidae larvae	5	20.0	6	5.0	-	-	-	-	-	-
Tipulidae larvae	-	-	1	0.8	-	-	-	-	1	1.9
Tabanidae larvae	-	-	1	0.8	-	-	-	-	-	-
SURFACE INSECTS:										
Ephemeroptera adults	-	-	17	14.3	-	-	-	-	-	-
Odonata adults	-	-	1	0.8	-	-	-	-	-	-
Plecoptera adults	-	-	19	16.0	-	-	-	-	-	-
Corixidae adults	14	56.0	3	2.5	-	-	3	8.1	-	-
Coleoptera adults	2	8.0	57	47.9	-	-	2	5.4	-	-
Diptera adults	-	-	9	7.6	-	-	-	-	1	1.9
Hymenoptera adults	-	-	17	14.3	-	-	-	-	-	-
Lepidoptera adults	-	-	2	1.7	-	-	-	-	-	-
Other terrestrial insects	-	-	8	6.7	-	-	-	-	1	1.9
Unidentified Insect Parts	2	8.0	-	-	-	-	7	18.9	-	-
Mollusca	2	8.0	-	-	-	-	-	-	-	-
Fish Remains	-	-	8	6.7	16	84.2	3	8.1	27	50.0
Fish Eggs	2	8.0	-	-	-	-	-	-	-	-
Mammal Remains	-	-	-	-	-	-	-	-	1	1.9
Vegetable Material	-	-	38	31.9	-	-	1	2.7	-	-
Digested Material	2	8.0	4	3.4	2	10.5	20	54.0	26	48.2
Miscellaneous	-	-	1	0.8	1	5.3	-	-	-	-
Stomachs containing food	25	39.1	119	90.8	19	35.9	37	90.2	54	33.1
Number of empty stomachs	39	60.9	12	9.2	34	64.1	4	9.8	109	66.9
Total stomachs analysed	64	100.0	131	100.0	53	100.0	41	100.0	163	100.0

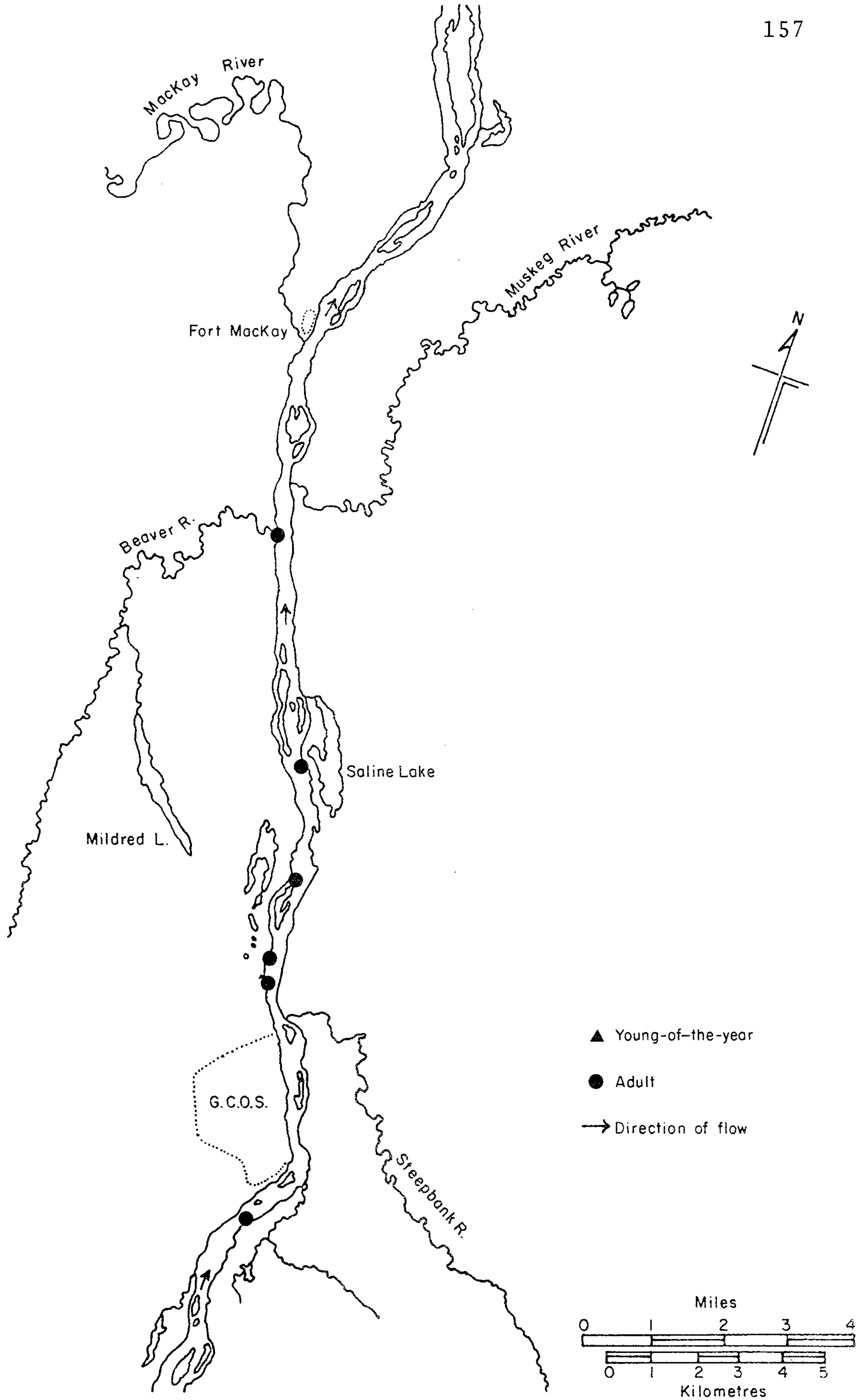

FIGURE 25. Sites at which goldeye were captured within the study area, 1974 and 1975.

(Scott and Crossman, 1973). At one time, goldeye were a commercially exploited species in the Peace-Athabasca Delta but the fishery was terminated in 1966 when the fishery collapsed apparently as the result of overexploitation (Kooyman, 1972).

A total of 179 goldeye was collected during the study, of which 131 were retained for detailed analysis. The otoliths of nine of these were unreadable, therefore, determinations of length-age relationships, sex ratios, and age at maturity of this species are based on 122 individuals (Table 40). The age at maturity of goldeye varies with sex. In the Lake Claire, Alberta, population, males mature at 6-9 years and females at 7-10 years (Battle and Sprules, 1960). Although the range of year classes from this study is limited (no fish less than age 3 or greater than age 6 were collected), similar sexual differences in maturation rates are apparent. Of the total sample, 16 of 93 males (17.2%) were mature (ages 3 to 6) but only 1 of 29 females (3.4%) was mature (age 5). Fork lengths ranged from 224-308 mm with the majority falling between 225 and 275 mm (Figure 26). Figure 27 compares the growth of goldeye from the study area with those from the Saskatchewan Delta, Manitoba, and Lake Claire, Alberta. The study population appears to be the slowest growing of the three populations. In part, the difference may be due to aging techniques: otoliths were used in this study and scales in all others.

TABLE 41. Observed length-age relationships, age specific sex ratios and age at maturity for goldeye collected in 1974 and 1975 from the Athabasca River. Fish were aged using otoliths.

Age	Fork Length (mm)			Males			Females			Unsexed	Total
	Mean	S.D.	Range	N	%	% Mature	N	%	% Mature		
0	-	-	-	0	-	-	0	-	-	0	0
1	-	-	-	0	-	-	0	-	-	0	0
2	-	-	-	0	-	-	0	-	-	0	0
3	238.9	4.18	235-245	7	100.0	28.6	0	-	-	0	7
4	253.6	15.57	224-301	68	75.6	11.8	22	24.4	0.0	0	90
5	263.7	19.24	241-308	17	73.9	29.4	6	26.1	16.7	0	23
6	274.0	31.11	252-296	1	50.0	100.0	1	50.0	0.0	0	2
TOTALS				93	76.2	17.2	29	23.8	3.5	0	122

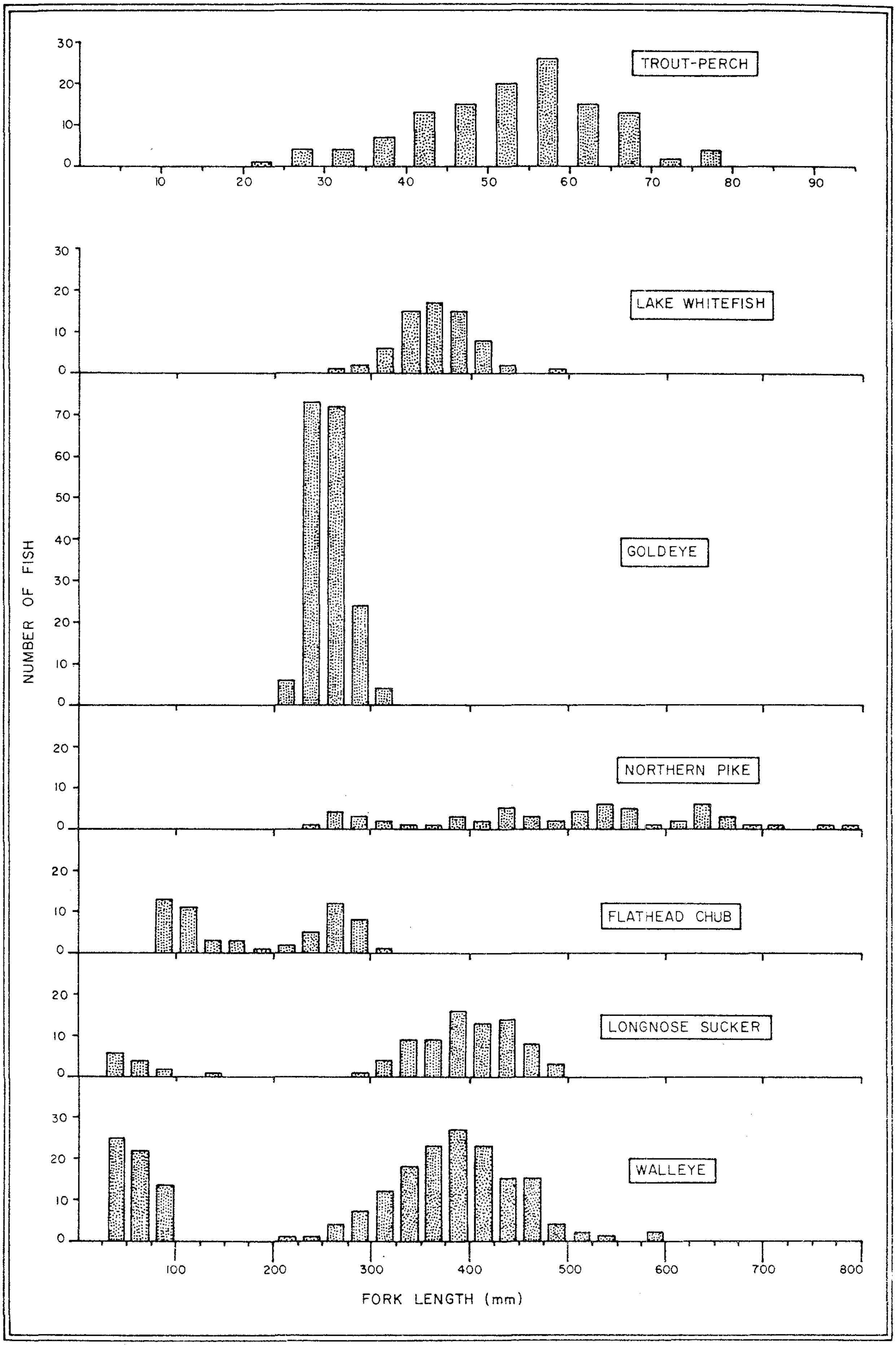

FIGURE 26. Length frequency of the seven major species collected during the study.

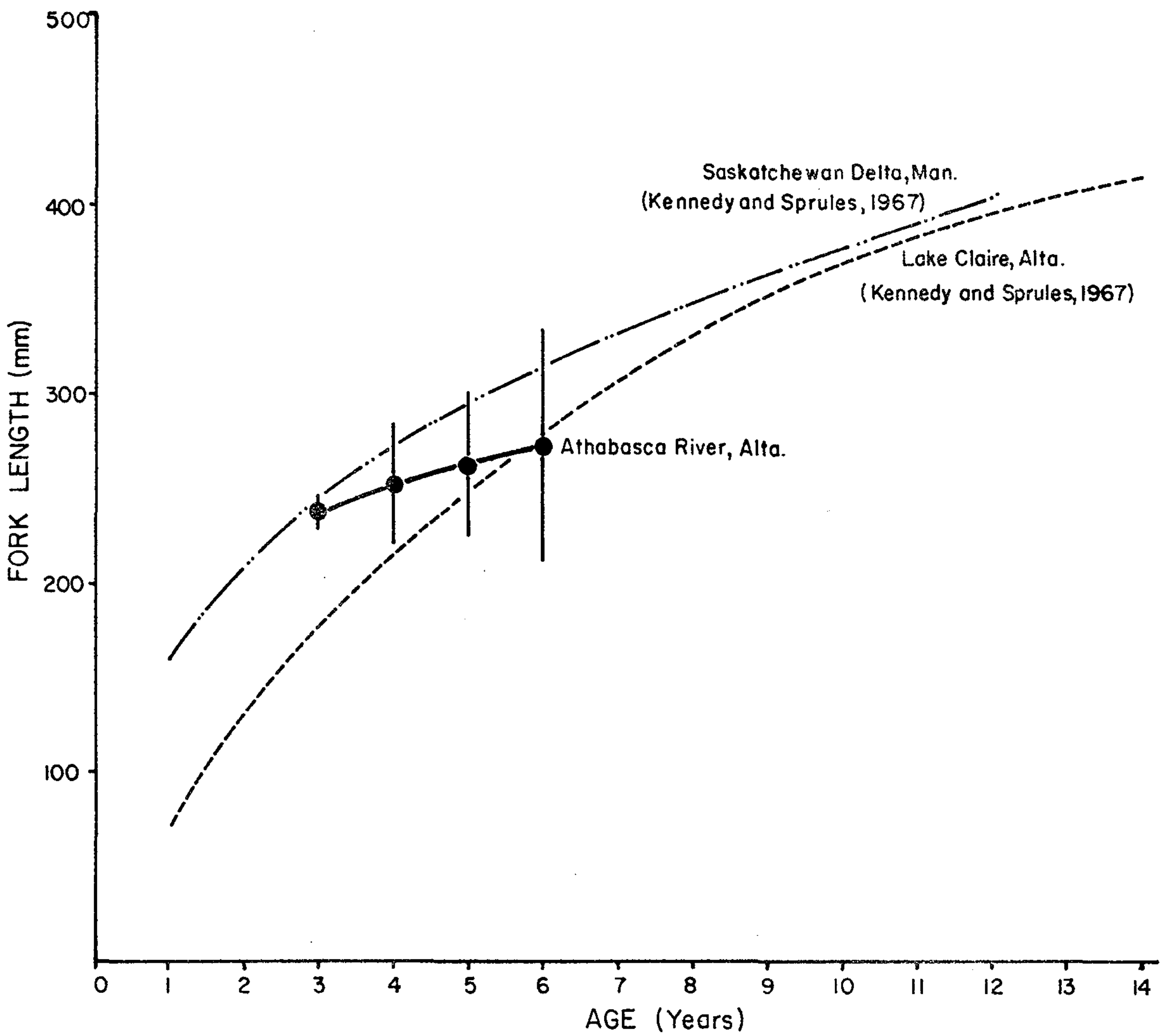

FIGURE 27. Comparison of growth rates of collected during this study on the Athabasca River, Alberta and at two other locations in Alberta and Manitoba. The Athabasca River sample was aged fro otoliths, the others from scales. Symbols for the Athabasca River sample are: closed circles, mean fork length; closed triangles, individual fish lengths; vertical lines, 95% confidence limits (calculated for age groups containing five or more fish).

Goldeye spawn over a period of 3-6 weeks commencing shortly after ice breakup (Scott and Crossman, 1973). Spawned-out males and a single spawned-out female were collected in the nets from June 2-21, however, the absence of ripe individuals and young-of-the-year from our collections suggest that goldeye do not spawn in the vicinity of the study area.

Figure 23, showing the seasonal abundance of this species at GN 2, does not indicate any peaks in abundance like those usually associated with major spawning runs. This, coupled with the absence of ripe individuals and young-of-the-year, suggests that goldeye utilize the study area primarily as a summer feeding ground. Long feeding migrations appear to be characteristic of river-dwelling populations of this species (Kennedy and Sprules, 1967; Paterson, 1966; McCart and Jones, 1975). It is possible that the goldeye which frequent the study area spawn in the Peace-Athabasca Delta.

The frequencies of occurrence of food items in 131 goldeye stomachs are presented in Table 40. A small proportion (9.2%) of these stomachs was empty. Analysis of the remaining 119 stomachs indicated that this species is very opportunistic, feeding on a wide variety of food as it becomes available. Surface insects, including Coleoptera adults (47.9%), Plecoptera adults (16.0%), Ephemeroptera adults (14.3%) and Hymenoptera adults (14.3%) were major food sources. Vegetable material (31.9%), particularly the wind-borne seeds ("cotton") of poplars, was also common. Other insects and fish remains occurred less frequently.

Northern Pike

The northern pike has a circumpolar distribution. In Canada, it is widely distributed, absent only from the Maritime Provinces and Newfoundland, from the High Arctic and from most Pacific Drainages in British Columbia. The species prefers warm, clear, heavily vegetated waters (Scott and Crossman, 1973), but occurs in a wide range of habitats. It is an important commercial and game species.

Adult pike are widely distributed in the study area but young-of-the-year were taken only in a side channel in the vicinity of Saline Lake Outlet (Figure 28).

Scales were utilized to age the 54 northern pike captured during the study. Males appear to mature as early as age 3 and all males in the sample were mature by age 5 (Table 42). Females, however, do not attain sexual maturity until ages 5 or 6 (Table 42). Fork lengths of fish in the sample ranged from 226 mm to 785 mm and ages from 2-13 years (Figure 26 , Table 42). The growth rate of this population lies within the ranges of other populations in Alberta and the Northwest Territories (Figure 29).

Northern pike spawn shortly after breakup, in April through early May, with water temperatures in the 4.4-11.1°C

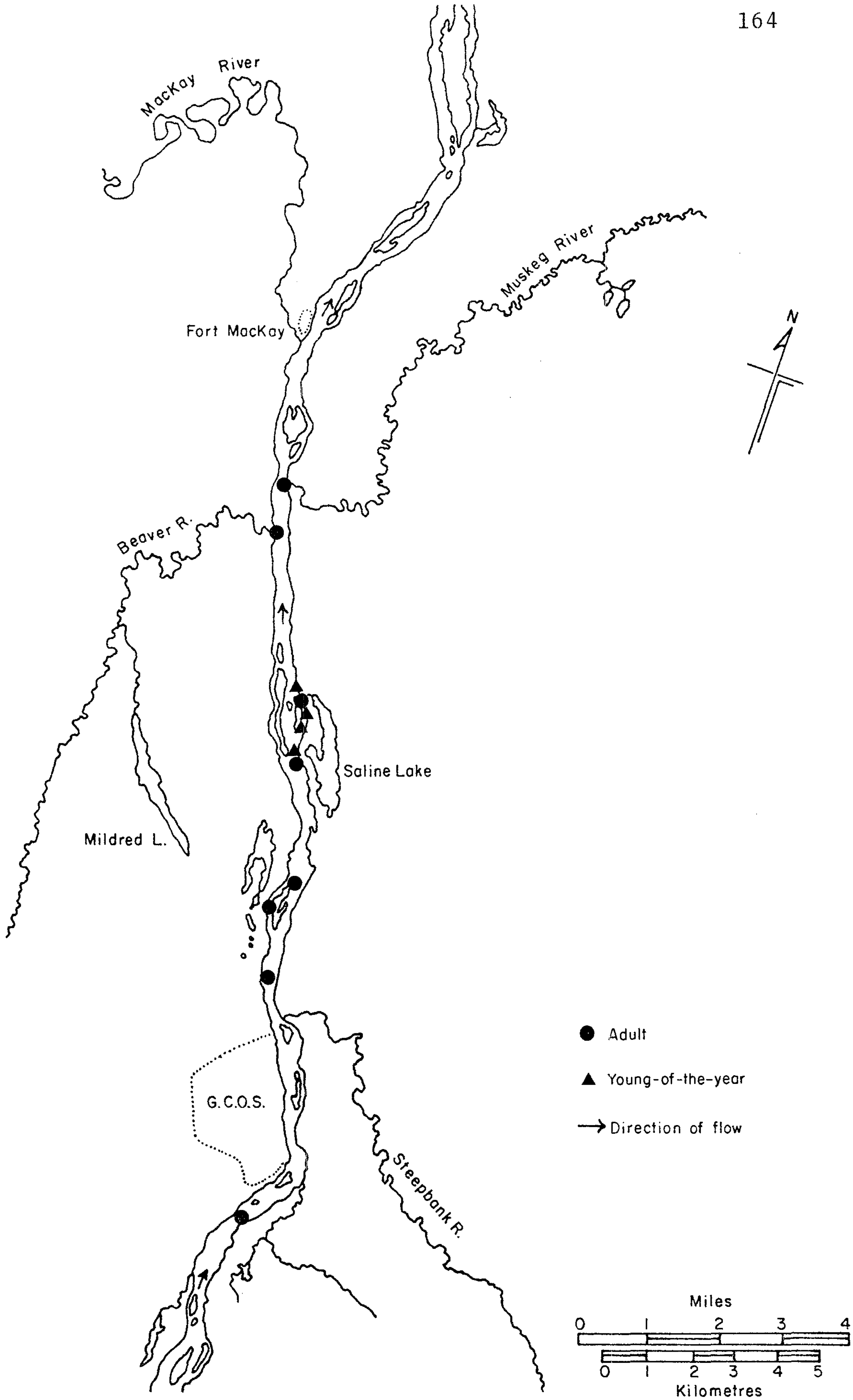

FIGURE 28. Sites at which northern pike were captured within the study area, 1974 and 1975.

TABLE 42. Observed length-age relationships, age specific sex ratios and age at maturity for pike collected in 1974 and 1975 from the Athabasca River. Fish were aged using scales.

Age	Fork Length (mm) Mean	S.D.	Range	Males N	%	% Mature	Females N	%	% Mature	Unsexed	Total
0	-	-	-	0	-	-	0	-	-	0	0
1	-	-	-	0	-	-	0	-	-	0	0
2	(260.0)	-	-	1	100.0	0.0	0	-	-	0	1
3	277.7	26.3	226-308	8	88.9	37.5	1	11.1	0.0	0	9
4	403.4	38.5	338-448	4	44.4	75.0	5	55.6	0.0	0	9
5	506.8	48.8	405-565	6	54.5	100.0	5	45.5	60.0	0	11
6	549.5	38.8	510-592	2	50.0	100.0	2	50.0	100.0	0	4
7	539.5	11.6	528-553	2	50.0	100.0	2	50.0	100.0	0	4
8	625.4	29.4	572-659	3	42.9	100.0	4	57.1	100.0	0	7
9	(626.0)	-	-	1	100.0	100.0	0	-	-	0	1
10	672.0	5.7	668-676	1	50.0	100.0	1	50.0	100.0	0	2
11	613.0	18.4	600-626	1	50.0	100.0	1	50.0	100.0	0	2
12	683.0	38.2	656-710	1	50.0	100.0	1	50.0	100.0	0	2
13	768.5	23.3	752-785	2	100.0	100.0	0	-	-	0	2
TOTALS				32	59.3	78.1	22	40.7	63.6	0	54

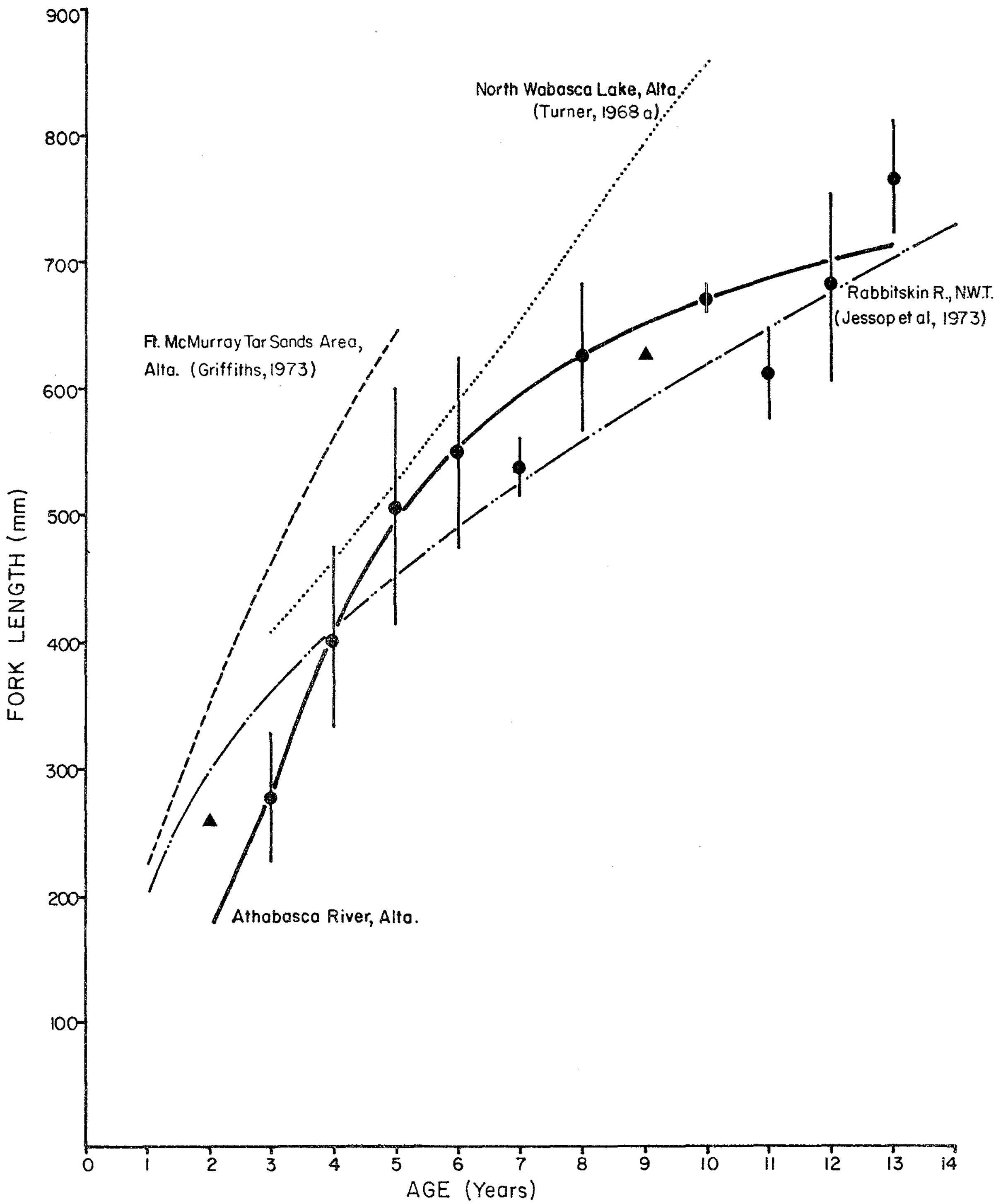

FIGURE 29. Comparison of growth rates of northern pike collected during this study on the Athabasca River, Alberta and at three other locations in Alberta and the Northwest Territories. All samples were aged from scales. Symbols for the Athabasca River samples are: closed circles, mean fork length; closed triangles, individual fish lengths; vertical lines, 95% confidence limits (calculated for age groups containing five or more fish).

range (Scott and Crossman, 1973). Spawned-out individuals of both sexes were gillnetted at GN 1, 2, 3, and 5 (Figure 21) during the late May sampling period (May 28-31). Suitable vegetative cover for spawning was not observed in the study area and the only young-of-the-year captured were those (N=5) taken in the vicinity of the Saline Lake Outlet between July 20 and August 8. Saline Lake is a possible spawning site for this species. Fecundities determined for 5 mature green females (fork lengths 528-710 mm) ranged from 20,267 to 53,295 with a mean of 32,452 (standard deviation ± 15,450).

No pattern of seasonal abundance is evident in Figure 23, possibly because of the small sample size.

Stomach content data for 53 pike appear in Table 40. A large proportion (64.1%) of the stomachs examined were empty. Fish (Arctic grayling, flathead chub, longnose sucker, white sucker, burbot, trout-perch, and northern pike) remains occurred in 84.2% of the stomachs containing food items. Material too digested to identify accounted for 10.5% of the total occurrence, followed by Odonata nymphs (5.3%), and miscellaneous items (5.3%).

Flathead Chub

The North American distribution of the flathead chub is restricted to the Great Plains, though it occurs as far north as the Mackenzie River Delta. Large turbid rivers, such as the Athabasca in the study area, are the preferred habitat of this species. Generally considered a forage fish, this species is held in low esteem by both commercial and sport fishermen.

Flathead chub were found throughout the study area (Figure 30) though young-of-the-year were absent from collections. A total of 58 individuals of this species was collected during these studies, 54 of which were successfully aged utilizing otoliths. Fork lengths ranged from 81 to 305 mm (Figure 26). Although the sample size is not large, certain trends are apparent. Little published information is available on the life history of this species in Canadian waters. Females appear to live longer and grow larger than males. In the Athabasca River, sexual maturity is attained at age 5 or 6 (Table 43). Growth of the Athabasca River population (Figure 31) seems to be faster than that reported for the flathead chub in the Mackenzie River (Hatfield et al., 1972; Stein et al., 1973). The latter, however, mention the possibility that errors in aging could have resulted from difficulties in reading crowded annuli on scales from older fish.

Based on the scattered data available, Scott and Crossman (1973) suggest that, in Canada, flathead chub spawn sometime during the summer months. No ripe individuals of this species were collected during the study although green females were present in the river as late as August 24 and a single mature female in post-spawning condition was collected on September 19. Fecundities were determined for 18 mature green females

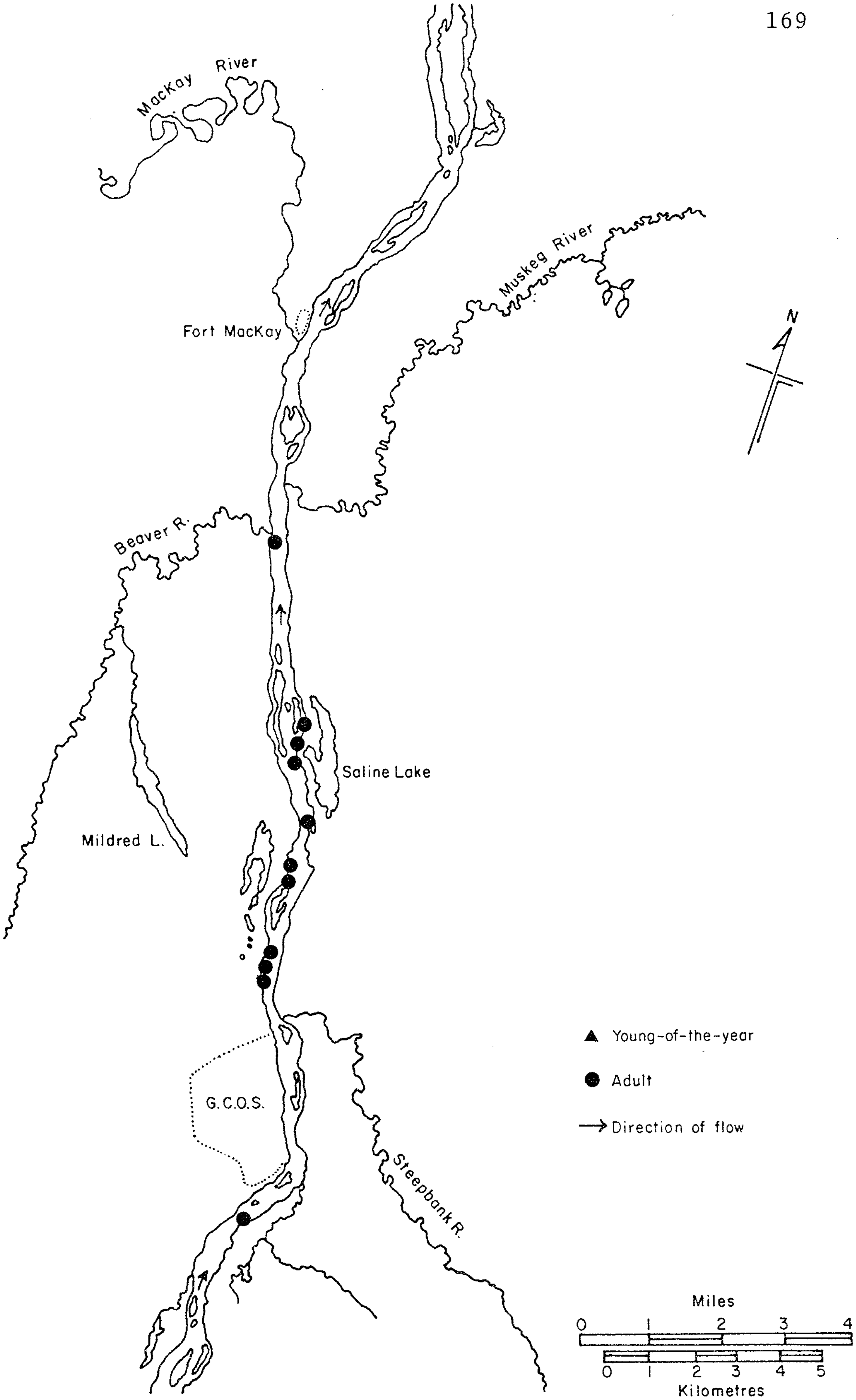

FIGURE 30. Sites at which flathead chub were captured within the study area, 1974 and 1975.

TABLE 43. Observed length-age relationships, age specific sex ratios and age at maturity for flathead chub collected in 1974 and 1975 from the Athabasca River. Sex ratios were based on fish for which sex was determinable. Fish were aged using otoliths.

Age	Fork Length (mm)			Males			Females			Unsexed	Total
	Mean	S.D.	Range	N	%	% Mature	N	%	% Mature		
0	-	-	-	0	-	-	0	-	-	0	0
1	-	-	-	0	-	-	0	-	-	0	0
2	94.3	10.00	81-113	1	100.0	0.0	0	-	-	15	16
3	110.4	9.02	102-125	1	33.3	0.0	2	66.7	0.0	2	5
4	139.5	32.19	104-189	5	62.5	0.0	3	37.5	0.0	0	8
5	229.5	6.36	225-234	0	-	-	2	100.0	100.0	0	2
6	245.0	20.50	206-262	1	16.7	100.0	5	83.3	100.0	0	6
7	273.1	9.14	262-288	0	-	-	7	100.0	100.0	0	7
8	276.3	14.53	260-299	0	-	-	7	100.0	100.0	0	7
9	-	-	-	0	-	-	0	-	-	0	0
10	298.3	5.77	295-305	0	-	-	3	100.0	100.0	0	3
TOTALS				8	21.6	12.5	29	78.4	82.8	17	54

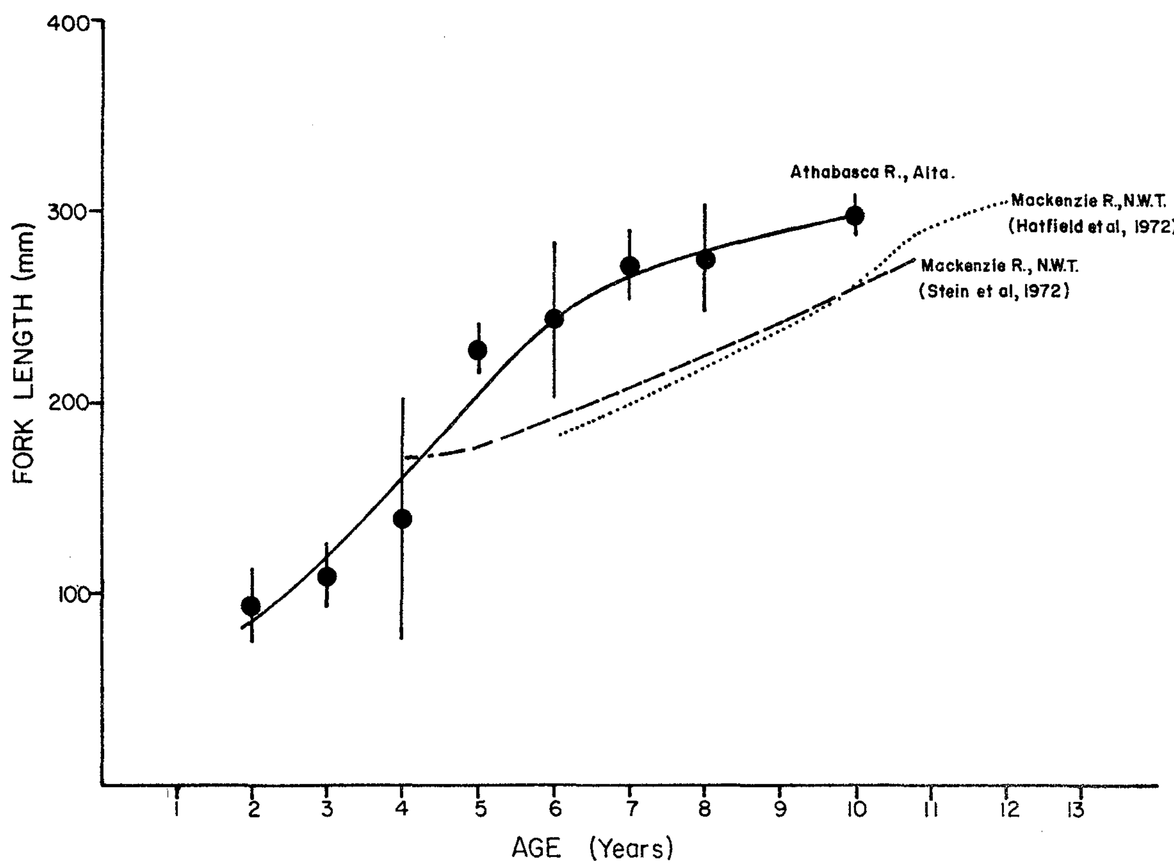

FIGURE 31. Comparison of growth rates of flathead chub collected during this study on the Athabasca River and at two locations on the Mackenzie River, Northwest Territories. The Athabasca River sample was aged from otoliths, the others from scales. Symbols for the Athabasca River samples are: closed circles, mean fork length; closed triangles, individual fish lengths; vertical lines, 95% confidence limits (calculated for age groups containing five or more fish).

(fork lengths 243-305 mm). Mean egg number was 10,884 (standard deviation ± 5,001) with a range of 2,899 to 20,037.

A small proportion (9.8%) of the 41 flathead chub stomachs examined was empty (Table 40). Over half (54.0%) of the occurrences of food items in the remaining 37 stomachs were too digested to be identified under field conditions. The remaining occurrences in order of dominance consisted of unidentified insect parts (18.9%), fish remains (8.1%), Trichoptera larvae (5.4%), Chironomidae larvae (5.4%), Coleoptera adults (5.4%), Ephemeroptera nymphs (2.7%), Odonata nymphs (2.7%), and vegetable material (2.7%).

Longnose Sucker

The longnose sucker is widely distributed in Canada, from New Brunswick and Quebec west to British Columbia and north to the Beaufort Sea. It prefers clear, cool water and inhabits both lakes and streams throughout most of Alberta. The flesh of the longnose sucker is edible (sold as "mullet"), however, at present, its main importance to man is as a forage fish for more desireable species.

All life history stages including young-of-the-year, juveniles (though scarce), and adults were captured in the study area (Figure 32).

During this study, 91 longnose suckers were captured, of which 80 were successfully aged using otoliths. Growth and

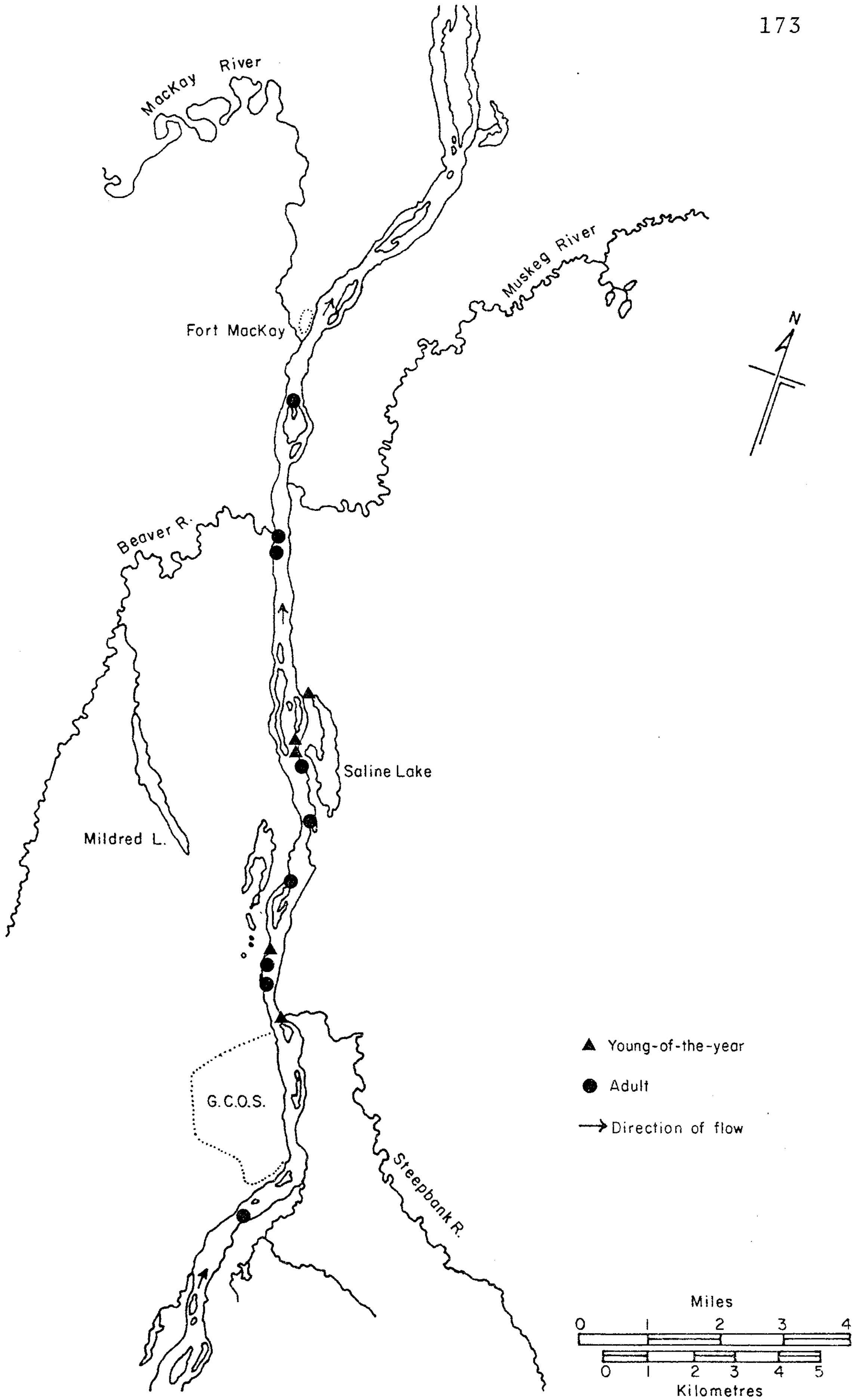

FIGURE 32. Sites at which longnose sucker were captured within the study area, 1974 and 1975.

maturity data are presented in Table 44. Fish aged 8-13 (300-500 mm fork length) were predominant in the catches (Table 44, Figure 26). Five, six, and seven year old fish appeared to be absent from the study area during the collection period. The youngest mature fish collected were 8 years of age and all were mature by age 11. Paetz and Nelson (1970) state that maturity is reached at about age 5 in Alberta. The growth rate of longnose suckers in the Athabasca River is similar to those described for this species elsewhere in Alberta and the Northwest Territories (Figure 33).

Longnose suckers spawn in the spring, from April to June in Alberta, shortly before white suckers (Paetz and Nelson, 1970). Green females and both green and ripe males were collected from May 13 to 16. Despite the more extensive netting carried out during the following sample period (May 27-June 2), only two mature individuals were collected, both of which were spawned-out. This, coupled with the large numbers of fry observed in shallow pools near the confluence of the Athabasca and Steepbank rivers and in the outlet stream from Saline Lake on June 24, suggests that in the study area, this species migrates up tributaries to spawn.

Fecundities, determined for 14 mature green females (fork lengths 381-488 mm), ranged from 20,267 to 62,000 with a mean of 34,597 (standard deviation $\pm$ 12,251).

In Figure 23, the seasonal abundance of longnose suckers at GN 2 shows a peak near the middle of May. Numbers then

TABLE 44. Observed length-age relationships, age specific sex ratios and age at maturity for longnose suckers collected in 1974 and 1975 from the Athabasca River. Sex ratios were based on fish for which sex was determinable. Fish were aged using otoliths.

	Fork length (mm)			Males			Females				
Age	Mean	S.D.	Range	N	%	% Mature	N	%	% Mature	Unsexed	Total
0	43.5	3.5	41-46	0	-	-	0	-	-	2	2
1	62.3	17.7	43-89	0	-	-	0	-	-	6	6
2	(91.0)	-	-	0	-	-	0	-	-	1	1
3	(143.0)	-	-	1	100.0	0.0	0	-	-	0	1
4	(202.0)	-	-	0	-	-	0	-	-	1	1
5	-	-	-	0	-	-	0	-	-	0	0
6	-	-	-	0	-	-	0	-	-	0	0
7	-	-	-	0	-	-	0	-	-	0	0
8	338.5	31.5	286-399	9	64.3	77.8	5	36.7	40.0	2	16
9	376.4	23.2	343-417	11	68.7	90.9	5	31.3	100.0	1	17
10	404.0	14.1	383-430	7	63.7	100.0	4	36.3	75.0	0	11
11	430.7	11.9	414-442	5	38.5	100.0	8	61.5	100.0	0	13
12	445.8	19.8	413-465	3	50.0	100.0	3	50.0	100.0	0	6
13	470.5	14.7	451-488	2	33.3	100.0	4	66.6	100.0	0	6
TOTALS				38	56.7	89.5	29	43.3	86.2	13	80

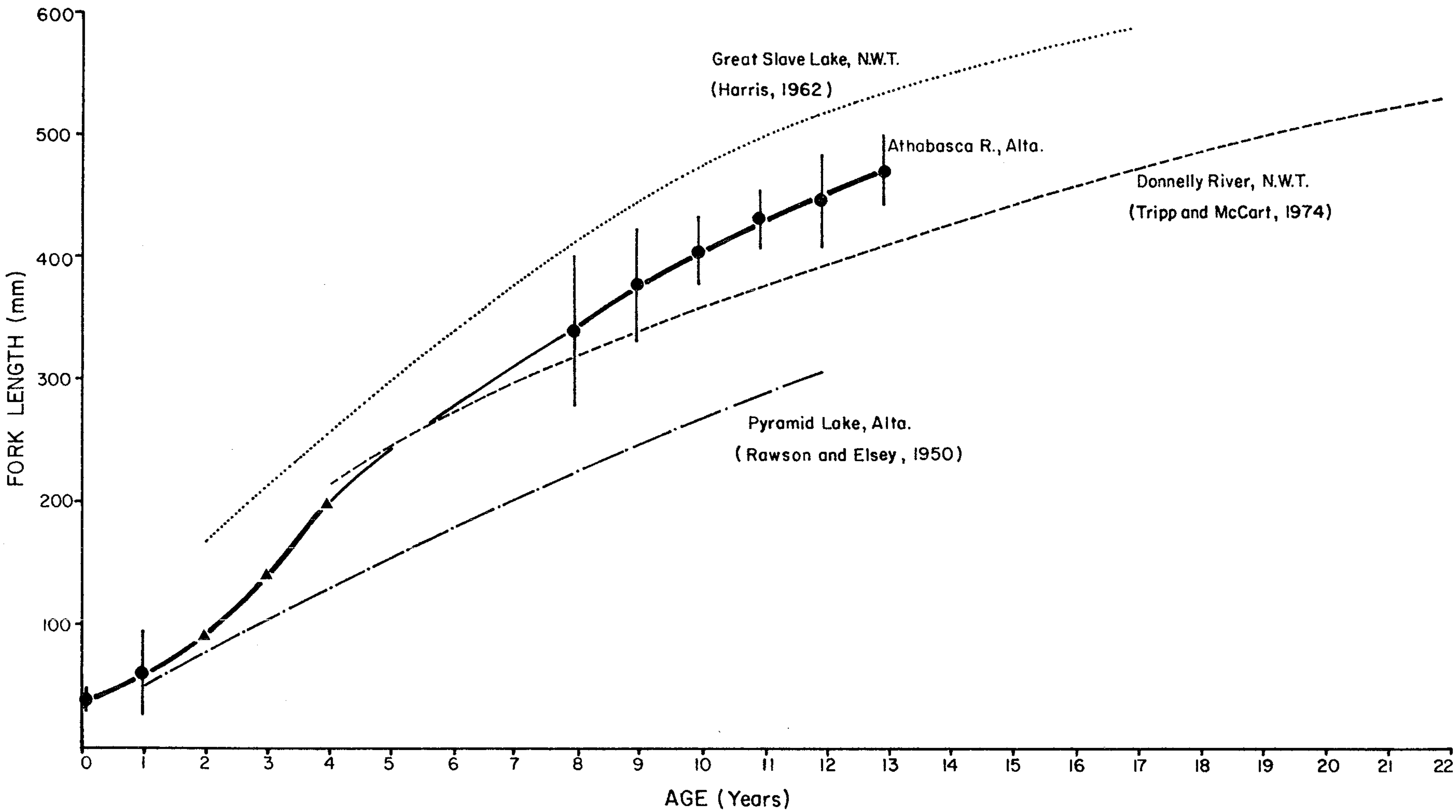

FIGURE 33. Comparison of growth rates of longnose suckers collected during this study on the Athabasca River, Alberta and at three other locations in Alberta and the Northwest Territories. The Athabasca River and Donnelly River samples were aged from otoliths, the others from scales. Symbols for the Athabasca River sample are: closed circles, mean fork length; closed triangles, individual fish lengths; vertical lines, 95% confidence limits (calculated for age groups containing five or more fish).

dropped rapidly, remaining relatively stable through the summer and rising again through the fall months. This pattern suggests the Athabasca River is primarily important as an overwintering area and that the fish are elsewhere, presumably in tributary streams, throughout most of the summer.

The stomachs of most longnose suckers were examined but the contents were found to be unidentifiable under field conditions.

Trout-Perch

The trout-perch, an important forage species, typically inhabits deep lakes and slow, sometimes turbid streams. It is widely distributed in lakes and streams in central and northern North America (Scott and Crossman, 1973).

The trout-perch is probably the single most abundant species in the study area (Table 36). Because of its small size, it was not taken in gillnet catches but juveniles and adults were taken in seine and electrofishing samples throughout the study area (Figure 34). Young-of-the-year, however, were only taken at one sampling site (EF 2) in July and August, 1975.

A total of 208 individuals of this species was collected during the studies, 121 of which were retained for detailed examination. The otoliths of 19 of these were found to be unreadable, therefore, the length-age relationships, sex

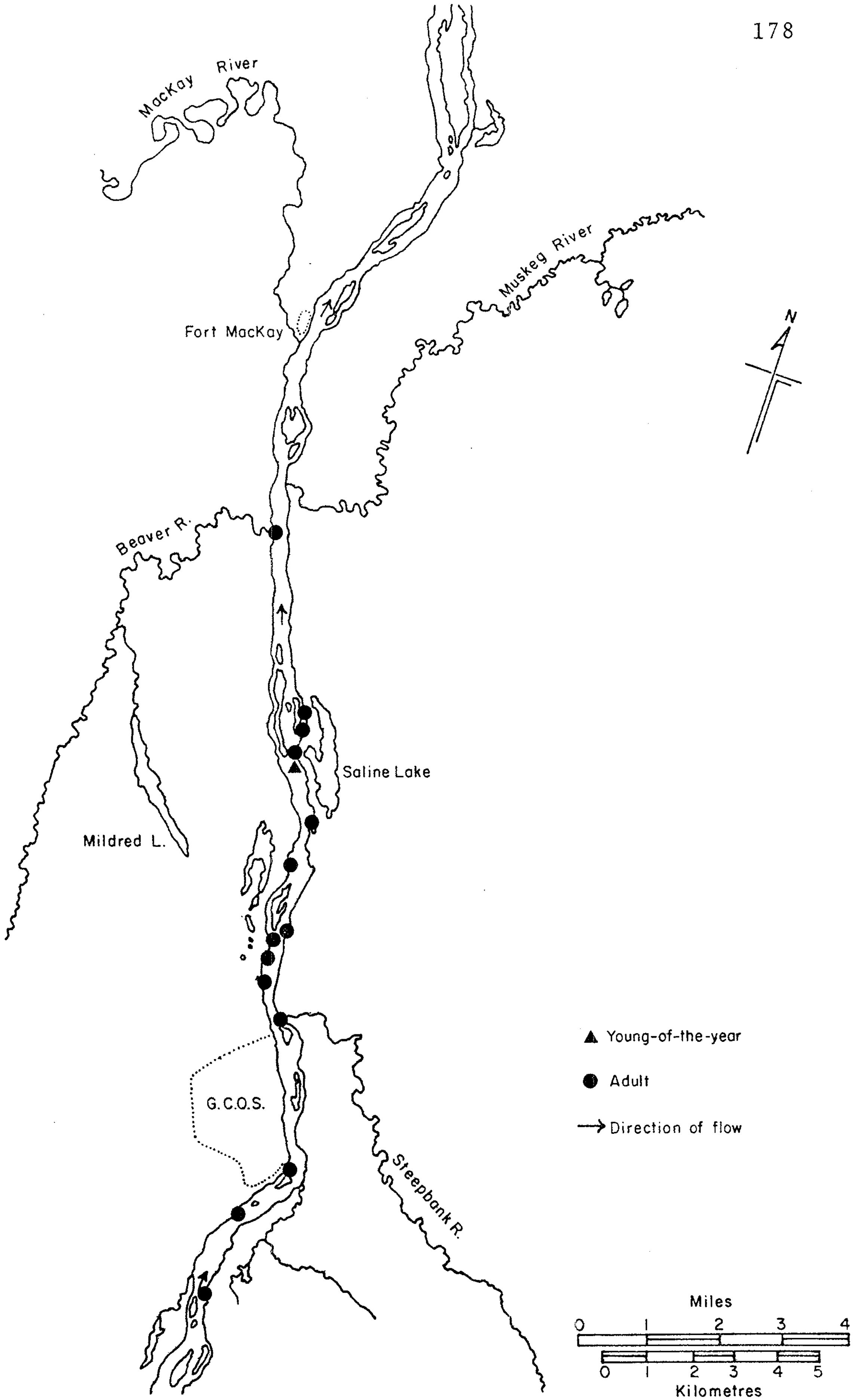

FIGURE 34. Sites at which trout-perch were captured within the study area, 1974 and 1975.

ratios, and ages of maturity of this species (Table 45) are based on 102 fish. Trout-perch from this population mature as early as age 2; by age 3, 50% of the males and 63.6% of the females had attained sexual maturity. No individuals older than age 3 appeared in our collections, therefore, maximum age and age at which all fish are mature are not known for this population. Over half (51.0%) of the sample was age 2 with a fork length range of 50-65 mm (Figure 26). The growth rate of this population is comparable to growth rates reported from the Mackenzie Delta and the Mackenzie River (Figure 35).

Trout-perch spawn in spring and summer in slow streams and in shallow water along lake beaches (McPhail and Lindsey, 1970). Although the trout-perch was the most abundant species collected, no ripe individuals were taken. However, three mature green females and a single spawned-out female were captured during collections made in July. These data indicate that spawning takes place in mid-summer.

At EF 2, trout-perch were generally abundant throughout the sampling season though there was a marked decline from a July peak to a late August low (Figure 36). This decline may have been due, in part, to heavy sampling for toxicity collections at this site and, in part, to a heavy post-spawning mortality which has been reported for other populations (Kinney, 1950; Priegel, 1962).

TABLE 45. Observed length-age relationships, age specific sex ratios and age at maturity for trout-perch collected in 1974 and 1975 from the Athabasca River. Sex ratios were based on fish for which sex was determinable. Fish were aged using otoliths.

	Fork Length (mm)			Males			Females				
Age	Mean	S.D.	Range	N	%	% Mature	N	%	% Mature	Unsexed	Total
0	31.1	3.63	26-38	0	-	-	0	-	-	7	7
1	45.1	4.43	35-52	6	46.2	0.0	7	53.8	0.0	13	26
2	56.8	3.84	50-65	29	55.8	13.8	23	44.2	4.3	0	52
3	68.8	4.13	64-77	6	35.3	50.0	11	64.7	63.6	0	17
TOTALS				41	50.0	14.6	41	50.0	17.1	20	102

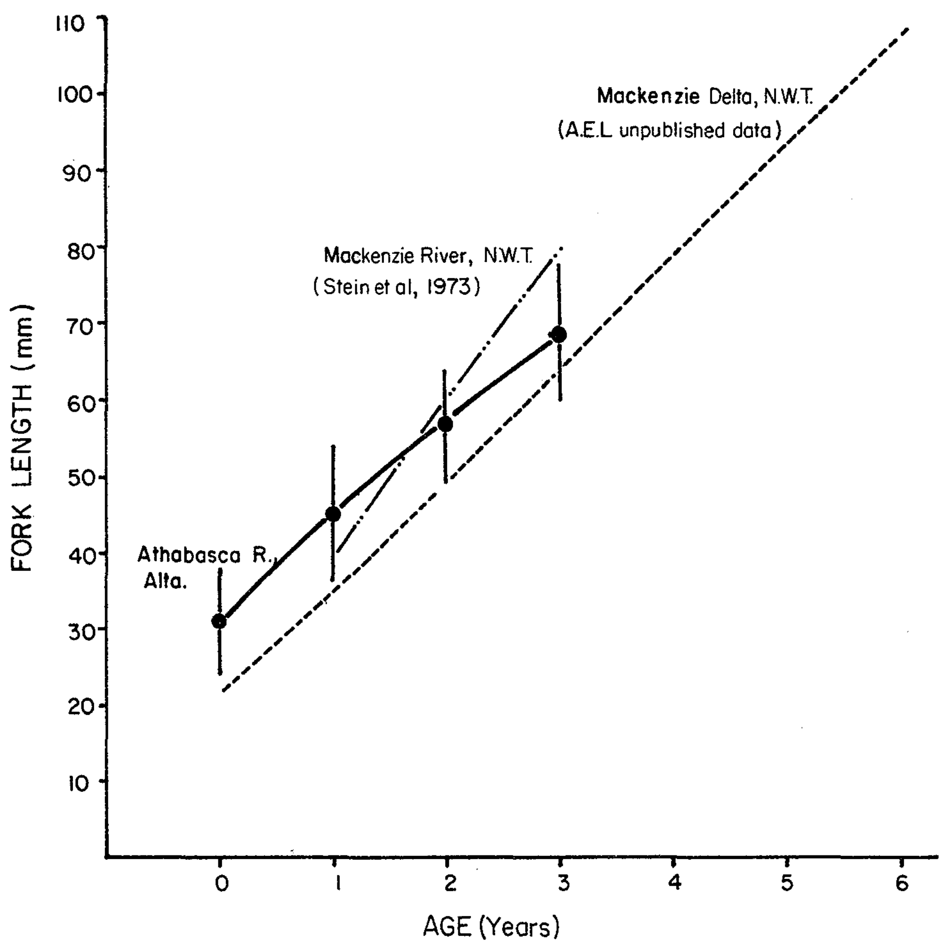

FIGURE 35. Comparison of growth rates of trout-perch collected during this study on the Athabasca River, Alberta and two other locations in the Northwest Territories. The Athabasca River and the Mackenzie Delta samples were aged from otoliths, the Mackenzie River sample from scales. Symbols for the Athabasca River sample are: closed circles, mean fork length; closed triangles, individual fish lengths; vertical lines, 95% confidence limits (calculated for age groups containing five or more fish).

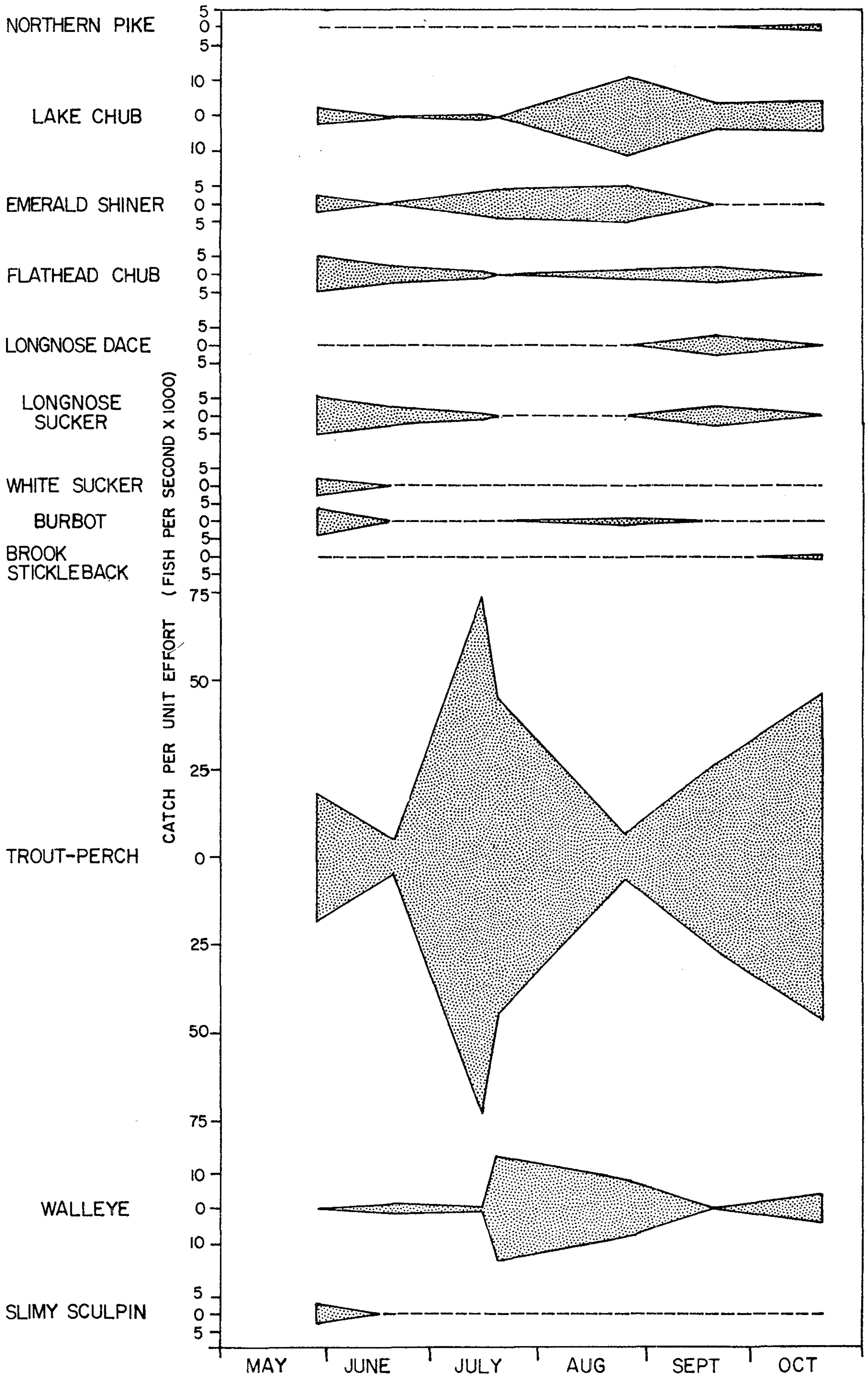

FIGURE 36. Seasonal abundance of 12 fish species at EF 2. Catch per unit effort is catch per second shocked x 1000.

No stomach analyses were performed on trout-perch.

Walleye

The walleye is widely distributed in eastern Canada and the prairies. In the Mackenzie River Drainage, its range extends as far north as the Beaufort Sea. This species is actively sought by both commercial and sport fishermen and, overall, is probably the most economically valuable freshwater fish in Canada (Scott and Crossman, 1973). Large turbid lakes and rivers are its preferred habitat.

Widely distributed throughout the study area (Figure 37), the walleye was the single most abundant species in gillnet catches (Table 35) and the second most abundant species in electrofishing catches (Table 36). Within this area, it is subject to angling pressure from Fort McMurray residents and a domestic fishery by residents of Fort McKay. A total of 225 walleye was collected during the study of which 215 were successfully aged from scales. Length, age, sex, and maturity data for these 215 individuals are presented in Table 46. Individuals of both sexes were maturing as early as age 4 and all were mature by ages 8 (males) or 10 (females). The growth of this population is similar to that described for other populations from Lac La Ronge, Saskatchewan, and Kehiwin Lake, Alberta. Growth is, however, somewhat slower than that reported for walleye from North Wabasca Lake, Alberta (Figure 38).

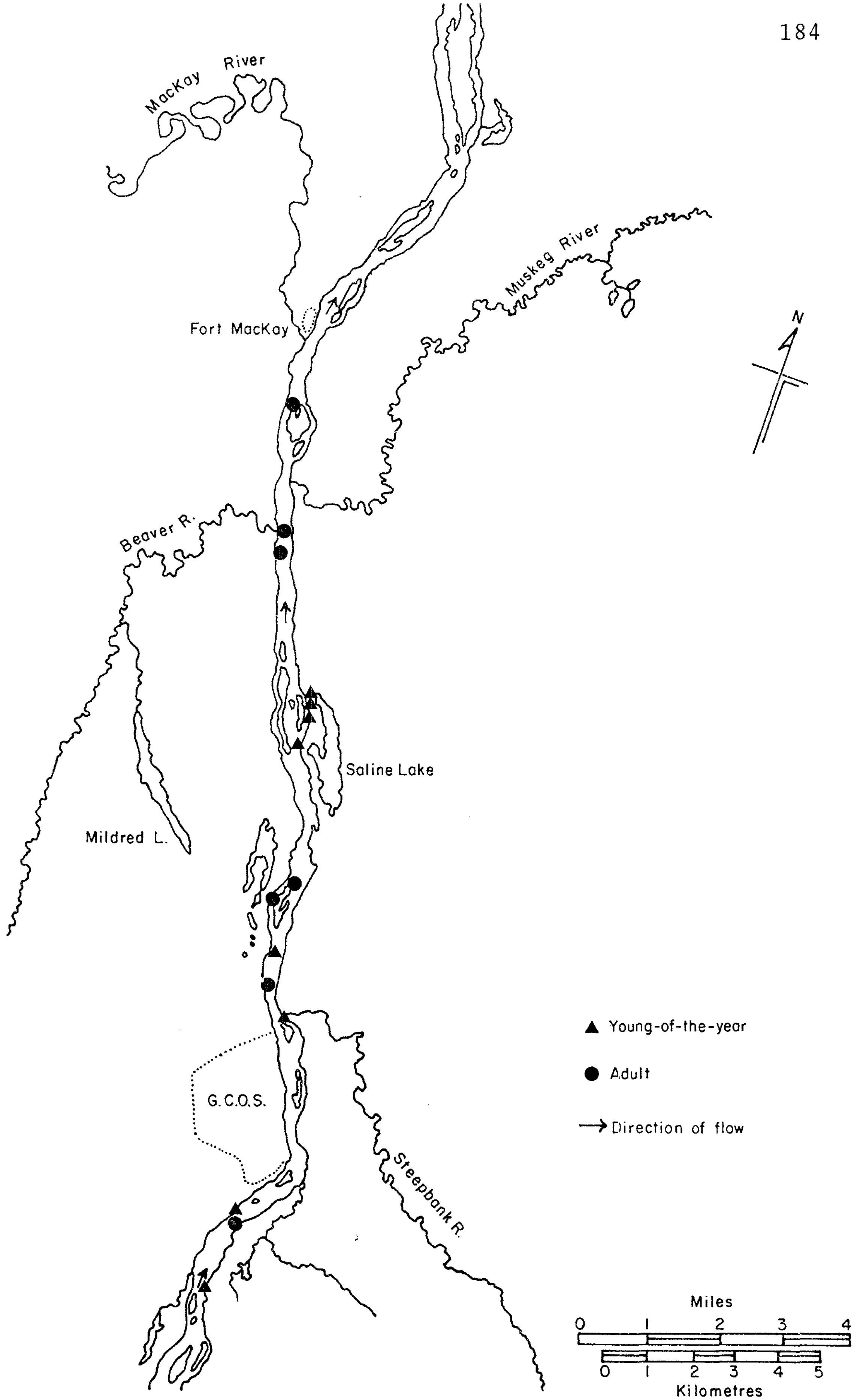

FIGURE 37. Sites at which walleye were captured within the study area, 1974 and 1975.

TABLE 46. Observed length-age relationships, age specific sex ratios and age at maturity for walleye collected in 1974 and 1975 from the Athabasca River. Sex ratios were based on fish for which sex was determinable. Fish were aged using scales.

Age	Fork Length (mm)			Males			Females			Unsexed	Total
	Mean	S.D.	Range	N	%	% Mature	N	%	% Mature		
0	61.4	15.89	43-89	0	-	-	0	-	-	55	55
1	-	-	-	0	-	-	0	-	-	0	0
2	254.0	21.29	214-270	6	100.0	0.0	0	-	-	0	6
3	308.9	19.93	287-343	12	75.0	0.0	4	25.0	0.0	0	16
4	334.7	20.18	294-375	23	82.1	26.1	5	17.9	20.0	0	28
5	372.1	14.47	343-398	21	72.4	71.4	8	27.6	12.5	0	29
6	398.8	15.26	362-425	20	80.0	75.0	5	20.0	40.0	0	25
7	423.1	13.87	393-449	22	88.0	90.9	3	12.0	33.3	0	25
8	454.8	17.47	420-481	16	80.0	100.0	4	20.0	75.0	0	20
9	474.6	21.85	457-520	7	100.0	100.0	0	-	-	0	7
10	522.0	15.56	511-533	1	50.0	100.0	1	50.0	100.0	0	2
11	587.0	7.07	582-592	0	-	-	2	100.0	100.0	0	2
TOTALS				128	80.0	62.5	32	20.0	34.4	55	215

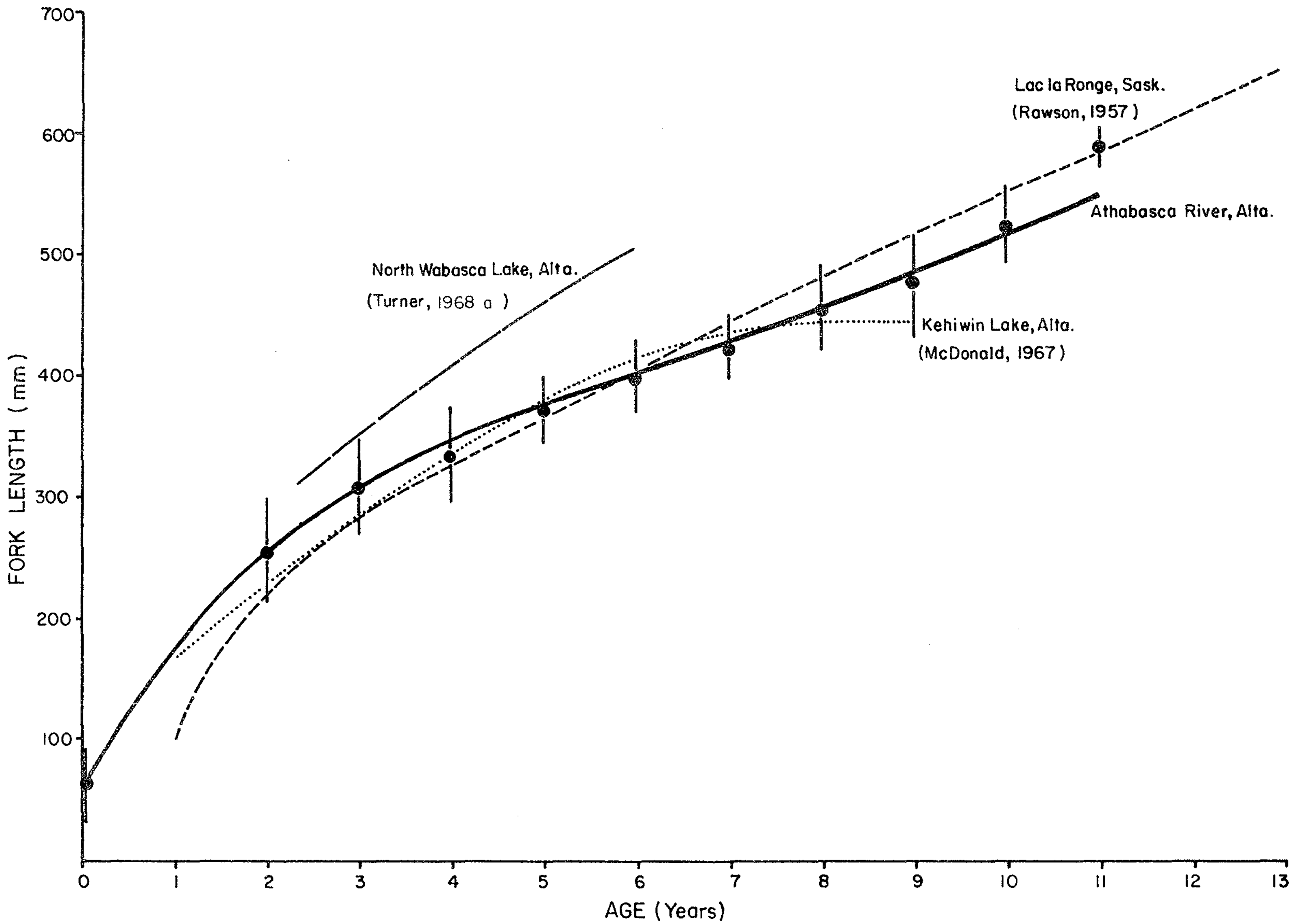

FIGURE 38. Comparison of growth rates of walleye collected during this study on the Athabasca River, Alberta and three other locations in Alberta and Saskatchewan. All samples were aged from scales. Symbols for the Athabasca River sample are: closed circles, mean fork length; closed triangles, individual fish lengths; vertical lines, 95% confidence limits (calculated for age groups containing five or more fish.

Walleye spawn in spring and early summer, commencing shortly after breakup. In rivers, spawning typically occurs over coarse gravel, rocks, or boulders in white water, generally below dams or impassable falls (Scott and Crossman, 1973). White water does not occur within the study area, however, ripe and spawned-out males (N=17) of this species were collected from May 16 to June 24 and spawned-out females (N=2) were captured on June 21. These collections, plus the numerous fry collected at EF 2 and in the side channel immediately downstream, indicate that some spawning of this species may take place in the study area, though exact locations are unknown. Alternatively, spawning may take place upstream of the study area (e.g., in the vicinity of Cascade Rapids or in the tributary streams) and spawned-out fish and young may move downstream into the study area.

Fecundities were determined for two mature green females with fork lengths of 533 mm and 592 mm. They were calculated to contain 76,806 and 94,633 eggs respectively.

Figure 23, showing seasonal abundance of this species in gillnet catches at GN 2, indicates a peak in the middle of May (possibly associated with a spawning migration) with moderate numbers of feeding fish present through the summer months, followed by a marked increase in the fall. The latter may be due to a migration from tributary streams to overwintering areas in the Athabasca River.

The majority (66.9%) of the 163 walleye stomachs examined were empty (Table 40). A large percentage (48.2%) of the occurrences consisted of material too digested to be identified under field conditions. Fish remains including brook stickleback, burbot, and walleye were the most common items (50.0%). Insect and small mammal remains and vegetable material appeared much less frequently.

Minor Species

Minor species are those of which less than 50 individuals were available for detailed examination. These include grayling, lake chub, emerald shiner, longnose dace, white sucker, burbot, brook stickleback, slimy sculpin, and yellow perch. Because of their limited numbers, no life history analyses have been prepared for these species. Length frequencies of the minor species are presented in Table 47, and their distributions and catches are indicated in Figures 39 through 43.

While all of these species may achieve some degree of importance as forage species, only one, the Arctic grayling, is at present of direct importance to man. Mature grayling were collected in late October, 1974 and March, 1975, and moderate numbers of mature fish were present in the confluences of tributary streams in October of 1975 (T. Jantzie, Renewable Resources Consulting Services, personal communication).

TABLE 47. Length frequencies of minor species collected from the Athabasca River during 1974 and 1975. Four letter codes for species are listed in Table .

Size Class (mm)	Total Number Caught						
	LKCB	EMSH	SPSH	LNDC	BRST	SLSC	YWPH
20-24			1				
25-29			1	2			
30-34				2			
35-39				1			2
40-44			1				5
45-49	5					1	9
50-54	6	1				1	1
55-59	8	2			1		
60-64	4	1					
65-69	9	1			1		
70-74	8	1					
75-79	4	1					
80-84	1	2					
TOTALS	45	9	3	5	2	2	17

	Total Number Caught		
	GRAY	BURB	WTSK
75-99		7	
100-124		9	1
125-149		1	
150-174		1	1
175-199			
200-224			
225-249		1	
250-274			
275-299	1		3
300-324	1		7
325-349	1		5
350-374		1	1
375-399			4
400-424			
425-449		1	
450-474			1
475-500			
500+		1	1
TOTALS	3	22	24

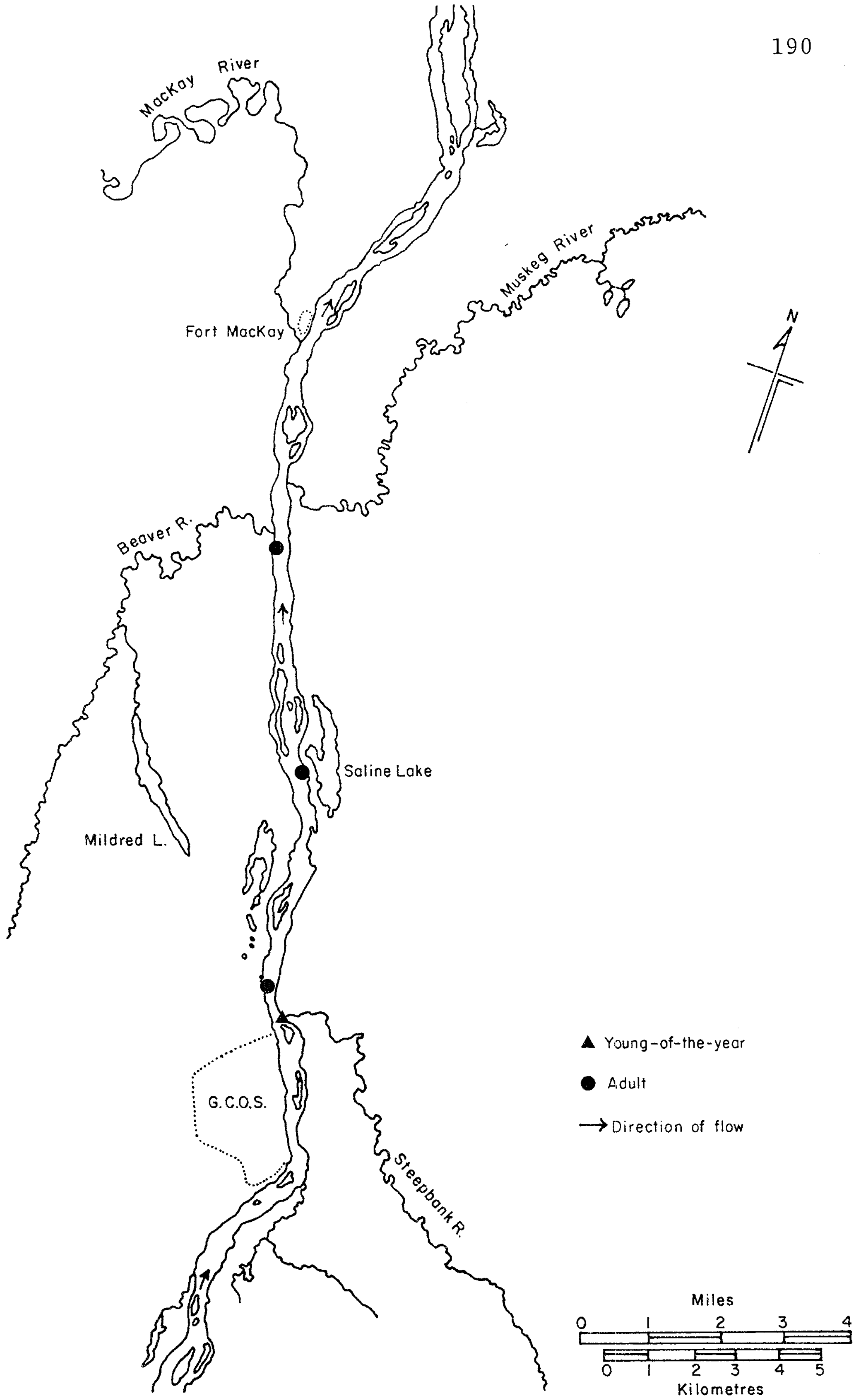

FIGURE 39. Sites at which Arctic grayling were captured within the study area, 1974 and 1975.

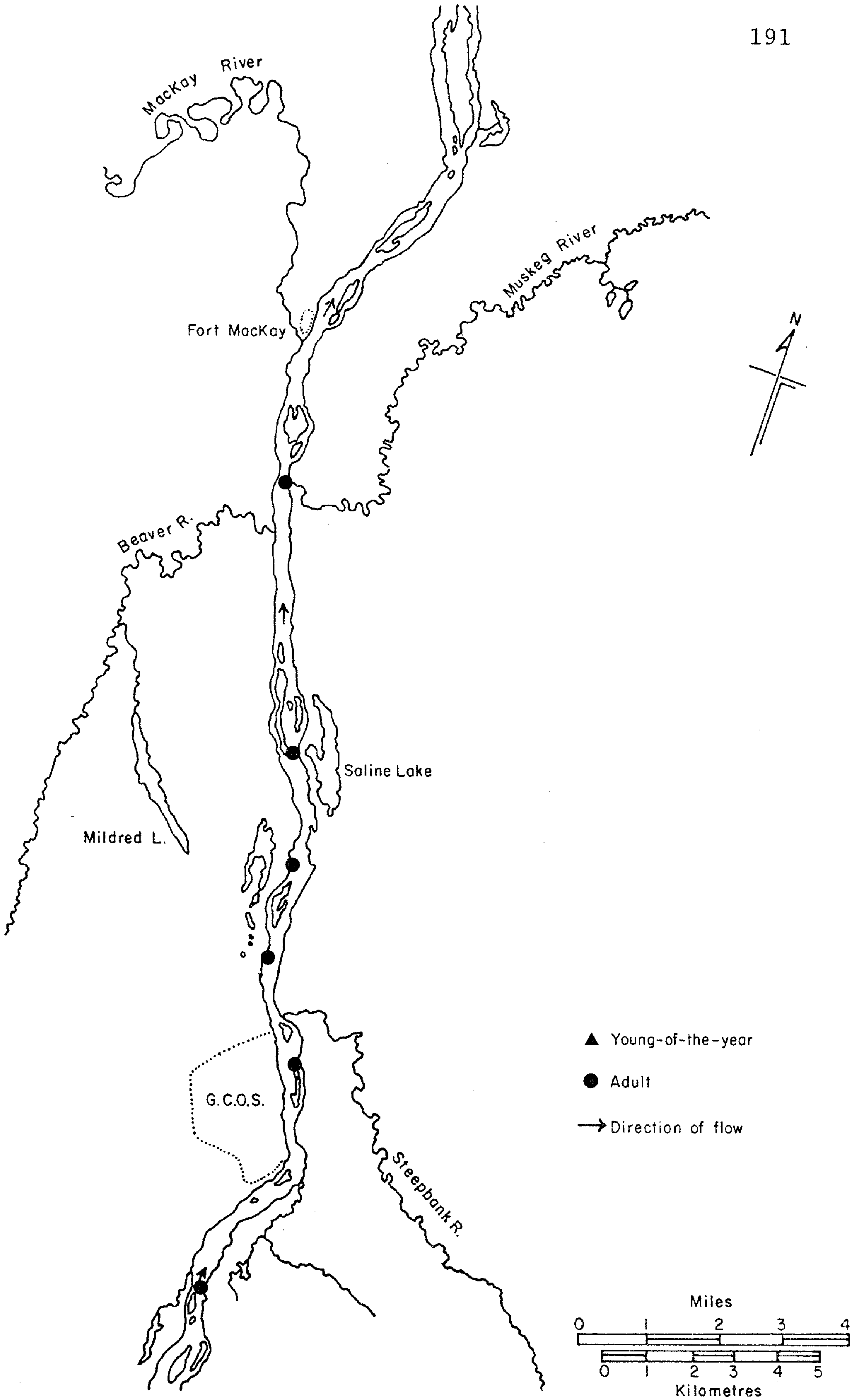

FIGURE 40. Sites at which lake chub were captured within the study area, 1974 and 1975.

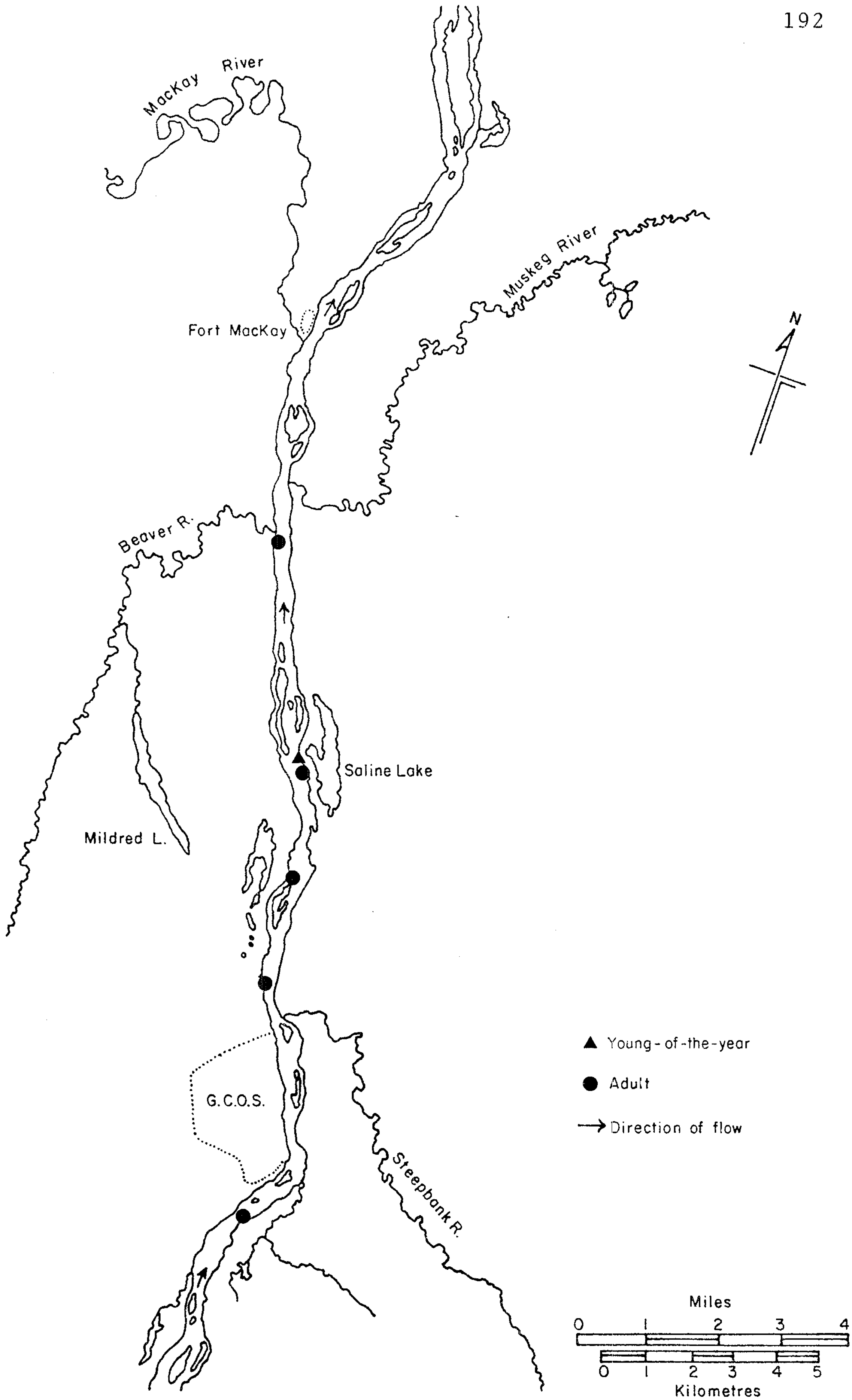

FIGURE 41. Sites at which white sucker were captured within the study area, 1974 and 1975.

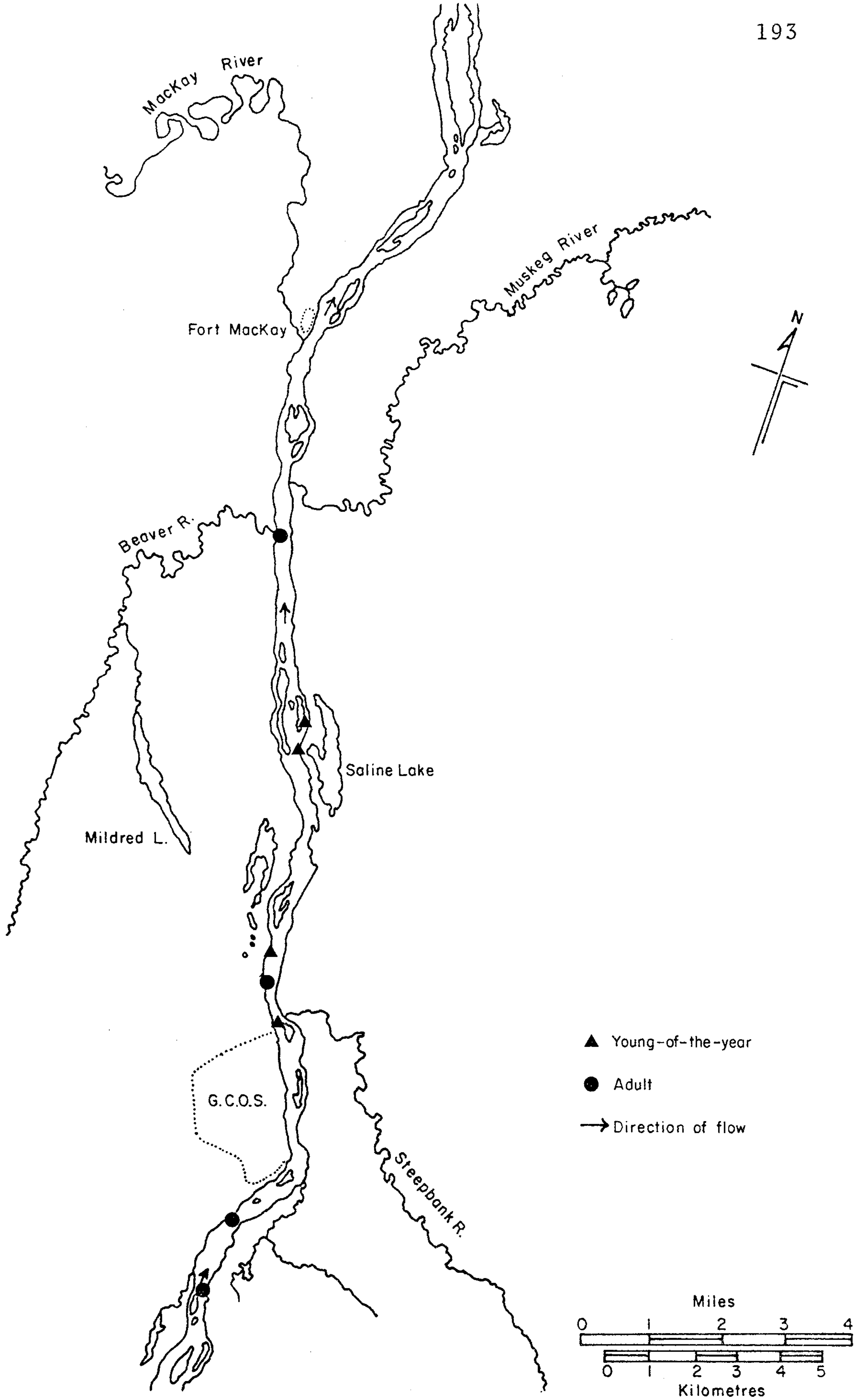

FIGURE 42. Sites at which burbot were captured within the study area, 1974 and 1975.

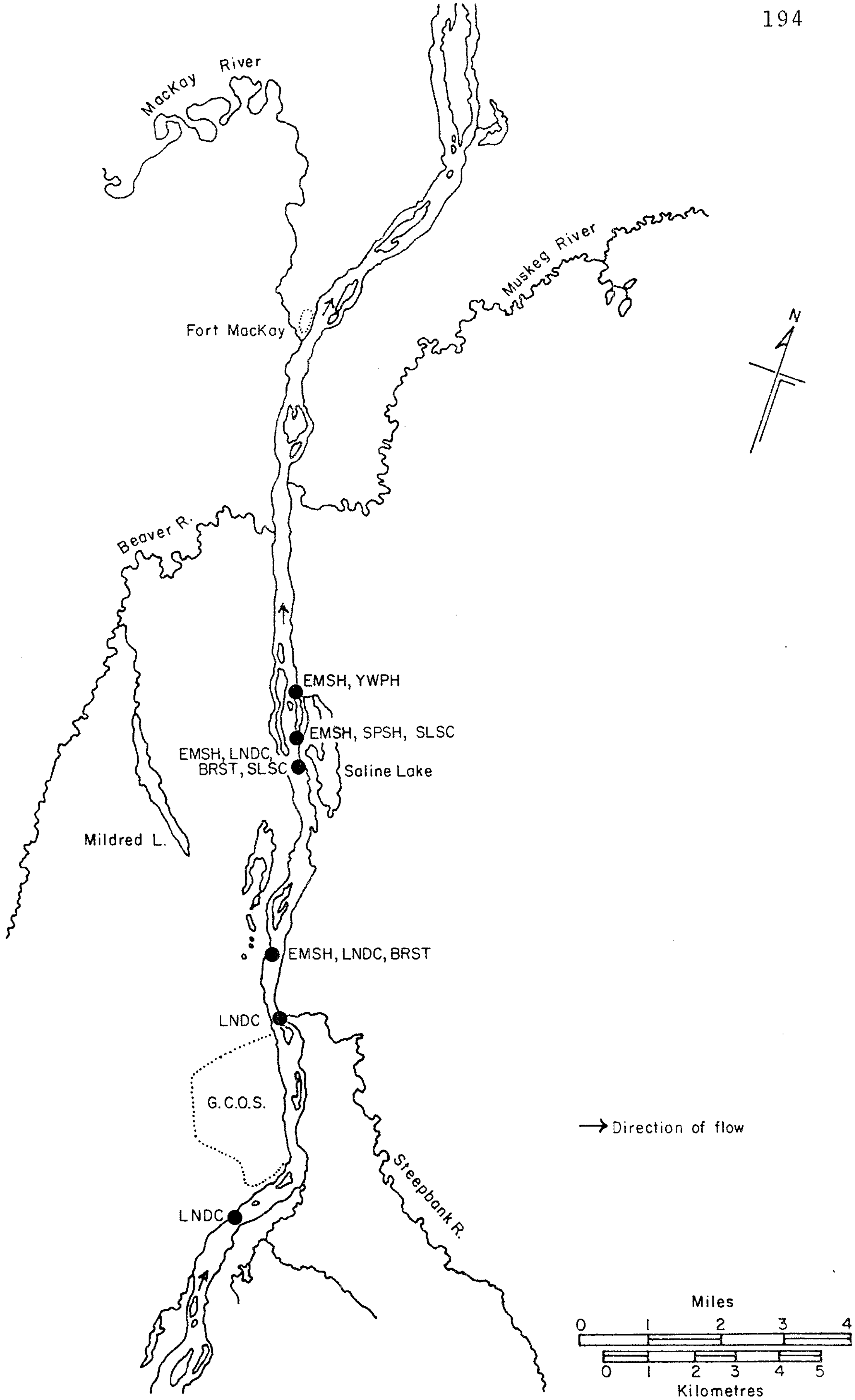

FIGURE 43. Sites at which emerald shiner, spottail shiner, longnose dace, brook stickleback, yellow perch, and slimy sculpin were captured within the study area, 1974 and 1975.

These appearances in the vicinity of major tributaries shortly before freeze-up suggest that grayling in the area are utilizing tributary streams as spawning and summer feeding areas, possibly descending into the Athabasca River to overwinter.

Of the minor species, the emerald shiner and spottail shiner do not appear to be common anywhere in the vicinity of the study area. However, species such as the grayling, lake chub, white sucker, burbot, and slimy sculpin are reported to be relatively common in tributary streams such as the Beaver River (Renewable Resources Consulting Services Ltd., 1971) and the Steepbank River (Griffiths, 1973). In addition, the former mentions the collection of white suckers and numerous lake chub and brook stickleback from Mildred Lake. Griffiths collected yellow perch in the vicinity of the mouths of the Muskeg and MacKay rivers, and longnose dace from the Dover and Steepbank rivers. The infrequent appearance in collections suggests that the Athabasca River is not extensively utilized for spawning or feeding purposes by any of the minor species during the open-water season.

CONCLUSIONS

Fish species often require access to specific habitat types during different stages in their life history. It is therefore not uncommon for a species to utilize different locations within a drainage for spawning, rearing (nursery), and overwintering purposes. Often, one or more of the required habitats is severely limited in extent and these habitats then become critical to the survival of the population. There is no evidence, however, to suggest that any part of the study area is of critical importance to local fish populations, i.e. there are no unique habitat types within the confines of the study area that are not widely distributed therein or that do not also occur elsewhere in the region.

With the probable exception of the trout-perch, there is no evidence of major spawning sites within the study area. Most species apparently spawn in tributaries to the Athabasca River (e.g. Arctic grayling, longnose and white suckers, lake chub, brook stickleback, northern pike etc.) or elsewhere in the river (e.g. lake whitefish, walleye, goldeye).

Many species do, however, make use of the study area as a rearing and summer feeding area. Young-of-the-year trout-perch and walleye are common. Juveniles and adults of several species feed in the area throughout the summer. Among these, the most abundant are juvenile goldeye which move into the area during the spring, presumably from overwintering areas further downstream, and remain through the summer.

Several species pass through the area during the course of migrations. These include goldeye passing to and from summer feeding and overwintering areas and lake whitefish presumably moving to spawning areas further upstream. It is also likely that many species which spawn in tributaries (e.g. grayling, suckers) pass through the area during spawning migrations.

Overwintering data are difficult to obtain in a river like the Athabasca but it is likely that, with the probable except of goldeye and lake whitefish which undertake exception migrations, most of the species which inhabit the study area or local tributaries during the summer, also overwinter in the area.

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SUMMARY

1. Athabasca River discharge peaked in late spring and early summer, and flow was lowest during winter.

2. During the winter, the ionic composition of the river water changed from a predominately sodium bicarbonate type to a sodium chloride type, apparently the result of a higher proportion of saline groundwater flow.

3. A comparison of the mean proportions of major ions in water samples taken along the east and west banks (in February) indicated a greater proportion of sodium and chloride ions in samples taken along the east bank.

4. Macronutrient concentrations in the river water, indicated as total dissolved nitrogen (TDN), total dissolved phosphorous (TDP), and reactive silica (SiO_2), were within the normal range for streams in Alberta.

5. The periphyton community of the Athabasca River did not appear to be unusual for large turbid rivers. There were definite seasonal patterns in species composition and standing crop which were apparently the result of large seasonal difference in river velocity and water level.

6. A total of 191 algal taxa were identified in the periphyton community which developed on artificial substrates. Of these, 117 were diatom species (Bacillariophycae). Because of their abundance, diatoms are potentially the most reliable and useful indicator group for biomonitoring water quality.

7. The benthic macroinvertebrate fauna of the study area had a species composition and standing crop that were typical of large rivers with a predominately mud substratum. The dominant groups were dipteran larvae and sludge worms.

8. There was no significant difference in the benthic animal community structure between stations with and without bituminous substrates. Stations with bituminous substrates usually had, however, a higher percent composition of midge larvae and sluge worms.

9. For biomonitoring purpose, the rock-filled basket artificial substrate sampler was found to be the most suitable device for collecting benthic invertebrates from the study area.

10. There was no evidence to suggest that any part of the study area was of critical importance to local fish populations.

11. With the probable exception of the trout-perch, there was no evidence of major spawning sites within the study area. However, many fish utilized the study area as a rearing and summer feeding ground.

12. Several fish species passed through the area during the course of migrations to and from their feeding, overwintering, and spawning grounds.

13. It was likely that most of the fish species which inhabited the study area or local tributaries during the summer, also overwintered there.

Conditions of Use

McCart, P., P. Tsui, W. Grant and R. Green, 1977. Baseline studies of aquatic environments in the Athabasca River near Lease 17. Syncrude Canada Ltd., Edmonton, Alberta. Environmental Research Monograph 1977-2. 205 pp.