ENVIRONMENTAL RESEARCH MONOGRAPH 1978-4
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# BASELINE STUDY OF THE WATER QUALITY AND AQUATIC RESOURCES OF THE MACKAY RIVER, ALBERTA

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Aquatic Environments Ltd.

## FOREWORD

Syncrude Canada Ltd. is producing synthetic crude oil from a surface mine on the eastern portion of Crown Lease 17, Alberta. Aquatic Environments Limited was commissioned to survey the MacKay River which crosses Leases 17 and 22, also held by Syncrude. The survey is intended to provide a baseline, as Syncrude's present operations do not affect the MacKay watershed.

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Syncrude Canada Ltd. continues to publish scientific reports in its Environmental Reseach Monograph series. With the publication of the three reports described below, twenty-eight monographs have been distributed since 1973.

Monograph 1978-4: "Baseline Study of the Water Quality and Aquatic Resources of the MacKay River, Alberta" describes the water quality, fisheries, periphyton and macroinvertebrates of the Mackay River at three locations: where the river enters Lease 17; after it leaves Lease 17 and where it enters the Athabasca River. The MacKay River has not been affected by the Syncrude operation at Mildred Lake.

Monograph 1978-5: "Revegetation and Management of Tailings Sand Slopes: 1977 Results" reports on the third consecutive year of revegetation research carried out by Syncrude on the Great Canadian Oil Sands Ltd. tailings pond dyke. As in previous years, the field research was supplemented by laboratory studies. Syncrude's full-scale revegetation activities began in 1976 and will increase substantially during the 1980's.

Monograph 1978-6: "A Study of Biological Colonization of the West Interceptor Ditch and Lower Beaver Creek" describes how natural colonization has proceeded in a new stream habitat created by Syncrude. The new stream, called the West Interceptor Ditch, was created as part of a program to keep plant process waters (which are stored on the lease) out of natural surface drainage systems.

At Syncrude we welcome your interest in our environmental activities. Please address your questions or comments to:

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# SUMMARY


## Water Quality

1. The pattern of discharge in the MacKay River in 1977 was characterized by three peaks, two major (April 19 and July 8) and one minor (October 16). Peak discharge for the year was 22.5 $m^3$/sec and the low 0.2 $m^3$/sec. Mean discharge was 4.2 $m^3$/sec per day and total discharge was $176.6 \times 10^6$ $m^3$.

2. Water temperature was 0 C throughout the winter rising to a recorded high of 19 C in July, 1977.

3. The concentration of dissolved substances was greatest in winter and lowest in summer, presumably due to a greater contribution of groundwater during winter. There was a longitudinal cline in concentrations of dissolved substances with water at the Upper Station consistently more dilute than that at the Lower Station.

4. pH was neutral to slightly alkaline ranging from 7.0 to 7.7.

5. Suspended sediment loads were highest in June and lowest in late summer and fall, but increased again in winter. The pattern was similar, though more exaggerated, for turbidity.

6. Dissolved oxygen concentrations ranged from a low of 7.9 ppm in March, 1977, to 11.3 ppm in September, 1977.

7. The water was basically of the calcium bicarbonate type but salinity increased during the winter.

8. Macronutrient levels were generally high, TDN concentrations were greatest in winter, and TDP concentrations were highest in winter and again in June and July. $SiO_2$ concentrations were low during the ice-free season but very high during the winter.

9. TOC values were very high, especially in mid-winter, probably reflecting the presence of exposed oil sands substrates.

10. Values for oil and grease, phenols, boron, iron, lead, mercury, total organic carbon, nitrogen, and cadmium all exceed the values recommended by the Alberta Department of Health during at least part of the year.

## Periphyton

1. The densities of periphyton were highest on natural substrates than on either artificial substrate. In general, the densities were low throughout the summer but increased in September. At some locations, however, densities on glass substrates were highest in July.

2. Biomass:
   a) tended to be highest in September,
   b) was generally greatest at the Upper Station and lowest at the Lower Station,

c) was greater on natural than on artificial substrates,

d) was greater on plexiglass than on glass.

3. A total of 142 algal species was recorded: 56.3% were Bacillariophyceae, 17.6% were Chlorophyta, 16.9% were Cyanophyta, 5.6% were Chrysophyceae, 2.1% were Euglenophyta, and 1.4% were Cryptophyta.

4. Bacillariophyceae (diatoms) and Cyanophyta (blue-green algae) generally dominated the periphyton though Chlorophyta (green algae) dominated a few samples.

5. All sites and substrate types have similar seasonal variations in the species diversity and taxonomic diversity with peak values generally occurring in September, coinciding with peak standing crops. Lowest diversity values commonly occurred in July and August.

6. Overall, natural substrates supported larger (in terms of both density and biomass) and more diverse periphyton communities than did either artificial substrate. The thirty day exposure period for the latter may be too short for northern streams.

Benthic Macroinvertebrates

1. A total of 80 benthic macroinvertebrate taxa was collected, with 59 taxa found at the Upper Station, 56 at the Middle Station, and 49 at the Lower Station.

2. Upper Station supported a comparatively diverse fauna of Chironomidae, Trichoptera, and Plecoptera. Middle Station had a more diverse Ephemeroptera and Chironomidae fauna. Except for Ephemeroptera, other major benthic taxa were not well represented at the Lower Station.

3. The dominant benthos at the MacKay River are the oligochaete worms; the mayflies *Baetis* spp. and *Heptagenia* sp.; the dragonfly *Ophiogomphus* sp.; the caddisflies *Arctopsyche* sp. and *Hydropsyche* spp.; the blackfly *Simulium* spp.; and the orthocladiinid midges *Cricotopus* spp. and *Orthocladius* spp.

4. Benthic diversity (both species and taxonomic) was greatest at the Upper Station, lowest at the Lower Station, and intermediate at the Middle Station.

5. Seasonally, standing crop of benthos increased from May to September. Spatially, the mean standing crop declined from the Upper to the Lower Station.

6. A comparison of the benthic samples collected by the rock-basket sampler and the Surber sampler indicated that 32-35% of the taxa were collected by both techniques; 29-43% of the taxa were only collected by the basket sampler; and 23-38% of the taxa were only found in Surber samples.

7. In most instances, the basket sampler collected more benthic

taxa and individuals than the Surber.

8. Benthic communities developed on artificial substrates tended to be less diverse and equitable than those on natural substrates.

9. Drift fauna in July was dominated by trichopterans (mainly *Mayatrichia* sp.), mayflies (*Baetis* spp. and *Heptagenia* sp.), blackflies (*Simulium* spp.), and chironomids. In August, the drift was mainly composed of mayflies, simulids, and chironomids.

10. Drift rates ranged from 2,520 to 66,787 organisms/hour; drift densities ranged from 2.06 to 80.37 organisms/$m^3$. Both drift rate and density were higher at night.

## Fish

1. In total, 19 fish species were collected from the MacKay River. The common or abundant species are: goldeye, northern pike, lake chub, longnose dace, longnose sucker, white sucker, trout-perch, walleye, and slimy sculpin.

2. Walleye was the most abundant of the larger fish species captured in the study area while lake chub was the most abundant small species.

3. The MacKay River is a major spawning, rearing, and summer feeding area for lake chub, longnose dace, longnose sucker, white sucker, and

trout-perch. The true extent of walleye spawning in the MacKay was not determined. In view of the large population of walleye in the MacKay River, further study on spawning and early movements is warranted.

4. No spawning or rearing areas were identified for either goldeye or northern pike. However, the MacKay River is an important summer feeding area for these species.

5. At least five species including Arctic grayling, northern pike, longnose sucker, white sucker, and slimy sculpin overwinter in the MacKay River at the Middle and Lower Stations.

6. The MacKay River supports an important walleye and northern pike sport fishery during spring migration. Recreational demands can be expected to increase as development of the Athabasca Oil Sands area proceeds.

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# INTRODUCTION

Aquatic Environments Limited was contracted by Syncrude Canada Ltd. to conduct baseline studies on the MacKay River. These studies were designed to provide an adequate basis against which future changes in the aquatic environment of the MacKay River could be compared. Four objectives of the study were:

1) to describe the seasonal variation of various physical and chemical characteristics of the MacKay River as it flows into Syncrude's Lease 17 and then into the Athabasca River;

2) to describe the seasonal variation in species composition and standing crop (density and biomass) of the periphyton community during the open water season;

3) to describe the seasonal variation in species composition and standing crop (density) of macroinvertebrate communities in the MacKay River;

4) to describe the fisheries of the MacKay River with regard to species composition, seasonal abundance, life histories, and spawning and overwintering areas.

Table 1 summarizes the parameters sampled at approximately monthly intervals from March, 1977, to January, 1978. At three permanent stations designated as Upper, Middle, and Lower (Figure 1), water quality and fish

TABLE 1. Summary of the sampling effort on the MacKay River. March, 1977, to January, 1978.

| Sampling Period | March 22-26 | May 13-16 | June 13-17 | July 11-15 | Aug 15-22 | Sept 25-29 | Dec 6-12 | Jan 16-20 |
|---|---|---|---|---|---|---|---|---|
| Water quality | + | + | + | + | + | + | + | + |
| Periphyton | | | | | | | | |
| Natural Substrates | | + | + | + | + | + | | |
| Artificial Substrates | | | + | + | + | + | | |
| Benthos | | | | | | | | |
| Natural Substrates | | + | + | + | + | + | | |
| Artificial Substrates | | | + | + | + | + | | |
| Benthic Drift | | | | + | + | | | |
| Fish | | | | | | | | |
| Regular Sampling | | + | + | + | + | + | + | + |
| General Distribution | | | | | + | | | |
| Stream Habitats | | | | | | | | |
| Description | | | | | + | | | |
| Sediments | | | | | + | + | | |

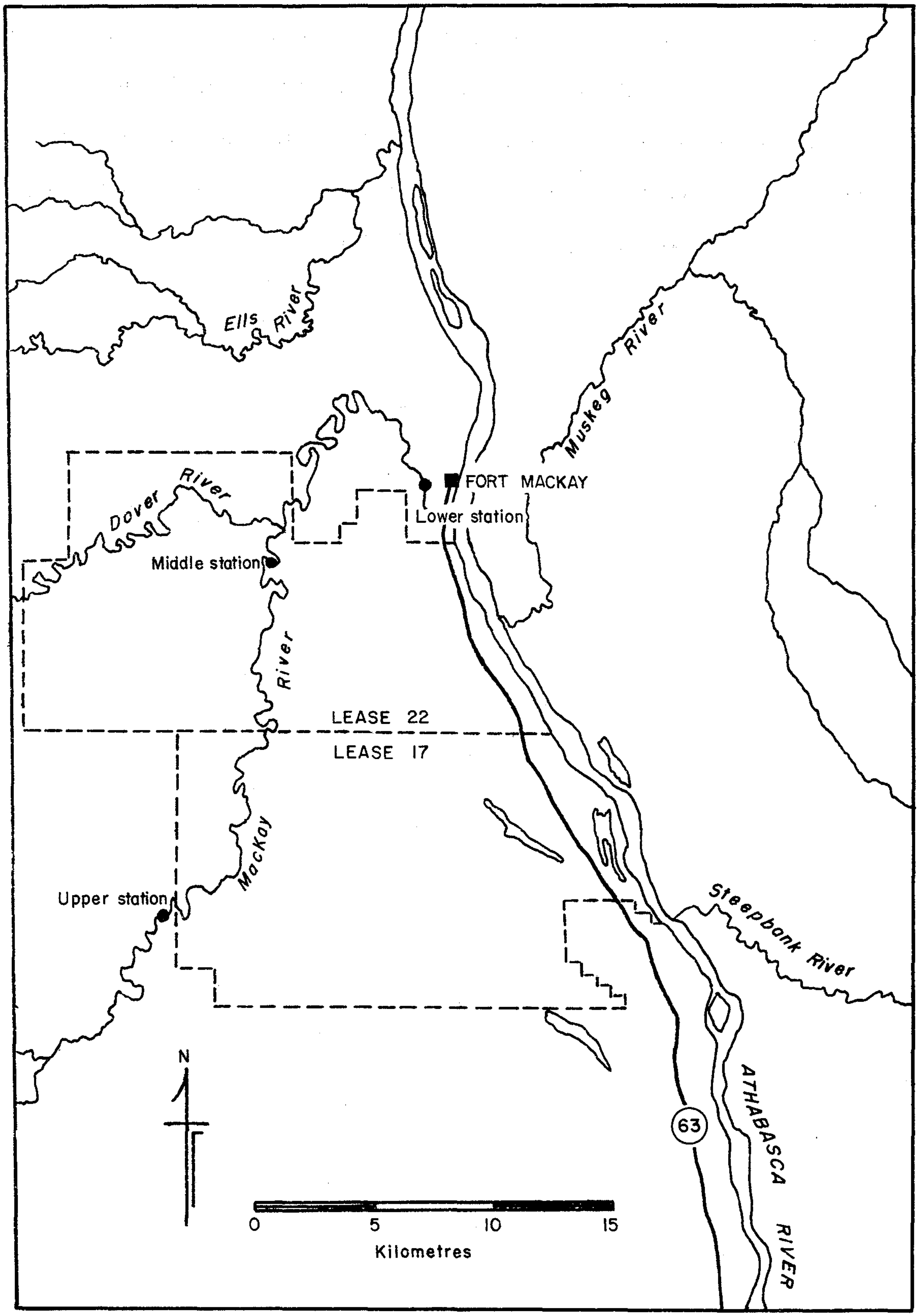


FIGURE 1. Map of the study area showing location of permanent water quality, periphyton, benthic macroinvertebrate, and fish sampling stations.

were sampled throughout the study while periphyton and benthic macroinvertebrates were sampled May to September, 1977. Additional information on stream habitats, fish distribution, and aquatic macrophytes was collected at 13 stations (Figure 2) on a float trip (August 17-19, 1977) from the Upper to Lower Station.

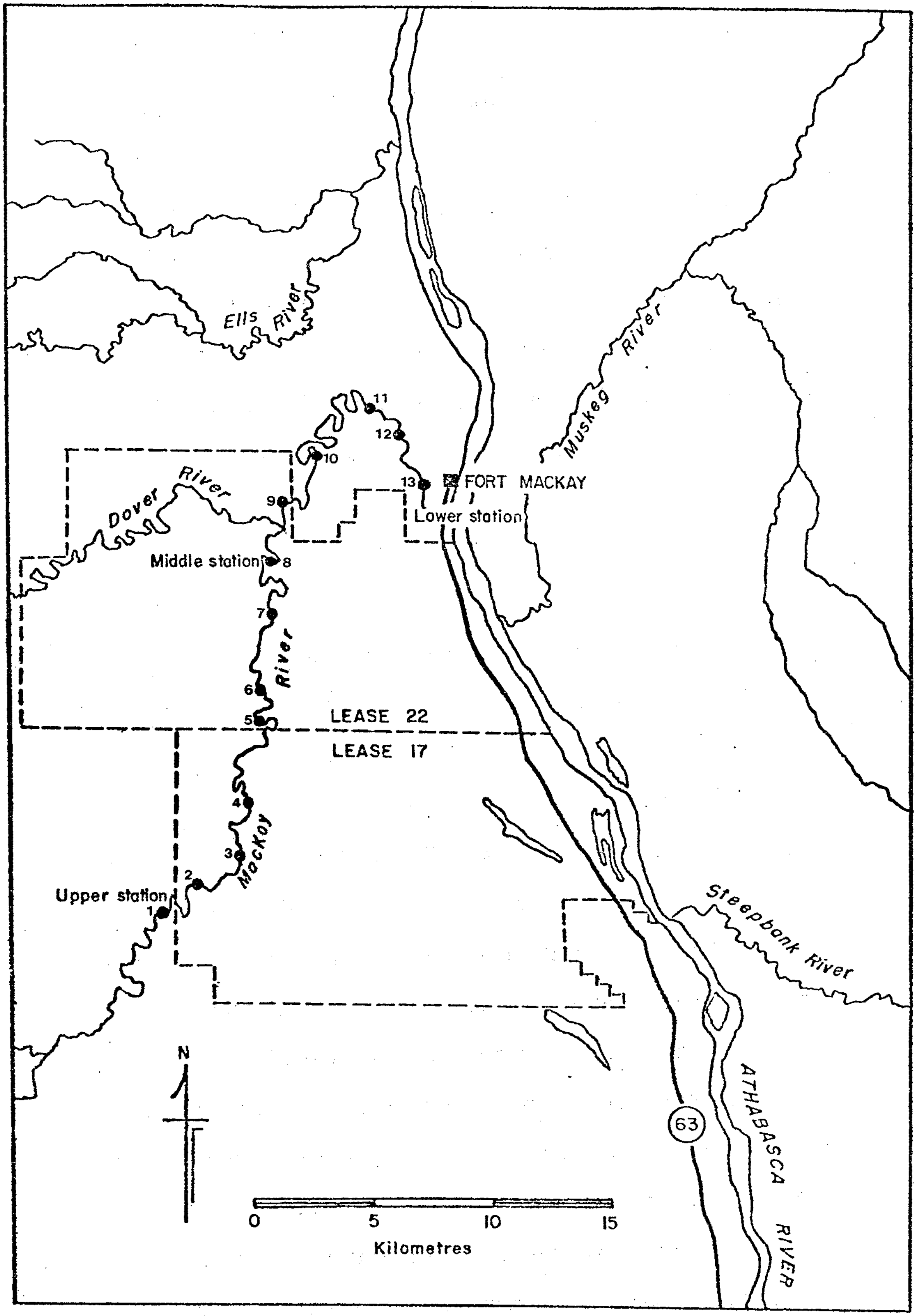


FIGURE 2 . Map of the study area showing location of stations sampled August 17-19, 1977.

# THE STUDY AREA

The MacKay River originates in a large muskeg area 80 km west of Fort McMurray, Alberta, and flows in a northeasterly direction for 215 km before joining the Athabasca River near Fort McMurray. The river drains an area of approximately 3500 $km^2$ and is one of the largest watersheds in the Athabasca Oil Sands area north of Fort McMurray. The Dunkirk and Dover rivers are major tributaries. Like most streams in this area, the MacKay River is a brown water stream due to the presence of humic and fulvic acids.

The study area on the MacKay River extends from the southern boundary of Syncrude Canada's Lease 17 to the Athabasca River, a straightline distance of 32 km. The actual length of the river is, however, much farther (64 km) because of extensive meandering, particularly in the lower section. The MacKay is a slow-moving stream dropping an average of 1.5 m per km from 328 m elevation at the Upper Station to 225 m at the mouth (Figure 3). Pool:riffle ratios were 6.4:1 at the Middle Station, 7.4:1 at the Upper Station, and 45.5:1 at the Lower Station. Average width and depth are 20 and 0.7 m, respectively. Banks are generally low, stable, and well vegetated in the upper reaches but become progressively steeper downstream as the river cuts through tarsand and limestone formations (Stations 4, 7, 8, 10, 12; Table 2). The substrate is predominantly rubble upstream with more gravel, sand, and mud-silt downstream. The texture (per cent sand, clay, and silt) and per cent organic composition of substrate samples collected at permanent sampling stations in August and September are presented in

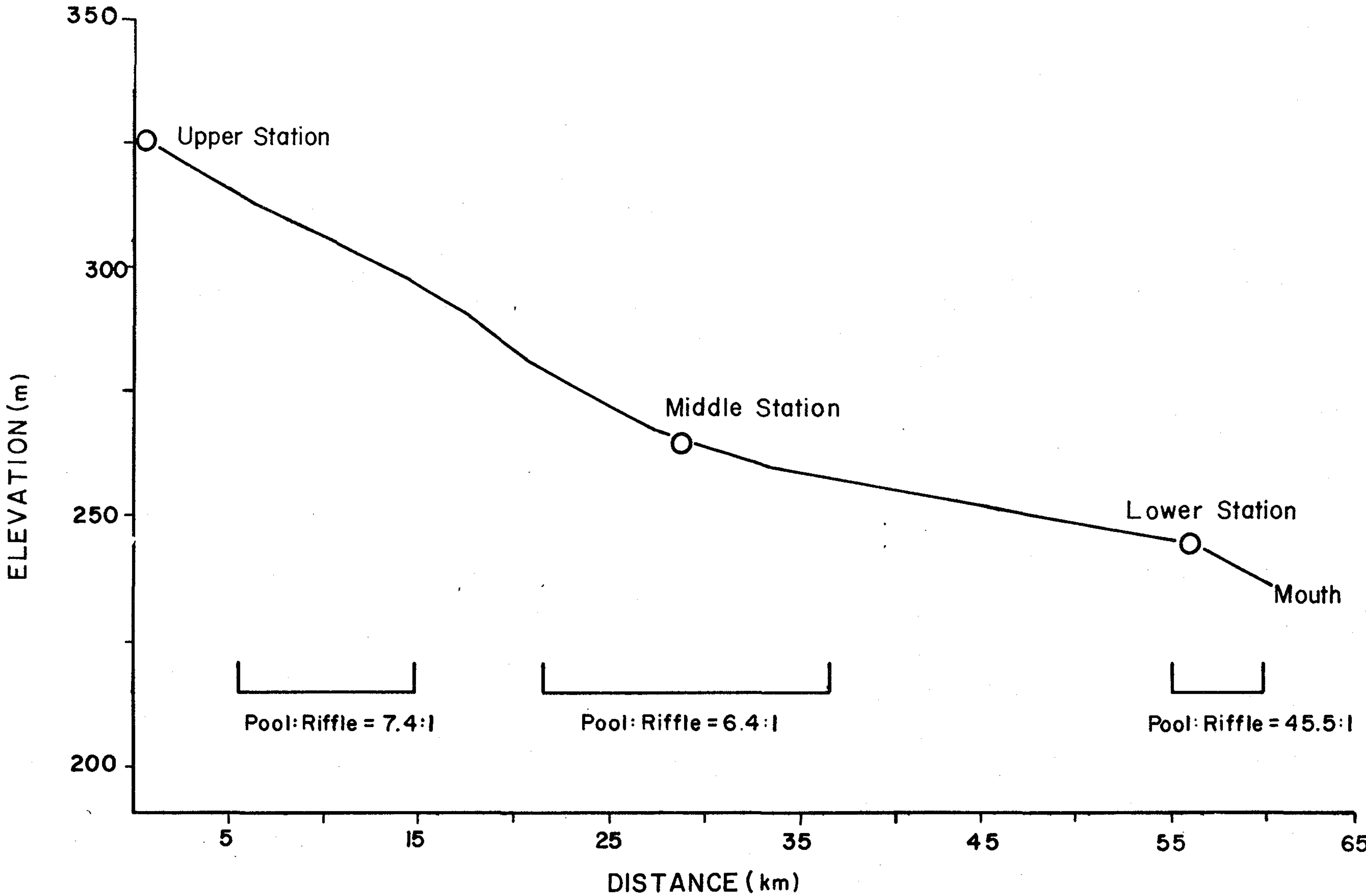


FIGURE 3. Stream profile of the MacKay River showing the gradient within the study area. Pool:riffle ratios measured over selected stretches of the river are also indicated.

TABLE 2 . Physical characteristics, species composition, and distribution of aquatic macrophytes at several stations along the MacKay River. Location of the stations are indicated in Figure 2 .

| Station | Width (m) | Depth (m) | Substrate | % Riffle | Banks | Aquatic Macrophytes |
|---|---|---|---|---|---|---|
| 1 (Upper) | 9.0 | 0.4 | Boulders and rubble, some gravel | 95 | Exposed cliff with some soil erosion. Inside banks stable and vegetated. | *Potomogeton richarsoni*<br>*Scirpus* sp.<br>*Equisetum* sp. |
| 2 | 27.5 | 1.0 | Rubble and gravel, with overlying mud-silt | 0 | Low and stable, vegetated | *P. richardsoni*<br>*P. pectinatus* |
| 3 | 24.5 | 0.5 | Mud-silt | 0 | Low and stable, vegetated | *P. richardsoni*<br>*P. pectinatus*<br>*Sium sauve*<br>*Sagittaria cuneata*<br>*Sparganium* sp.<br>*Carex* sp.<br>*Scirpus* sp. |
| 4 | 17.5 | 0.4 | Boulder and rubble | 80 | Bituminous cliffs common with some slumping | *P. richardsoni*<br>*P. pectinatus* |
| 5 | 17.5 | 0.5 | Boulder and rubble with overlying silt | 5 | Low and stable, vegetated | None |
| 7 | 26.0 | 1.3 | Boulder and rubble with overlying silt | 0 | Bituminous cliffs with some slumping, inside banks low and stable, vegetated. | *P. richardsoni*<br>*P. pectinatus*<br>*S. cuneata*<br>*Typha latifolia*<br>*Equisetum* sp.<br>*Scirpus* sp. |

(Continued)

TABLE 2. Continued.

| Station | Width (m) | Depth (m) | Substrate | % Riffle | Banks | Aquatic Macrophytes |
|---|---|---|---|---|---|---|
| 8 (Middle) | 23.0 | 0.8 | Boulder and rubble, some gravel and slight silting | 0 | Occasional bituminous cliffs with some slumping, inside banks low and stable, vegetated. | *P. richardsoni*<br>*P. pectinatus*<br>*P. pusillus*<br>*Scirpus* sp.<br>*Equisetum* sp. |
| 9 | 24.5 | 0.8 | Rubble and gravel | 0 | Low and stable, vegetated | *P. pectinatus*<br>*P. richardsoni*<br>*Carex* sp. |
| 10 | 24.5 | 0.8 | Bedrock and sand | 0 | Limestone cliffs, inside banks low and stable, vegetated | *P. pectinatus*<br>*P. richardsoni*<br>*T. latifolia* |
| 11 | 27.5 | 0.8 | Rubble with heavy silting | 0 | Low and stable, vegetated | *P. pectinatus*<br>*P. richardsoni*<br>*Carex* sp.<br>*Scirpus* sp. |
| 12 | 12.0 | 0.7 | Gravel | 30 | Limestone cliffs, inside banks low and stable, vegetated | *P. pectinatus*<br>*P. richardsoni* |
| 13 (Lower) | 27.5 | 0.5 | Gravel, sand, mud-silt | 0 | Low and stable, vegetated | *P. pectinatus*<br>*P. richardsoni*<br>*S. cuneata* |

Table 3. No discernible trends are apparent either longitudinally or seasonally.

*Potamogeton richardsoni* (clasping-leaf pondweed) and *P. pectinatus* (Sago pondweed) were the most common and widely distributed aquatic macrophytes in the study area (Table 2), while *Carex* spp., *Scirpus* sp., and *Equisetum* spp. were common components of the bank vegetation. Species rarely collected included *P. pusillus*, *Sagittaria cuneata*, *Sium sauve*, *Typha latifolia*, and *Sparganium* sp.

TABLE 3 . Texture (per cent sand, clay, and silt) and per cent organic composition of substrate samples collected at permanent sampling stations in August and September, 1977.

| Station | Date | % Organic Composition | % Sand | % Clay | % Silt |
|---|---|---|---|---|---|
| Upper | Aug | 1.21 | 94.7 | 2.7 | 2.6 |
| | Sept | 1.55 | 91.2 | 3.8 | 5.0 |
| Middle | Aug | 1.57 | 96.2 | 2.0 | 1.8 |
| | Sept | 2.15 | 96.0 | 1.8 | 2.2 |
| Lower | Aug | 1.26 | 97.2 | 1.8 | 1.0 |
| | Sept | 1.43 | 96.7 | 1.8 | 1.5 |

# WATER QUALITY

## Introduction

The water quality segment of the study was intended to provide a wide range of baseline information. No attempt has been made to analyse and discuss all of the parameters for which data is available. Instead, the presentation is concentrated on those which have the greatest ecological significance.

## Materials and Methods

During the open water season, samples were collected with hand-held plastic bottles at a depth of approximately 0.3 m. Winter samples were collected from the water surface.

Methods used in the routine analysis of various physical and chemical parameters are summarized in Table 4. Samples analysed for heavy metals, major ions, nitrate, orthophosphate, and reactive silicate were filtered through Whatman GF/C filter discs before preservation (Table 5). Samples for the analysis of total organic carbon were frozen and then transferred to a freezer at the laboratory until analysed.

## Results and Discussion

Complete data for water quality samples taken at stations in the MacKay

TABLE 4. Methods used in the routine chemical analysis of water samples from the MacKay River. May 1977 to January 1978.

| Parameter | Methods | Source of Method | Modification |
|---|---|---|---|
| $NO_3$ | Amalgamated Cadmium Column | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971). | None |
| Total Nitrogen | Ultraviolet photochemical oxidation followed by Amalgamated Cadmium Column | Strickland and Parsons (1968) | Overnight (15 hr) irradiation period using a 500 watt lamp |
| Total Phosphates | Persulfate digestion followed by Ascorbic Acid $PO_4$ method | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | None |
| Ortho-$PO_4$ | Ascorbic Acid | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | None |
| Reactive Si | Heteropoly blue | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | None |
| Turbidity | Nephelometry | Measured at FTU using a Hach Model 2100A Turbidimeter | None |
| Suspended Sediments | Filtration and drying | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | Dried at 180 C |

(Continued)

TABLE 4. Continued.



| Parameter | Methods | Source of Method | Modification |
|---|---|---|---|
| Total Solids | Evaporation and drying | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | None |
| Total Dissolved Solids | Filtration, evaporation, and drying | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | None |
| Volatile Solids | Ignition of filtered sample | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | None |
| True Colour | Comparison to standards | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | None |
| pH | Combined electrode, type Radiometer GK 2311 C | Radiometer pH meter Type 296 | None |
| COD | Dichromate reflux | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | None |
| TOC | Carbon analyser | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | None |
| Alkalinity System ($HCO_3$ and $CO_3$) | Acid titration | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971). | None |

(Continued)

TABLE 4. Continued.

| Parameter | Methods | Source of Method | Modification |
|---|---|---|---|
| Hardness | EDTA Titration | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | None |
| Cl | Argentometric titration | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | None |
| $SO_4$ | Turbidimetric method | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | Plunger mixing Hach Turbidimeter Model 2100A |
| Na, Mg, Ca, K, Fe, Pb, Ni, B, Hg, V | Atomic Absorption | Variant AA 5 | None |
| Temperature | Mercury pocket thermometer | - | None |
| Dissolved Oxygen | 1. YSI meter | - | None |
| | *2. Winkler | Standard Methods for the Examination of Water and Wastewater. 13th Ed. (1971) | Axide modification |
| | **3. Hach Kit | - | Low range |

*Used during winter field trips only.
**Back-up determination for YSI meter.

TABLE 5. Preservation of water samples collected from the MacKay River from May, 1977, to January, 1978.

| Parameter | Preservative | Volume Required | Filtered or Unfiltered |
|---|---|---|---|
| $NO_3$ | 5 ml 4N HCl | 100 ml | F |
| Total Nitrogen | 5 ml 4N HCl | 100 ml | U |
| Total Phosphates | 5 ml 4N HCl | 50 ml | U |
| Ortho-$PO_4$ | 5 ml 4N HCl | 20 ml | F |
| Reactive Si | $CHCl_3$ (sufficent to leave a small, undissolved bead after shaking) | 50 ml | F |
| Turbidity | 1 ml $CuSO_4$ solution | 25 ml | U |
| Suspended Solids | 1 ml $CuSO_4$ solution | 500 ml | U |
| Total Solids | None | 100 ml | U |
| Total Dissolved Solids | None | 100 ml | U |
| Volatile Solids | None | 100 ml | U |
| True Colour | None | 50 ml | F |
| pH | 1 ml $CuSO_4$ solution | 25 ml | F or U |
| COD | 5 ml 4N HCl | 20 ml | U |
| TOC | None (sample should be frozen or kept cold until it can be frozen) | 10 ml | U |
| Alkalinity System ($HCO_3$ and $CO_3$) | $CHCl_3$ (sufficient to leave a small, undissolved bead after shaking) | 100 ml | F |
| Hardness | 5 ml 4N HCl | 100 ml | F |
| Cl | $CHCl_3$ (sufficient to leave a small, undissolved bead after shaking) | 100 ml | F |
| $SO_4$ | same as above | 100 ml | F |
| Na, Mg, Ca, K, Fe, Pb, Ni, B, Hg, V | 5 ml 4N HCl | 1000 ml | F |

River are presented in Table 6. In what follows, the major water quality parameters are discussed with an emphasis on those of biological significance.

## Physical Parameters

### Discharge

The seasonal pattern of discharge for the MacKay River, 1977, is illustrated in Figure 4. During the year, there were three peaks in discharge: two major ones and one minor. The major peaks occurred in spring (20.9 $m^3$/sec, April 19), primarily as the result of snowmelt, and in summer (22.5 $m^3$/sec, July 8), primarily as the result of precipitation. The minor peak which occurred in the fall on October 16 was presumably also the result of precipitation and/or thawing and snowmelt. The annual low discharge, 0.2 $m^3$/sec, was recorded April 3. The mean discharge for the year was 4.2 $m^3$/sec per day with a total discharge of $176.6 \times 10^6$ $m^3$. Floe ice was present in the river as late as April 26 and reformed October 28.

### Water Temperature

Water temperatures recorded during the study period ranged from 0 C during the winter (March, December, and January samples) to a high mean value of 17 C during the August sampling period (Figure 5). The highest individual temperature, 19 C, was recorded at the uppermost sampling site on July, 1977. Higher temperatures may have occurred during the intervals between sampling periods.

TABLE 6. Summary of water quality data, MacKay River, Alberta. March 1977 to January 1978.

| Date | Sample Site | Total Dissolved Solids mg/1 | Total Volatile Solids mg/1 | True Colour APHA Units | Total Solids mg/1 | C.O.D. mg/1 | Total Organic Carbon mg/1 | Boron mg/1 | Lead mg/1 | Nickel mg/1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Mar. 1977 | Lower | 735 | 375 | 47 | 755 | 160 | 20.9 | 0.8 | - | <0.01 |
| | Middle | 565 | 245 | 42 | 575 | 207 | 25.5 | 0.8 | - | <0.01 |
| | Upper | 540 | 245 | 70 | 550 | 210 | 15.8 | 0.8 | - | <0.01 |
| | Mean | 613 | 288 | 53 | 627 | 192 | 20.7 | 0.8 | - | <0.01 |
| May 1977 | Lower | 280 | 130 | 110 | 290 | 29 | 18.6 | <0.05 | <0.002 | 0.15 |
| | Middle | 250 | 90 | 120 | 280 | 74 | 22.5 | <0.05 | <0.002 | 0.15 |
| | Upper | 310 | 220 | 140 | 320 | 58 | 20.9 | 0.6 | <0.002 | 0.15 |
| | Mean | 280 | 147 | 123 | 297 | 54 | 20.7 | <0.2 | <0.002 | 0.15 |
| June 1977 | Lower | 225 | 105 | 160 | 285 | 79 | 28.8 | 0.7 | <0.002 | 0.01 |
| | Middle | 210 | 115 | 115 | 295 | 93 | 28.7 | 0.9 | <0.002 | 0.02 |
| | Upper | 215 | 110 | 145 | 305 | 87 | 33.8 | 1.0 | <0.002 | 0.02 |
| | Mean | 217 | 110 | 140 | 295 | 86 | 30.4 | 0.87 | <0.002 | 0.017 |
| July 1977 | Lower | 175 | 100 | 165 | 190 | 150 | 10.5 | 1.0 | 0.02 | <0.01 |
| | Middle | 170 | 100 | 150 | 180 | 60 | 25.0 | 1.0 | 0.02 | <0.01 |
| | Upper | 160 | 85 | 165 | 180 | 63 | 15.2 | 0.9 | 0.02 | <0.01 |
| | Mean | 168 | 95 | 160 | 183 | 91 | 16.9 | 0.97 | 0.02 | <0.01 |
| Aug. 1977 | Lower | 215 | 110 | 125 | 270 | 77 | 22.65 | 0.6 | <0.002 | 0.02 |
| | Middle | 240 | 115 | 125 | 290 | 68 | - | 0.6 | <0.002 | 0.01 |
| | Upper | 215 | 90 | 100 | 240 | 73 | - | 0.6 | <0.002 | 0.01 |
| | Mean | 223 | 105 | 117 | 267 | 73 | 22.65 | 0.6 | <0.002 | 0.01 |
| Sept 1977 | Lower | 224 | 136 | 120 | 256 | 58 | 18.3 | <0.2 | <0.002 | 0.04 |
| | Middle | 216 | 140 | 110 | 264 | 61 | 22.4 | <0.2 | <0.002 | 0.04 |
| | Upper | 208 | 140 | 130 | 280 | 49 | 23.8 | <0.2 | <0.002 | 0.05 |
| | Mean | 216 | 139 | 120 | 267 | 56 | 21.5 | <0.2 | <0.002 | 0.043 |

(Continued)

TABLE 6. Continued.

| Date | Sample Site | Total Dissolved Solids mg/1 | Total Volatile Solids mg/1 | True Colour APHA Units | Total Solids mg/1 | C.O.D. mg/1 | Total Organic Carbon mg/1 | Boron mg/1 | Lead mg/1 | Nickel mg/1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dec. 1977 | Lower | 430 | 128 | 140 | 465 | 103 | 26.9 | <0.2 | 0.01 | <0.01 |
| | Middle | 310 | 165 | 165 | 390 | 100 | 29.1 | <0.2 | 0.01 | <0.01 |
| | Upper | 430 | 120 | 140 | 435 | 89 | 25.9 | <0.2 | 0.01 | <0.01 |
| | Mean | 390 | 138 | 148 | 430 | 97 | 27.3 | <0.2 | 0.01 | <0.01 |
| Jan. 1978 | Lower | 420 | 72 | 110 | 544 | 68 | 36.3 | 0.6 | <0.002 | <0.01 |
| | Middle | 456 | 76 | 120 | 500 | 69 | 42.0 | 0.4 | <0.002 | <0.01 |
| | Upper | 368 | 60 | 120 | 448 | 69 | 40.8 | 0.5 | <0.002 | <0.01 |
| | Mean | 415 | 69 | 117 | 497 | 69 | 39.7 | 0.5 | <0.002 | <0.01 |
| Surface Water Quality Objectives, Alberta Environment, 1977 | | a,b | a | Not to be increased 30 units above natural value | a,b | a | 0.2 | 0.5 | 0.05 | a |

(Continued)

TABLE 6. Continued.



| Date | Sample Site | Suspended Solids mg/1 | Conductivity µmho/cm 25°C | pH | Hardness mg/1 | Dissolved Oxygen mg/1 | Temp. C | % Saturation |
|---|---|---|---|---|---|---|---|---|
| Mar. 1977 | Lower | 5.8 | | 7.1 | 324 | 6.2 | 0 | 43 |
| | Middle | 8.0 | | 7.0 | 300 | 8.4 | 0 | 58 |
| | Upper | 4.5 | | 7.0 | 292 | 9.2 | 0 | 63 |
| | Mean | 6.1 | | 7.0 | 305 | 7.9 | 0 | 55 |
| May 1977 | Lower | 12.0 | | 7.5 | 80 | 8.6 | 15 | 84 |
| | Middle | 10.0 | | 7.5 | 76 | 9.2 | 14 | 89 |
| | Upper | 7.5 | | 7.5 | 80 | 8.8 | 15 | 86 |
| | Mean | 9.8 | | 7.5 | 79 | 8.9 | 14.7 | 86 |
| June 1977 | Lower | 32.6 | 199 | 7.4 | 84 | 8.0 | 18 | 84 |
| | Middle | 44.0 | 186 | 7.5 | 80 | 9.0 | 16 | 90 |
| | Upper | 22.3 | 179 | 7.4 | 80 | 9.0 | 16 | 90 |
| | Mean | 33.0 | 188 | 7.4 | 81 | 8.7 | 16.7 | 88 |
| July 1977 | Lower | 9.1 | 194 | 7.8 | 88 | 8.4 | 18 | 88 |
| | Middle | 14.6 | 165 | 7.7 | 84 | 8.8 | 15 | 86 |
| | Upper | 8.6 | 165 | 7.6 | 76 | 8.6 | 15 | 84 |
| | Mean | 10.8 | 175 | 7.7 | 83 | 8.6 | 16 | 86 |
| Aug. 1977 | Lower | 2.6 | 276 | 7.6 | 108 | 9.2 | 16 | 92 |
| | Middle | 2.0 | 243 | 7.6 | 96 | 9.3 | 16 | 93 |
| | Upper | 2.9 | 172 | 7.6 | 80 | 9.9 | 19 | 105 |
| | Mean | 2.5 | 230 | 7.6 | 94 | 9.5 | 17 | 97 |
| Sept 1977 | Lower | 0.9 | 314 | 7.2 | 88 | 9.8 | 13 | 92 |
| | Middle | 1.7 | 278 | 7.1 | 104 | 12.4 | 12 | 115 |
| | Upper | 1.1 | 245 | 7.2 | 96 | 11.8 | 9 | 102 |
| | Mean | 1.2 | 279 | 7.2 | 96 | 11.3 | 11.3 | 103 |

(Continued)

TABLE 6. Continued.

| Date | Sample Site | Suspended Solids mg/l | Conductivity µmho/cm 25°C | pH | Hardness mg/l | Dissolved Oxygen mg/l | Temp. C | % Saturation |
|---|---|---|---|---|---|---|---|---|
| Dec. 1977 | Lower | 2.8 | 571 | 7.7 | 188 | 12.2 | 0 | 84 |
| | Middle | 2.6 | 571 | 7.5 | 212 | 7.8 | 0 | 53 |
| | Upper | 7.1 | 520 | 7.3 | 220 | 9.1 | 0 | 62 |
| | Mean | 4.2 | 554 | 7.5 | 207 | 9.7 | 0 | 66 |
| Jan. 1978 | Lower | 5.8 | 742 | 7.6 | 264 | 8.7 | 0 | 60 |
| | Middle | - | - | - | 244 | 8.5 | 0 | 58 |
| | Upper | 4.8 | 621 | 7.8 | 216 | 8.4 | 0 | 57 |
| | Mean | 5.3 | 681 | 7.7 | 241 | 8.5 | 0 | 58 |
| Surface Water Quality Objectives, Alberta Environment, 1977 | | Not to be increased by more than 10 mg/l over background value | a,b | 6.5-8.5; not to be altered by more than 0.5 units from background value | a,b | 5.0 | 3 C above ambient temperature | |

(Continued)

TABLE 6. Continued.

| Date | Sample Site | Na mg/1 | K mg/1 | Ca mg/1 | Mg mg/1 | Fe mg/1 | $SO_4$ mg/1 | Cl mg/1 | Alk mg $CaCO_3$/1 | $HCO_3$ mg $CaCO_3$/1 | $CO_3$ mg $CaCO_3$/1 | Total Cations meq/1 | Total Anions meq/1 | % Error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar. 1977 | Lower | 71.9* | 4.9 | 86 | 39 | 1.0 | 90 | 27.5 | 366 | 330 | 36 | 10.8125 | 9.9723 | 4.6 |
| | Middle | 61.0* | 5.3 | 91 | 39 | 1.4 | 133 | 10.0 | 360 | 308 | 52 | 10.6154 | 10.2529 | 1.7 |
| | Upper | 54.6* | 4.8 | 85 | 37 | 1.6 | 111 | 11.0 | 328 | 284 | 44 | 9.8710 | 9.1831 | 3.6 |
| | Mean | 62.5 | 5.0 | 87 | 38 | 1.3 | 111 | 16.2 | 351 | 307 | 44 | | | |
| May 1977 | Lower | 16 | 2.0 | 23 | 9.6 | 0.7 | 23 | 0.5 | 108 | 108 | nil | 2.7228 | 2.6541 | 1.3 |
| | Middle | 14 | 1.9 | 23 | 9.1 | 0.7 | 29 | 0.5 | 102 | 102 | nil | 2.5920 | 2.6583 | 1.3 |
| | Upper | 12 | 1.8 | 20 | 8.0 | 0.7 | 15 | 0.5 | 94 | 94 | nil | 2.2623 | 2.2075 | 1.2 |
| | Mean | 14 | 1.9 | 22 | 8.9 | 0.7 | 22 | 0.5 | 101 | 101 | nil | | | |
| June 1977 | Lower | 15.6 | 1.4 | 19.2 | 8.0 | 0.6 | 14.0 | 1.0 | 97 | 97 | nil | 2.3633 | 2.2608 | 2.2 |
| | Middle | 12.8 | 1.3 | 18.0 | 7.7 | 0.6 | 18.4 | 1.0 | 87 | 87 | nil | 2.1544 | 2.1522 | 0.1 |
| | Upper | 12.0 | 1.3 | 17.4 | 7.4 | 0.6 | 10.5 | 0.5 | 84 | 84 | nil | 2.0650 | 1.9137 | 3.8 |
| | Mean | 13.5 | 1.3 | 18.2 | 7.7 | 0.6 | 14.3 | 0.8 | 89 | 89 | nil | | | |
| July 1977 | Lower | 10.9 | 0.5 | 20.4 | 8.5 | 0.7 | 14.0 | 0.5 | 98 | 98 | nil | 2.2424 | 2.2667 | 0.5 |
| | Middle | 11.8 | 0.6 | 21.9 | 8.9 | 0.7 | 17.0 | 0.5 | 84 | 84 | nil | 2.3918 | 2.0489 | 7.7 |
| | Upper | 10.4 | 0.4 | 19.6 | 7.9 | 0.7 | 9.8 | 1.0 | 94 | 94 | nil | 2.1286 | 2.1134 | 0.4 |
| | Mean | 11.0 | 0.5 | 20.6 | 8.4 | 0.7 | 13.6 | 0.7 | 92 | 92 | nil | | | |
| Aug. 1977 | Lower | 19.0 | 1.0 | 32.0 | 10.7 | 1.0 | 27 | 3.0 | 115 | 115 | nil | 3.3835 | 2.9479 | 6.9 |
| | Middle | 14.9 | 0.9 | 30.4 | 10.3 | 0.8 | 23 | 2.5 | 106 | 106 | nil | 3.0791 | 2.6704 | 7.1 |
| | Upper | 12.5 | 1.2 | 24.6 | 12.1 | 0.9 | 13 | 1.0 | 99 | 99 | nil | 2.8464 | 2.2800 | 11.0 |
| | Mean | 15.5 | 1.0 | 29.0 | 11.0 | 0.9 | 21 | 2.2 | 107 | 107 | nil | | | |
| Sept 1977 | Lower | 34.3 | 1.3 | 33.5 | 13.1 | 0.3 | 26 | 4.0 | 142 | 142 | nil | 4.2914 | 3.4957 | 10.2 |
| | Middle | 18.1 | 1.1 | 25.6 | 10.8 | 0.3 | 19 | 2.0 | 127 | 127 | nil | 2.9980 | 2.9934 | 0.1 |
| | Upper | 15.9 | 1.2 | 31.8 | 12.2 | 0.4 | 21 | 1.0 | 117 | 117 | nil | 3.3349 | 2.8067 | 8.6 |
| | Mean | 22.8 | 1.2 | 30.3 | 12.0 | 0.3 | 22 | 2.3 | 129 | 129 | nil | | | |

(Continued)

TABLE 6. Continued.

| Date | Sample Site | Na mg/1 | K mg/1 | Ca mg/1 | Mg mg/1 | Fe mg/1 | $SO_4$ mg/1 | Cl mg/1 | Alk mg $CaCO_3$/1 | $HCO_3$ mg $CaCO_3$/1 | $CO_3$ mg $CaCO_3$/1 | Total Cations meq/1 | Total Anions meq/1 | % Error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dec. 1977 | Lower | 45 | 2.7 | 51 | 37 | 1.3 | 40 | 14.0 | 284 | 284 | nil | 7.6868 | 6.9109 | 5.3 |
| | Middle | 44 | 2.5 | 53 | 32 | 1.5 | 64 | 22.0 | 244 | 244 | nil | 7.3373 | 6.8352 | 3.5 |
| | Upper | 40 | 2.6 | 53 | 33 | 1.7 | 48 | 4.5 | 264 | 264 | nil | 7.2590 | 6.4091 | 6.2 |
| | Mean | 43 | 2.6 | 52 | 34 | 1.5 | 51 | 13.5 | 264 | 264 | | | | |
| Jan. 1978 | Lower | 63 | 3.1 | 57 | 31 | 1.0 | 51 | 17.5 | 338 | 338 | nil | 8.2695 | 8.3192 | 0.3 |
| | Middle | 56 | 2.7 | 53 | 28 | 1.3 | 60 | 20.5 | 304 | 304 | nil | 7.5244 | 7.9105 | 2.5 |
| | Upper | 44 | 2.7 | 49 | 25 | 1.5 | 54 | 4.5 | 276 | 276 | nil | 6.5667 | 6.7741 | 1.6 |
| | Mean | 54 | 2.8 | 53 | 28 | 1.3 | 55 | 14.2 | 306 | 306 | | | | |
| Surface Water Quality Objectives, Alberta Environment, 1977 | | 30.75 of total cations | b | b | b | 0.3 | b | b | b | b | b | | | |

(Continued)

* Calculated

TABLE 6. Continued.

| Date | Sample Site | V mg/l | Hg µg/l | $NO_3$ µg/l | TN µg/l | O-$PO_4$ µg/l | TP µg/l | Si µg/l | Turbidity FTU Shaken | Settled |
|---|---|---|---|---|---|---|---|---|---|---|
| Mar. 1977 | Lower | <0.001 | 2.0 | 288 | 720 | 22 | 54 | 8100 | 9.7 | 7.4 |
| | Middle | <0.001 | 1.9 | 374 | 1130 | 56 | 145 | 7440 | 11.0 | 9.5 |
| | Upper | <0.001 | 2.0 | 342 | 1060 | 66 | 101 | 7020 | 9.9 | 9.4 |
| | Mean | <0.001 | 1.97 | 335 | 970 | 48 | 100 | 7520 | 10.2 | 8.8 |
| May 1977 | Lower | <0.001 | 1.6 | 4 | 780 | 11 | 79 | 860 | 6.4 | 3.3 |
| | Middle | <0.001 | 6.0 | 8 | 710 | 14 | 76 | 840 | 6.2 | 3.0 |
| | Upper | <0.001 | 9.0 | 9 | 680 | 13 | 86 | 800 | 5.5 | 2.9 |
| | Mean | <0.001 | 5.5 | 7 | 723 | 13 | 80 | 833 | 6.0 | 3.1 |
| June 1977 | Lower | <0.001 | - | 4 | 595 | 22 | 82 | 1320 | 8.6 | 3.2 |
| | Middle | <0.001 | - | 7 | 610 | 29 | 122 | 1310 | 12.0 | 3.6 |
| | Upper | <0.001 | - | 6 | 540 | 25 | 135 | 1396 | 11.0 | 4.0 |
| | Mean | <0.001 | - | 5.7 | 582 | 25 | 113 | 1342 | 10.5 | 3.6 |
| July 1977 | Lower | <0.001 | 1.0 | 3 | 685 | 33 | 87 | 1600 | 6.8 | 3.9 |
| | Middle | <0.001 | 1.0 | 3 | 655 | 32 | 93 | 1380 | 7.8 | 3.9 |
| | Upper | <0.001 | 2.0 | 8 | 680 | 39 | 86 | 1380 | 5.3 | 3.0 |
| | Mean | <0.001 | 1.3 | 4.7 | 673 | 35 | 89 | 1453 | 6.6 | 3.6 |
| Aug. 1977 | Lower | <0.001 | 0.9 | 9 | 516 | 21 | 33 | 540 | 4.3 | 2.8 |
| | Middle | <0.001 | 0.6 | 2 | 730 | 24 | 50 | 700 | 2.5 | 1.9 |
| | Upper | <0.001 | 1.2 | 2 | 730 | 33 | 48 | 1280 | 2.6 | 1.0 |
| | Mean | <0.001 | 0.9 | 4.3 | 659 | 26 | 44 | 840 | 3.1 | 1.9 |
| Sept 1977 | Lower | <0.001 | 1.5 | 23 | 715 | 13 | 28 | 660 | 3.5 | 3.2 |
| | Middle | <0.001 | 1.5 | 7 | 770 | 13 | 33 | 680 | 4.1 | 3.7 |
| | Upper | <0.001 | 1.0 | 6 | 745 | 20 | 39 | 1180 | 3.8 | 3.4 |
| | Mean | <0.001 | 1.3 | 12 | 743 | 15 | 33 | 840 | 3.8 | 3.4 |

(Continued)

TABLE 6. Continued.

| Date | Sample Site | V mg/1 | Hg µg/1 | $NO_3$ µg/1 | TN µg/1 | $O\text{-}PO_4$ µg/1 | TP µg/1 | Si µg/1 | Turbidity FTU Shaken | Turbidity FTU Settled |
|---|---|---|---|---|---|---|---|---|---|---|
| Dec. 1977 | Lower | <0.001 | <1.0 | 186 | 1160 | 45 | 84 | 4100 | 9.2 | 6.1 |
| | Middle | <0.001 | <1.0 | 230 | 1540 | 54 | 91 | 5950 | 7.2 | 5.8 |
| | Upper | <0.001 | 1.0 | 230 | 1420 | 70 | 124 | 6750 | 9.9 | 8.3 |
| | Mean | <0.001 | <1.0 | 215 | 1373 | 56 | 100 | 5600 | 8.8 | 6.7 |
| Jan. 1978 | Lower | <0.001 | <1.0 | 378 | 1140 | 41 | 98 | 6050 | 9.3 | 7.5 |
| | Middle | <0.001 | <1.0 | 460 | 1420 | 57 | 122 | 5700 | - | - |
| | Upper | <0.001 | <1.0 | 438 | 1340 | 68 | 132 | 5500 | 11.0 | 8.6 |
| | Mean | <0.001 | <1.0 | 425 | 1300 | 55 | 117 | 5750 | 10.2 | 8.1 |
| Surface Water Quality Objectives, Alberta Environment, 1977 | | a | 0.1 | a | 1000 | a | 150 | a | Not to exceed 25 JTU over natural turbidity | |

(Continued)

TABLE 6. Continued.

| Date | Sample Site | Al mg/1 | Cr mg/1 | Co mg/1 | Cu mg/1 | Zn mg/1 | Cd mg/1 | Oil & Grease mg/1 | Phenols mg/1 |
|---|---|---|---|---|---|---|---|---|---|
| Mar. 1977 | Lower | <0.04 | <0.01 | <0.008 | <0.001 | 0.04 | 0.44 | 6.8 | 0.03 |
| | Middle | <0.04 | <0.01 | <0.008 | <0.001 | 0.05 | <0.007 | 4.1 | 0.02 |
| | Upper | <0.04 | <0.01 | <0.008 | <0.001 | 0.04 | <0.007 | 6.8 | 0.03 |
| | Mean | <0.04 | <0.01 | <0.008 | <0.001 | 0.04 | <0.151 | 5.9 | 0.03 |
| May 1977 | Lower | 0.22 | <0.01 | <0.005 | 0.02 | <0.02 | 0.01 | 7.4 | 0.02 |
| | Middle | <0.04 | <0.01 | <0.005 | 0.01 | <0.02 | 0.01 | 7.1 | 0.002 |
| | Upper | 0.24 | <0.01 | <0.005 | 0.01 | <0.02 | 0.01 | 9.2 | 0.02 |
| | Mean | <0.17 | <0.01 | <0.005 | 0.013 | <0.02 | 0.01 | 7.9 | 0.02 |
| Surface Water Quality Objectives, Alberta Environment, 1977 | | a | 0.05 | a | 0.02 | 0.05 | 0.01 | Substantially absent; no iridescent sheen | 0.005 |

a "Substances not specific should not exceed values which are considered to be deleterious for the most critical use as established by the administrative authority" (Surface Water Quality Objectives, Alberta Environment, 1977).

b "The predominant cations of sodium, calcium and magnesium and anions of sulfate, chloride and bicarbonate are too variable in the natural water quality state to attempt to define limits. Nevertheless, in order to prevent impairment of water quality, where effluents containing these ions are discharged to a water body the permissible concentration will be determined by the administrative authority in accordance with existing quality and use" (Surface Water Quality Objectives, Alberta Environment, 1977).

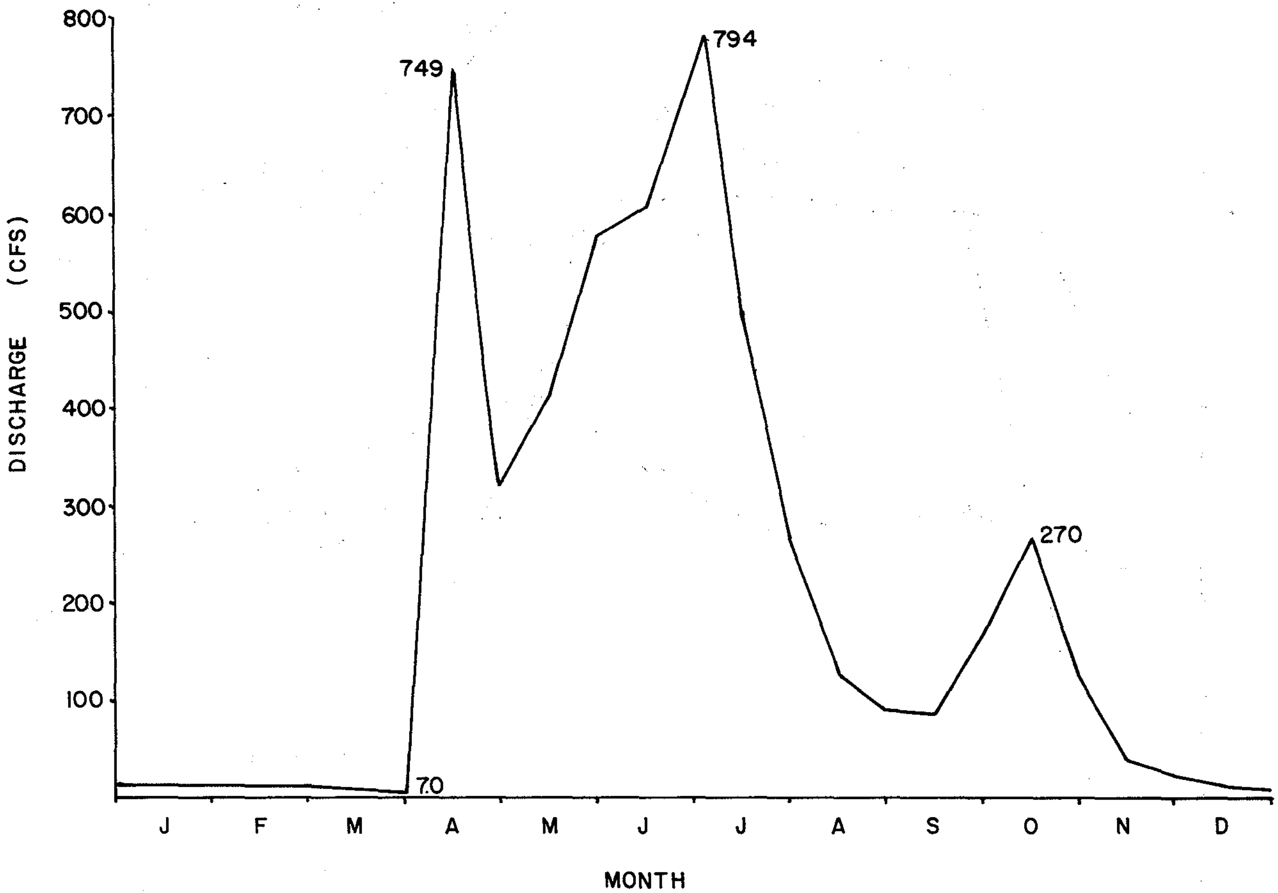


FIGURE 4. Seasonal pattern of discharge, MacKay River, Alberta, 1977. Based on preliminary data from Water Survey of Canada, Calgary, Alberta.

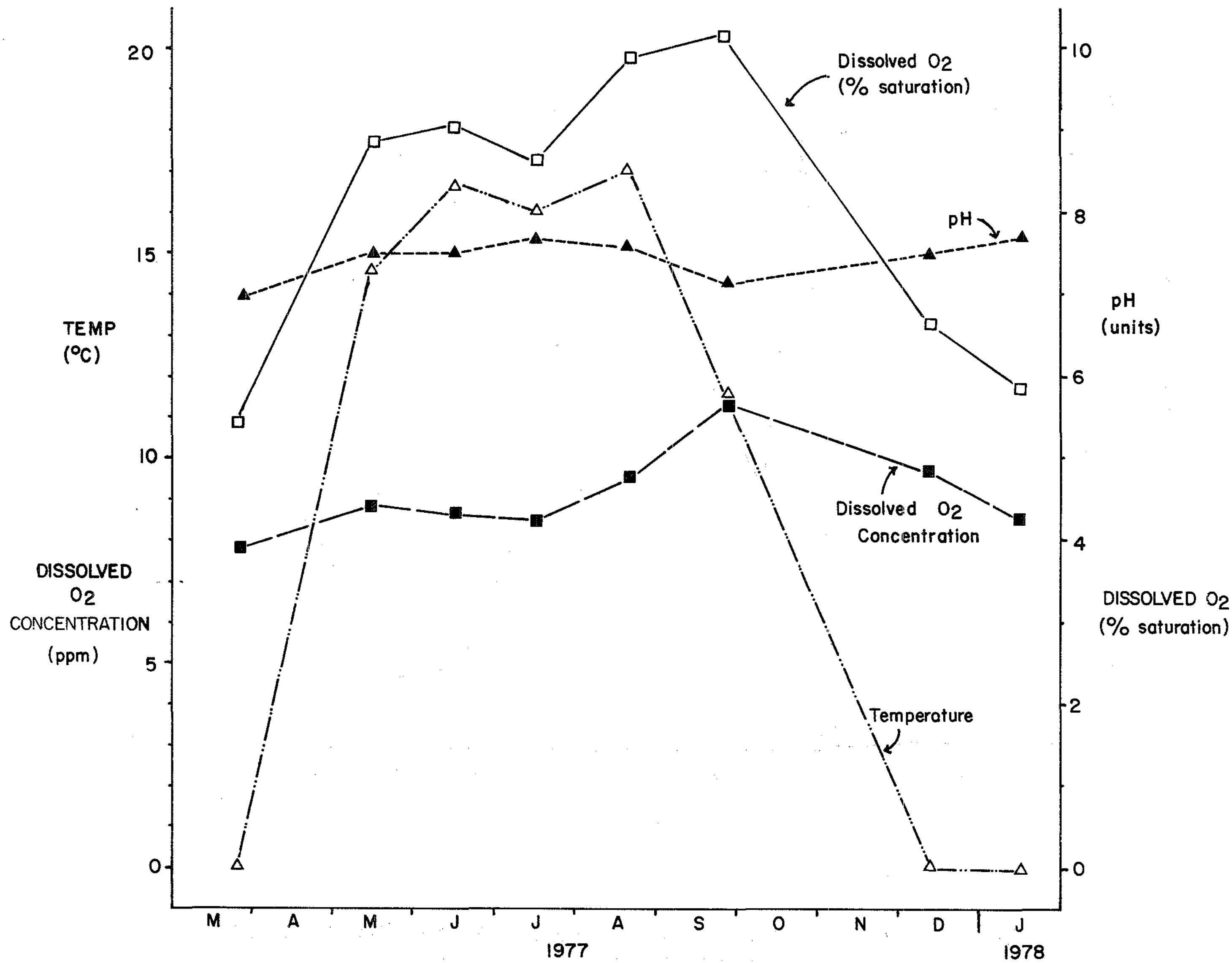


FIGURE 5. Seasonal variation in mean values for pH, dissolved oxygen, and temperature in the study area. MacKay River, 1977 and 1978.

Specific Conductivity, Total Ion Concentration, and Total Dissolved Solids

Data describing specific conductivity are available for the period from June, 1977, to January, 1978 (Figure 6). Specific conductivity was lowest in samples taken during the June and July sampling periods (means of 188 and 175 μmho/cm, respectively) and increased seasonally thereafter to a mean value of 672 μmho/cm for January samples. Thus, from mid-summer to mid-winter, conductivity increased approximately 3.8 times. This increase is paralleled by increases in total dissolved solids (Figure 6) and total ion concentrations (Figure 7) which occurred during the same period. All three parameters illustrate that concentrations of dissolved substances are highest in winter, and lowest during the period of maximum discharge (and dilution) in spring and summer. This presumably reflects the changing balance between contributions of high conductance groundwater and lower conductance surface runoff.

The data for total ion concentrations have been used to illustrate another aspect of the data, the existence of a longitudinal cline in the concentrations of dissolved substances. Water in samples from the uppermost sampling site was consistently more dilute than that in samples from the lowermost site (Figure 7). Samples from the middle site tended to be intermediate. An examination of the available data (Table 6) indicates that the pattern is similar for both total dissolved solids and specific conductivity. The reasons for the increases in total concentration downstream are not definitely known but there is evidence of groundwater activity in the area. During the winter, many small icings signifying the presence of groundwater flow were noted along the banks of the MacKay River.

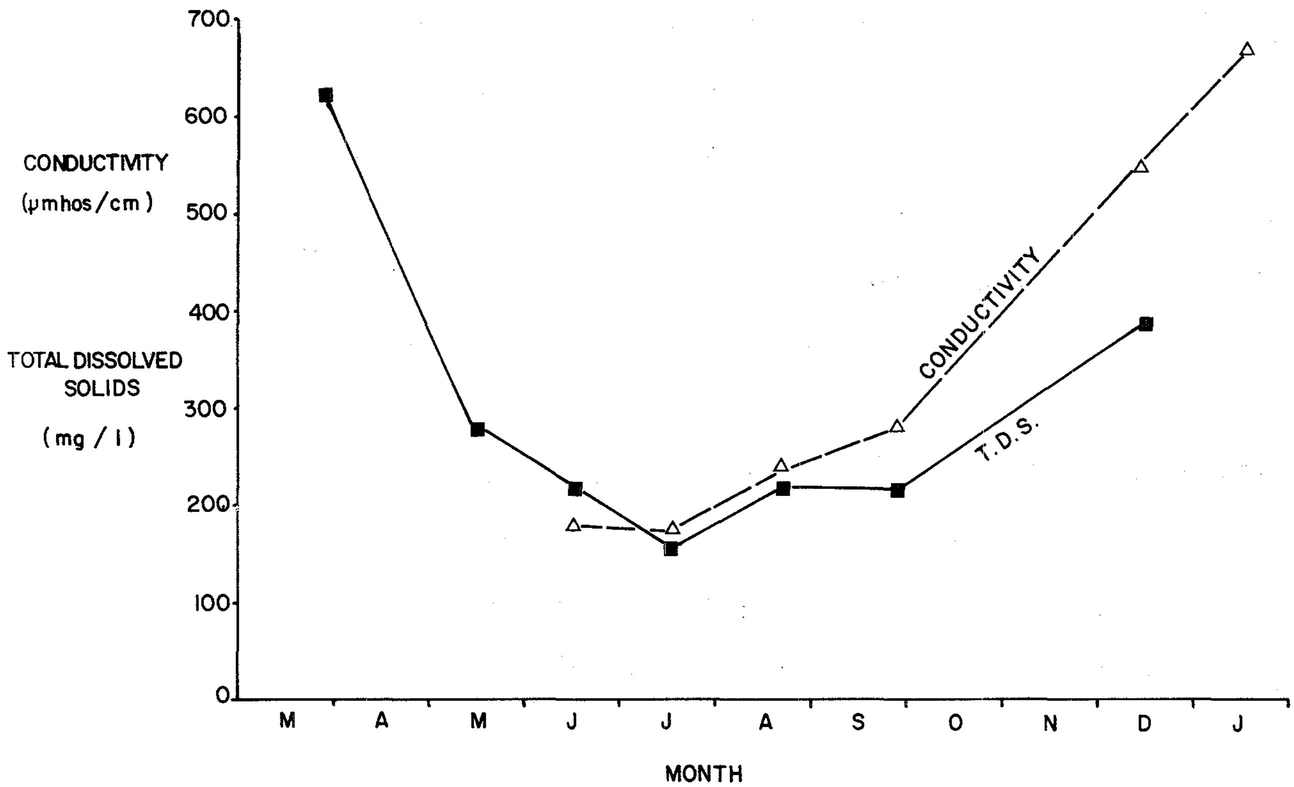


FIGURE 6. Seasonal variations in mean values for conductivity and total dissolved solids in the study area, MacKay River, 1977 and 1978.

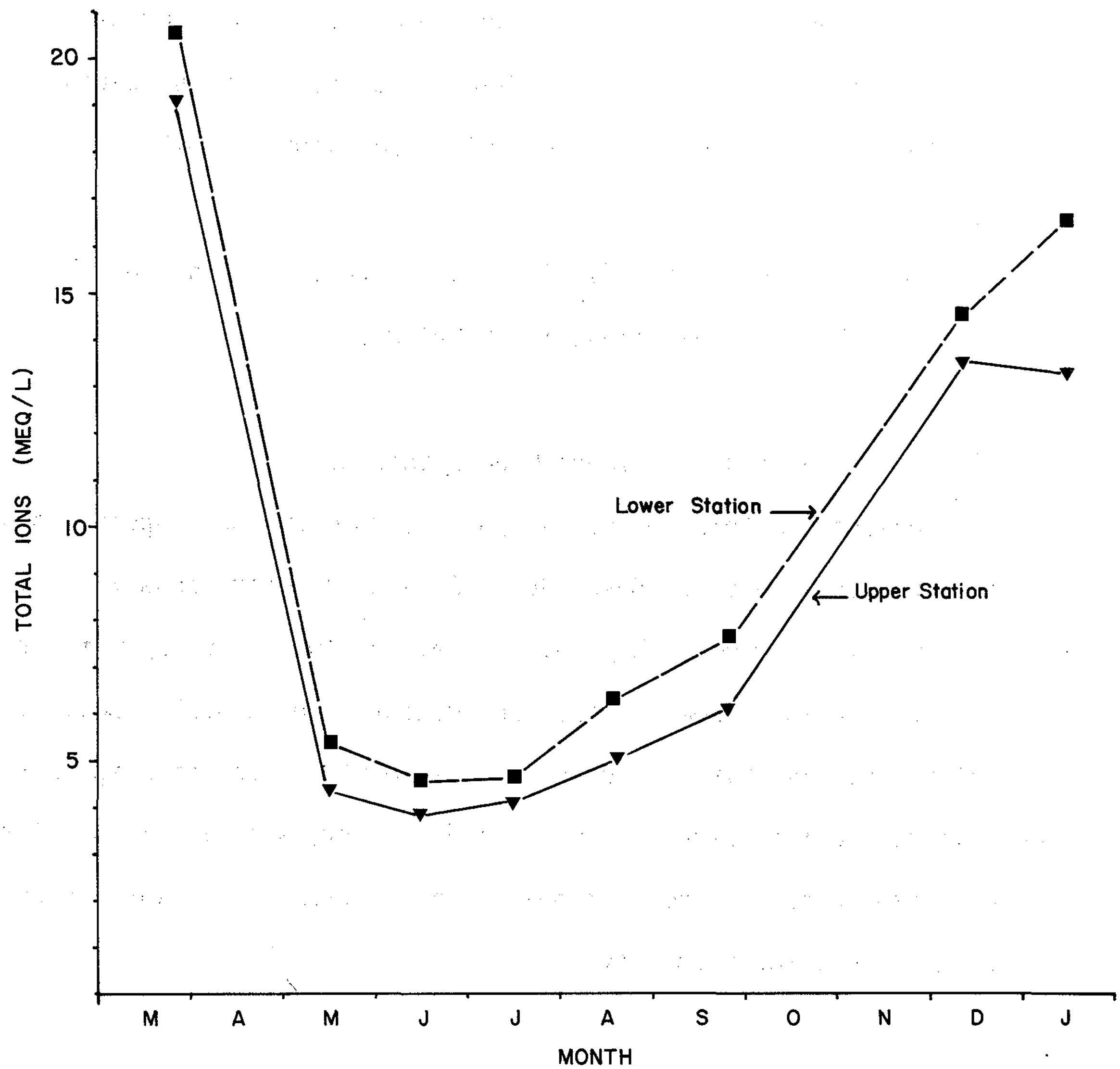


FIGURE 7. Seasonal variation in mean values for total ion concentrations in the study area. MacKay River, 1977 and 1978.

Such evidence of grounwater flow was common in the lower reaches of the river in this area, groundwater may make a substantial contribution to winter flow.

pH

pH values recorded during the study were all in the neutral to slightly alkaline range (Table 6). Mean values for sampling dates ranged from 7.0 (March, 1977) to 7.7 (July, 1977, and January, 1978).

The lowest and highest individual values were 7.0 and 7.8. There was no discernible seasonal trend in pH (Figure 5).

Turbidity and Suspended Sediment Concentrations

The seasonal patterns of variation in turbidity and suspended sediments are presented in Figure 8. Suspended sediment concentrations were highest in June, during a period of high discharge, and lowest during periods of low discharge in late summer, fall, and winter. An unusual aspect of the seasonal pattern is that mean suspended sediment values for samples taken under winter ice (in March, December, and January) are higher than for samples taken in August and September. The pattern is similar, though more exaggerated, for turbidity.

The reasons for the high winter values for the two parameters are not definitely known. Care was taken to avoid contamination by sediments disturbed during ice drilling. In many cases, the samples were taken from holes which had been drilled the previous day. Some (e.g., the sample taken in January at the uppermost sampling site) were taken from flowing water which would have soon carried away any disturbed sediments. It

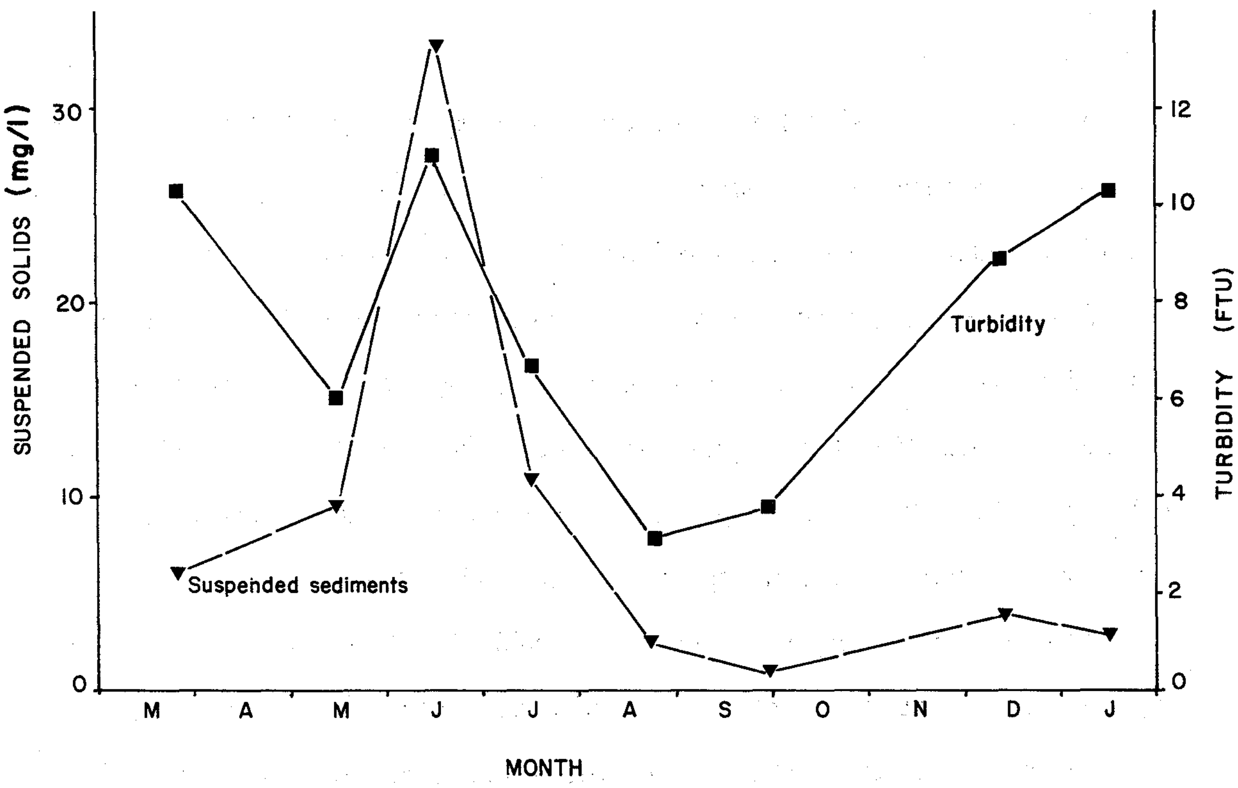


FIGURE 8. Seasonal variation in mean values for suspended solids and turbidity in the study area. MacKay River, 1977 and 1978.

appears that the increased values are a real phenomenon and not an artificat of the sampling technique. One possibility is that they are the result of increased biological activity, for example, increased populations of drifting periphyton.

### Dissolved Oxygen

All the recorded values exceeded the 5 mg/1 suggested as a minimum standard by Alberta Environment (1977)(Table 6), a value generally considered adequate for the survival of even sensitive species of fish. Mean dissolved oxygen concentrations ranged from 7.9 mg/1 in January (including the lowest individual record, 6.2 mg/1) to 11.3 mg/1 in September (including the highest individual record, 12.4 mg/1)(Table 6 and Figure 5). In terms of per cent saturation, mean values ranged from 53% in January (including the lowest individual value, 43%) to 103% in September (including the highest individual value, 115%)(Table 6 and Figure 5). The supersaturation recorded at stations sampled in August and September was undoubtedly a temporary condition possibly resulting from sudden increases in temperature or from high rates of oxygen production by photosynthesizing plants. (The highest densities of periphytic algae were recorded in September).

## Chemical Parameters

### Major Ions

Figure 9 compares the proportions of major ions in samples taken from MacKay River in June, 1977, and January, 1978. The data illustrate that from summer to winter there was an increase in the concentrations of all

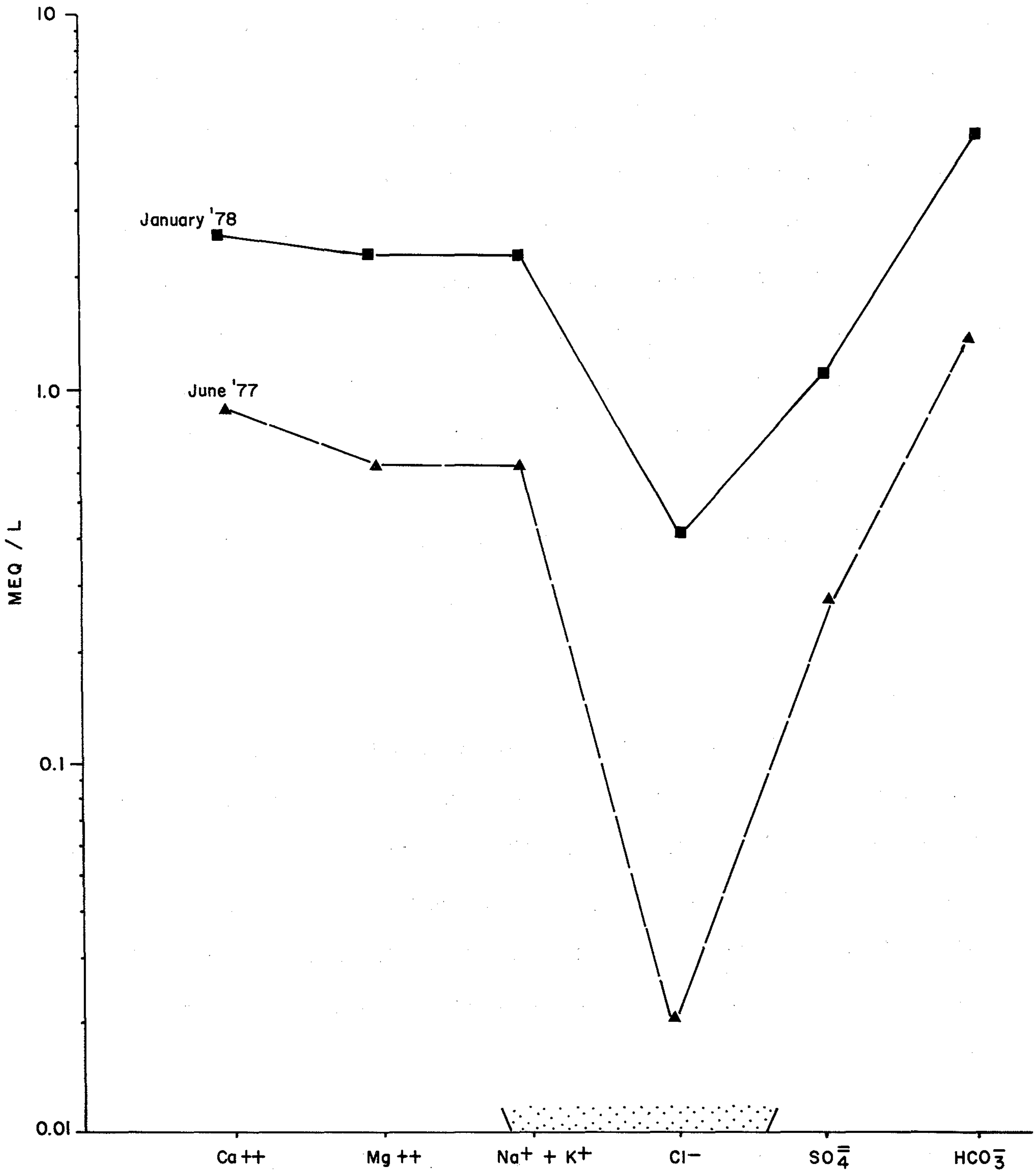


FIGURE 9. Relative values (milli-equivalents per litre, meq) for major ions in waters from the MacKay River.

the major ions. The water is basically of the calcium bicarbonate type but, during the winter, as salinity increases, there is a shift toward the sodium chloride type. Concentrations of the chloride ion, in particular, increase relative to those of other ions. The suggestion has already been made above, that the changes in concentration of various ions from summer to winter reflect an increase in the proportionate contribution of water from groundwater springs. Figure 10, which compares the proportions of major ions in samples taken at the three sampling stations, indicates that there is a major source of chloride ions between the upper and middle sampling sites. The fact that the Na/Cl ratios fall from the upper station (14.6:1) to the middle (4.1:1) and lower (5.5:1) stations suggests that much of the additional chloride is in the form of sodium chloride.

## Macronutrients

Macronutrients are plant nutrients that are important in determining the primary productivity of lakes and streams. The most important of these are total dissolved nitrogen (TDN) and total dissolved phosphorous (TDP). Reactive silicate ($SiO_2$) is important to diatoms, the most abundant group of periphytic algae, whose frustules are composed of silicates. Seasonal trends in the concentrations of these macronutrients are presented in Figure 11.

TDN concentrations are highest in winter and generally lower during the ice-free season. TDP concentrations were high in the winter and again in June and July during a period of high discharge. They were lowest in

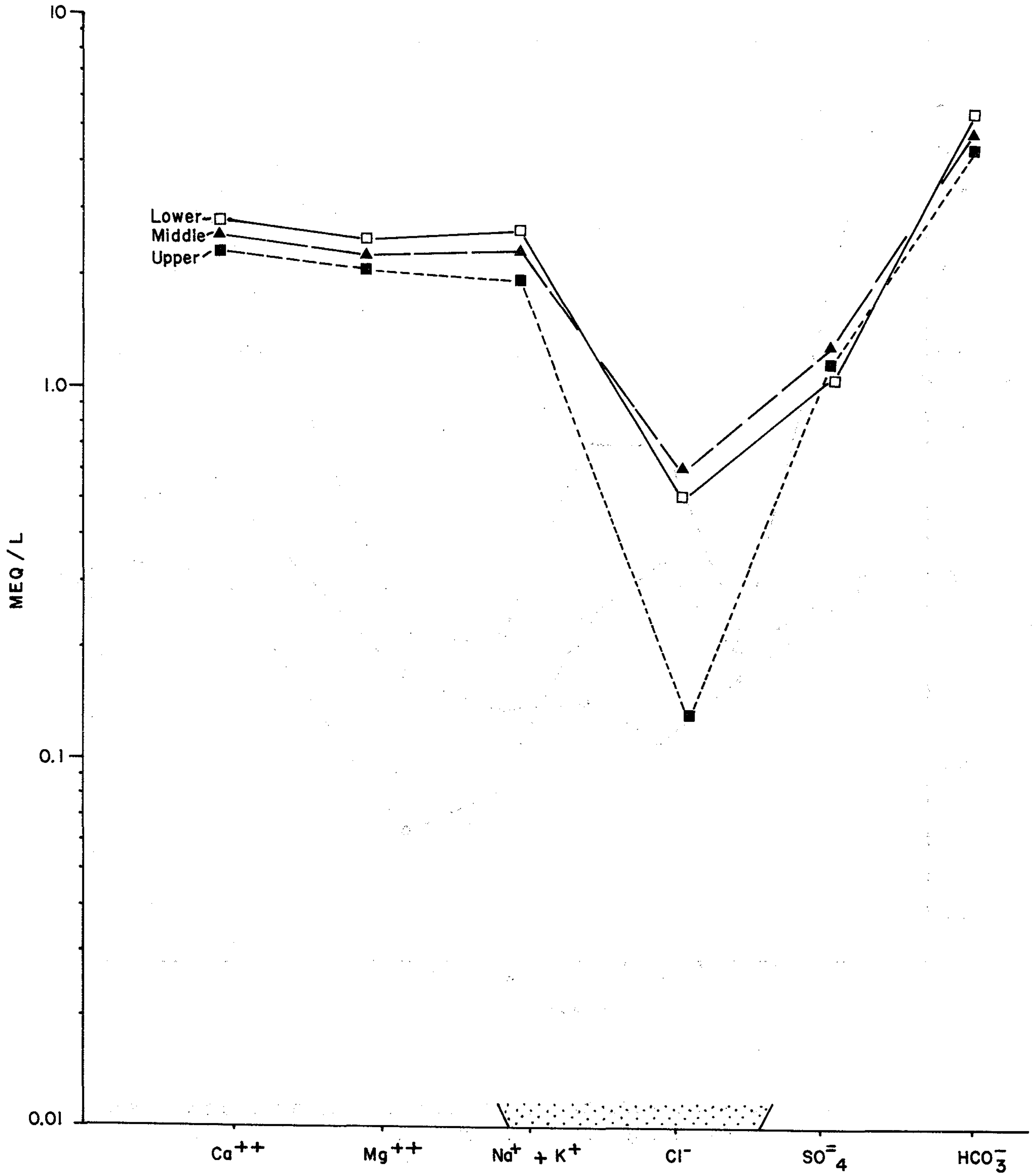


FIGURE 10. Relative mean values (milli-equivalents per litre, meq) for major ions in waters in the Upper, Middle, and Lower Stations on the MacKay River.

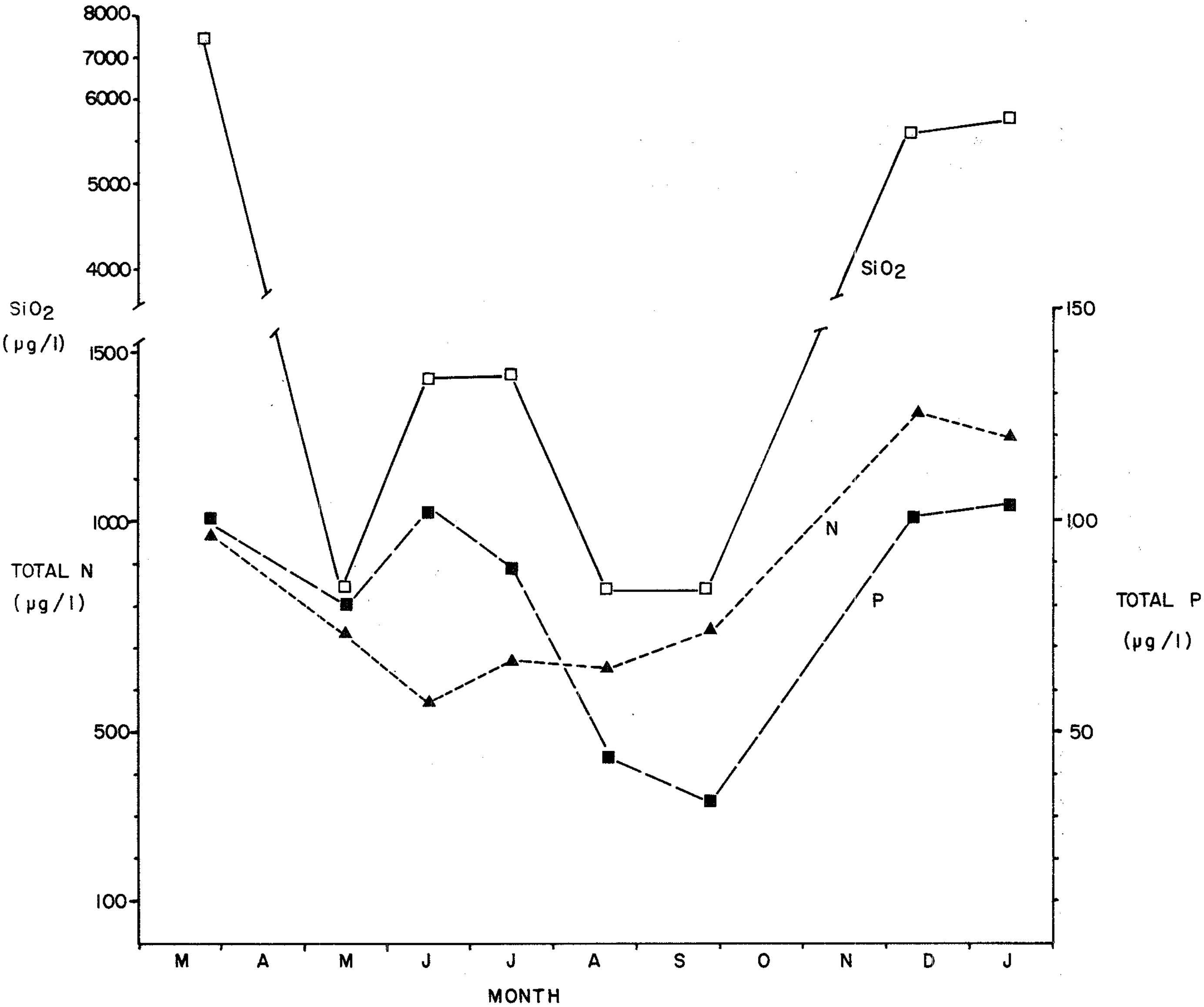


FIGURE 11. Seasonal variation in concentrations of macronutrients in the study area. MacKay River, 1977 and 1978.

August and September. Except for a minor peak in June and July, concentrations of $SiO_2$ were low during the ice-free season but very high during the winter. Overall, the concentrations of macronutrients tended to be highest during the winter and lowest during the summer months.

### Total Organic Carbon

Concentrations of total organic carbon (TOC) were highest in mid-winter (mean 39.7 mg/l in January, 1978) and lowest in mid-summer (mean 16.9 mg/l in July, 1977)(Table 6). With the exception of the July sample, the average of the values for the three sampling stations on the river exceeded 20 mg/l on every occasion. These values are high; higher, for example, than the background levels of 17 to 18 mg/l recorded in late October, 1974, on the Athabasca River near Syncrude's Lease 17 (McCart *et al.*, 1977). The high TOC values are probably related to the presence of exposed oil sands substrate along the MacKay River.

### Comparison of MacKay River Water and Alberta Surface Water Quality Objectives

In Table 6, observed values for selected water quality parameters for samples from the MacKay River are compared with standards described in Surface Water Quality Objectives, Alberta Environment, Water Quality Branch (1977). Values for oil and grease, phenols, boron, iron, lead, mercury, total organic carbon, nitrogen, and cadmium all exceed the recommended standard during at least part of the year. Most of the values which exceed the recommended limits occur during the winter and probably reflect the effects of low dilution and a high proportion of groundwater flow.

# PERIPHYTON

## Introduction

Periphyton or attached algae are the principal primary producers in river systems and form the base of most food chains (Blum, 1956). Algal communities have been found to be useful indicators of water quality conditions in rivers (Cairns *et al.*, 1972; Erth *et al.*, 1972; Northcote *et al.*, 1975; Patrick, 1973). Baseline information describing periphyton communities in the MacKay River drainage are expected to be a useful means of relating present to future conditions and of assessing the effects of development.

Periphyton can be sampled from natural substrates (the surface of stones, twigs, etc.) or by exposing artificial substrates (glass, plexiglass, polished stone, etc.) for a period of time and then examining the periphyton flora which develops. The latter method has the advantage that it reduces sample variability due to differences in habitat, particularly substrate type. Recent studies, however, indicate that the periphyton communities which develop on artificial substrates may differ significantly from those which develop on natural substrates at the same location (Evans and Stockner, 1972; Roeder *et al.*, 1975; Langer and Nassichuk, 1975; Den Beste *et al.*, 1977a). To provide data comparable to those available for the Athabasca River in the vicinity of Syncrude Lease 17, glass artificial substrates were used to assess periphyton populations in the MacKay River. In addition, comparable samples were taken from natural substrates and from plexiglass artificial substrates. Together, the three sampling techniques provide a more complete picture of periphyton communities in the river than any single technique. The studies also provide a basis for determining which of the three techniques would be most appropriate in future monitoring studies on the MacKay River.

## Materials and Methods

Sampling sites are those indicated in Figure 1 and described above. Except when samplers were lost due to flooding or were removed by the public, periphyton samples were collected monthly (May to September, 1977) from natural, plexiglass, and glass substrates. Natural rock substrates were scraped with a brush sampler (Stockner and Armstrong, 1971) that sampled an area of 5.49 $cm^2$. A total of 10 scrapings was combined in a graduated cylinder, agitated vigorously, and divided volumetrically into two, 8 oz jars for species identification (preserved with Lugol's solution) and biomass determination (preserved with 1 ml concentrated formalin). To reduce variability between stations, both depth (10 to 15 cm) and current (20 to 30 cm/sec) were kept as similar as possible.

Glass slides were held in plexiglass racks (Hansmann, 1969) with dimensions 25x8x9 cm, each rack holding 24 slides. A single rack was floated at each station, 0.25 m below the surface although some irregularities occurred due to fluctuations in stream flow and tampering by the public. At monthly intervals, the slides were removed from the samplers. The periphyton on 20 slides was scraped into two, 8 oz jars (10 slides per jar) containing distilled water and preserved as described above. To provide periphyton from plexiglass substrates, each side of the plexiglass rack itself was scraped and the periphyton from the two sides preserved separately for species identification and enumeration and biomass determination. The racks were then cleaned, furnished with new slides, and replaced in the stream.

Sample Analysis

Methods used in determining the accumulated organic biomass of periphyton were those of Stockner and Armstrong (1971) and Standard Methods for the Examination of Water and Wastewater (APHA, 1971). The material was filtered on a preweighed Whatman No. 40 ashless 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. Weights obtained by this method are accurate to $\pm$0.1 mg. Periphyton biomass was estimated for each sample as the loss of organic matter on ignition and converted to mg organic matter/$m^2$ as follows:

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

Periphyton species identification and densities were determined according to the method of Utermöhl (1958), Margalet (1974), and Zoto *et al.* (1973). Samples preserved in Lugol's solution were thoroughly agitated and the volume was determined. A subsample was removed, measured by volume, and allowed to settle in a settling chamber. Volume of the subsample depended upon density of the original sample (i.e., amount of silt, detritus, etc.). Settling time was based upon three hours per cm of chamber height. Counts and identifications were made to the species level where possible, using a Wild M40 Inverted Microscope equipped with phase contrast illumination with magnifications of 750x for enumeration and up to 1875x for identification. All counts were expressed as cells/$cm^2$; counts for large colonies and filamentous forms were determined by estimating the number of cells present.

For the identification and enumeration of diatoms, the upper portion of a second subsample was removed after settling, leaving a film of liquid and the settled organisms. The remaining liquid was evaporated at a temperature of 38 C. The coverslips with the organisms were then ashed in a muffle furnace (560 C $\pm$ 10 C for 15 min) to remove all debris and extraneous organic matter. The cleared diatoms were mounted in Piccolyte and examined under the microscope. This method allows accurate identification of diatoms in the original subsample by comparison with cleaned diatoms in the ashed subsample.

Identification of periphyton was based upon the works of Bourrelly (1968), Cleve-Euler (1951-1955), Desikachary (1959), Hillard (1966, 1967), Patrick and Reimer (1966, 1975), Prescott (1962), Skuka (1948, 1964), Smith (1950), Sreevinasa and Duthie (1973), Tiffany and Britton (1952), and Tilden (1910).

Species Diversity

Shannon-Weaver species diversity indices (Shannon and Weaver, 1949) were computed for all periphyton samples by the machine formula of Lloyd *et al.* (1968). This formula is:

$$\bar{d} = \frac{C}{N} (N \; Log_{10} \; N - \Sigma n_i \; Log_{10} \; n_i)$$

where: C = 3.32193

N = total number of individuals

$n_i$= total number of individuals in the $i^{th}$ species (form)

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 10. 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. Most benthic freshwater communities in streams which are not severely polluted have diversities ranging from 2-4 (Wilhm, 1970). In this study, each $\bar{d}$ value obtained was compared with a hypothetical maximum based on MacArthur's broken stick model (MacArthur, 1957) of natural populations (population with a few relatively abundant species and increasing numbers of species with only a few individuals). Such a comparison results in an index termed "equitability" or "e" by Lloyd and Ghelardi (1964). Equitability values were computed by using Table 5 in Weber (1973) in conjunction with the following formula:

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

where: S = number of species (forms) in the sample

S'= the tabulated number of species from MacArthur's model of equal diversity

Values of "e" normally range from 0 to 1. Environmental Protection Agency biologists in the U.S. have found the equitability index to be very sensitive to even slight levels of environmental degradation, provided the stream communities are adequately censused. In natural streams, "e" values range between 0.6-0.8, while in stressed streams values are usually below 0.5. Values higher than 1.0 result when the distribution of individuals among the species is more even than predicted by MacArthur's broken stick model (MacArthur, 1957).

## Results

Complete data for the periphyton studies are presented in Table 7.

### Standing Crop

#### Density

Seasonal variations in the density of periphytic algae are illustrated, by substrate type and sample location, in Figures 12 through 14 (data from Table 7). The densities were generally highest on natural substrates, ranging up to $1.4 \times 10^6$ cells/$cm^2$ (at the Upper Station in November).

TABLE 7. Total counts (as cells/cm$^2$) for the periphytic algae from the MacKay River at the Lower, Mid, and Upper Stations for May-September, 1977. The substrate type, number of species, diversity index, and equitability values are also given for each sample. N=natural substrate, P=plexiglass substrate, G=glass substrate. Dominant species within each sample are indicated with an asterisk. The N and P samples taken August 15 at the Lower Station were insufficiently preserved to permit species enumeration. Species were classified only as R=rare, O=occasional, C=common, and A=abundant.

UPPER STATION

| | June 15 N | June 15 P | June 15 G | July 7 N | July 7 P | July 7 G | Aug. 17 N | Aug. 17 G | Sept 29 N | Sept 29 P | Sept 29 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chlorophyta | | | | | | | | | | | |
| *Ankistrodesmus convolutus* | 103 | 46 | 91 | 257 | | | | | 30,828 | 3,857 | 91 |
| *A. falcatus* var. *acicularis* | | | 91 | | | | | | | 4,133 | 28,305 |
| *A. falcatus* | 103 | | | | 138 | | 772 | 91 | 66,794 | 3,857 | |
| *Carteria* sp. | 103 | | | | | | | | | | |
| *Chlamydomonas* sp. | 103 | | | 257 | | 137 | | | | | |
| *Cladophora* sp. | | | | | | | | | | | |
| *Cosmarium* sp. | 103 | | 274 | 3,855 | 688 | 914 | | | | 276 | |
| *Coelastrum microporum* | | | | | | | | | | | |
| *Closterium leibleinii* | 103 | | 91 | | | | 257 | | | | |
| *C. parvulum* | | | | | | | | | 10,276 | 827 | 730 |
| *Dictyosphaerium ehrenbergianum* | | | | | | | 1,029 | | | | |
| *Euastropsis richteri* | | | | | | | | | | | |
| *Mougeotia* sp. | | | | | | | | | 56,518 | | 365 |
| *Oocystis parva* | | | | | | | | | | | |
| *Pediastrum tetras* | | | | | | | | | | | |
| *Scenedesmus abundans* | | | | | | | | | 20,552 | | |
| *S. bijuga* | | | | | | | | | | | 457 |
| *S. obliquus* | | | | | | | | | | | |
| *S. quadricauda* | | | | | | | | | 20,552 | 1,102 | |
| *Spirogyra* sp. | | | | | | | | | | | |
| *Stigeoclonium stagnatile* | | | | | | | | | | | |
| *Stigeoclonium* sp. | | | | | | | 2,058 | | | | |
| *Tetraedron minimum* | | | | | | | 257 | | 5,138 | 276 | 91 |
| *Ulothrix* spp. | 3,396 | | | | | | | | | | |
| *Zygnema* sp. | | | | | | | | | | | |

(Continued)

TABLE 7. Continued.

| | June 15 N | June 15 P | June 15 G | July 7 N | July 7 P | July 7 G | Aug. 17 N | Aug. 17 G | Sept 29 N | Sept 29 P | Sept 29 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyanophyta | | | | | | | | | | | |
| *Anabaena inaequalis* | | | | | | | | | | 6,061 | |
| *Anabaena* sp. | | | | 12,079 | | 2,649 | | | | | 913 |
| *Chamaesiphon incrustans* | | | | | | 1,188 | | 913 | | | |
| *Chamaesiphon* sp. | | 2,020 | 1,461 | | 1,307 | 183 | 16,461 | | | | |
| *Calothrix braunii* | | | | | | | | 913 | | | |
| *C. fusca* | | | | | | | | | | | |
| *Calothrix* sp. | | | | | | | 12,860 | | | | |
| *Chroococcus minutus* | | | | | | | | | | | |
| *Chroococcus* sp. | | | | | | | | | 30,828 | | |
| *Gloeocapsa* sp. | | | | | | | 4,630 | | | | |
| *Gomphosphaeria lacustris* | | | | 20,560 | | | | | | | |
| *Lyngbya aerugineo-caerulea* | | | | | | | | | | | |
| *L. birgei* | | | | | | | | | | | |
| *L. epiphytica* | | | | | | | | | | | |
| *Lyngbya* sp. | | | | | | 2,558 | | | | 24,244 | |
| *Merismopedia glauca* | | | | 7,196 | | | | | | 4,408 | 3,835 |
| *Oscillatoria minnesotense* | | | | | | | | | | | |
| *O. splendida* | | | | | | | | | | | |
| *O. tenuis* | | | | | | | | | 154,140 | | |
| *Oscillatoria* spp. | | | | | | | 7,973 | | | 4,133 | |
| *Phormidium* sp. | 7,203 | 14,780 | 15,338 | 21,074 | 99,144 | 51,147 | 60,652 | 14,060 | 236,348 | 34,162 | |
| *Rivularia* spp. | | | | | | | | | | | |
| *Spirulina princeps* | | | | | | | | | | | |
| *Tolypothrix limbata* | | | | | | | | | | | |

(Continued)

TABLE 7. Continued.

| | June 15 N | June 15 P | June 15 G | July 7 N | July 7 P | July 7 G | Aug. 17 N | Aug. 17 G | Sept 29 N | Sept 29 P | Sept 29 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chrysophyta | | | | | | | | | | | |
| Class Chrysophyceae | | | | | | | | | | | |
| *Chrysolykos planctonicus* | | | | | | | | | | | |
| *Dinobryon sertularia* | 103 | | | | | | | | | | |
| *D. sociale* | | | | | | | | | | | |
| *Epipyxis* sp. | | | | | | | | | | | |
| *Ochromonas* spp. | | | | | | | | | | | |
| *Pseudokephyrion undulatissimum* | | | | | | | | | | | |
| *Salpingoeca frequentissima* | | | | | | | | 457 | | 3,582 | 91 |
| *Stokesiella* sp. | | | | | | | | | | | |
| Class Bacillariophyceae | | | | | | | | | | | |
| *Achnanthes exigua* | | | | 771 | | | | | 5,138 | | |
| *A. flexella* | | | | | | | | | | | |
| *A. lanceolata* | 309 | | | | | 92 | | | 5,138 | | |
| *A. lanceolata* var. *dubia* | | | | | | | | | | | |
| *A. linearis* var. *curta* | | | | | | | | | | | |
| *A. minutissima* | | | | | | 137 | | | | | |
| *Achnanthes* spp. | 206 | 92 | | | | 274 | 772 | 365 | | 1,102 | 91 |
| *Amphipleura pellucida* | 309 | | | 514 | | | | | 30,828 | 7,163 | 183 |
| *Amphora ovalis* | | | | | | | | | | | |
| *Amphora* spp. | | | | | | | | | 5,138 | | |
| *Cocconeis pediculus* | 103 | 92 | | 2,313 | 206 | 411 | 6,944 | 1,735 | 35,966 | 1,653 | 183 |
| *C. placentula* var. *lineata* | | 4,957 | 26,568 | 3,084 | 10,802 | 5,795 | 1,029 | 52,041 | 5,138 | 1,378 | 457 |
| *Cymbella minuta* | | | | | | | 257 | | | 276 | |
| *C. postrata* var. *auerswaldii* | | | | | | | | | | | |
| *C. sinuata* | | | | 257 | 69 | | | | 5,138 | | |
| *C. subaequalis* var. *krass* | | | | | | | | | | 276 | |

(Continued)

TABLE 7. Continued.

| | June 15 N | June 15 P | June 15 G | July 7 N | July 7 P | July 7 G | Aug. 17 N | Aug. 17 G | Sept 29 N | Sept 29 P | Sept 29 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cymbella* spp. | | | 91 | 257 | | | | | | 827 | |
| *Cyclotella meneghiana* | | | | | | | 772 | | 35,966 | 276 | 1,278 |
| *Cyclotella* sp. | | | 91 | 514 | | 92 | | | | 551 | |
| *Diatoma hiemale* | | | | | | | | | | | |
| *D. tenue* var. *elongatum* | | | | | | | | | | | |
| *D. tenue* | 206 | | 91 | | | 92 | | | | 8,265 | 91 |
| *D. vulgare* | | | | | 138 | | | | | | |
| *Diatoma* spp. | | | | | | | | | | | |
| *Epithemia emarginulata* | | | | | | | 257 | | | | |
| *E. sorex* | 412 | 275 | 822 | 771 | 826 | 1,507 | 8,488 | 2,283 | 133,588 | 23,969 | 1,917 |
| *E. turgida* | | 413 | 91 | | 138 | 1,873 | 2,572 | 7,578 | 20,552 | 551 | 365 |
| *Fragilaria vaucheriae* | | | | | | | 772 | | 10,276 | 276 | 274 |
| *Fragilaria* spp. | | | | | | | | | | | |
| *Frustulia rhomboides* | 103 | | | | | | | | | | |
| *Gomphonema angustatum* | 309 | | | | 138 | | | | 5,138 | | |
| *G. intricatum* | | | | | | 46 | | | 5,138 | | |
| *G. olivaceum* | | | | | | | | | | | |
| *G. parvulum* | 103 | 46 | | | | 46 | | 457 | | 551 | 274 |
| *G. ventricosum* | | | | | | | | | 20,552 | 1,653 | 183 |
| *Gomphonema* spp. | | 918 | 730 | | 1,376 | 1,233 | 1,543 | | | 6,061 | 365 |
| *Gyrosigma acuminatum* | | | | | | | | | | | |
| *Gyrosigma* sp. | | | | | | | | | | | |
| *Hannaea arcus* | 206 | | | | | | | | | | |
| *Melosira varians* | 412 | | | | | | | | | | |
| *Melosira* sp. | 206 | | | | | | | | | | |
| *Navicula angusta* | 103 | | | | | | | | | | |
| *N. arvensis* | 206 | | | | | | | | | | 91 |
| *N. aurora* | | | | | | | | | | | |
| *N. capitata* | 103 | | | | | | | | 10,276 | | |
| *N. cryptocephala* | 617 | 321 | 365 | 2,570 | 344 | 366 | 514 | 183 | | 1,929 | 365 |
| *N. cryptocephala* var. *venter* | | | | | | | | | 5,138 | | |

(Continued)

TABLE 7. Continued.

| | June 15 N | June 15 P | June 15 G | July 7 N | July 7 P | July 7 G | Aug. 17 N | Aug. 17 G | Sept 29 N | Sept 29 P | Sept 29 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *N. elginensis* | 103 | | | | | | | | | | 91 |
| *N. graciloides* | | | | | | | | | 5,138 | | |
| *N. pupula* var. *capitata* | | | | | | | | | | | |
| *N. pupula* var. *rectangularis* | 103 | | | 257 | | | | | | | 91 |
| *N. radiosa* | | | 183 | | | | 772 | | 15,414 | | |
| *N. rhyncocephala* | 206 | | | | | | | | | | |
| *N. salinarum* var. *intermedia* | | | | | | | | | 30,828 | 2,204 | 274 |
| *N. tripunctata* | | | 91 | | | | | | | | 183 |
| *N. viridula* | 103 | | | | | | | | | | |
| *N. viridula* var. *avenacea* | | | | | | | | | | | |
| *N. viridula* var. *linearis* | | | | | | | | | | | |
| *Navicula* spp. | 515 | 92 | | 1,542 | | 457 | | | 41,104 | 2,755 | 456 |
| *Neidium binode* | | | | | | | | | 5,138 | | |
| *Neidium* sp. | | | | | | | | | | | |
| *Nitzschia acicularis* | 926 | | | 1,028 | | 92 | | | 10,276 | 276 | 183 |
| *N. dissipata* | 309 | | | | 69 | 46 | | | | | |
| *N. sigma* | 206 | | | | | | | | | | |
| *N. vermicularis* | | | | | | | | | | | |
| *Nitzschia* spp. | 5,557 | 1,056 | 3,013 | 6,682 | 619 | 1,461 | 2,829 | 1,187 | 262,038 | 122,323 | 19,082 |
| *Pinnularia* sp. | 103 | | | | | | | | | | |
| *Rhopalodia gibba* | | | | | | | | | | | |
| *Rhoicosphenia curvata* | | 92 | | | | | | | | | |
| *Stepharodiscus hantzschia* | 515 | | | | | | | | | | |
| *Surirella angustata* | | | | | 69 | | | | | | |
| *S. ovalis* | | | | | | | | | | | |
| *Synedra delicatissima* | | | | | | | | | | | |
| *S. mazamaensis* | | | | | | | | | | | |
| *S. rumpens* | | | | | | | | | | | |

(Continued)

TABLE 7. Continued.

| | June 15 N | June 15 P | June 15 G | July 7 N | July 7 P | July 7 G | Aug. 17 N | Aug. 17 G | Sept 29 N | Sept 29 P | Sept 29 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *S. ulna* | 412 | 46 | | | | | | | 5,138 | 551 | |
| *S. ulna* var. *amphirhyncus* | | | | | | | | | | | |
| *S. ulna* var. *danica* | | | | | | | | | | | |
| *Synedra* sp. | | | 183 | | | | | | | | |
| *Tabellaria flocculosa* | | | | | | | | | | | |
| Euglenophyta | | | | | | | | | | | |
| *Euglena gracilis* | | | | | | | | | | | |
| *Phacus* sp. | | | | | | | | | | 276 | |
| *Trachelomonas* spp. | | | | | | | | | | | |
| Cryptophyta | | | | | | | | | | | |
| *Cryptomonas* sp. | 206 | | | 257 | | | | | | | |
| *Rhodomonas minuta* | | | | 257 | | | 257 | | | | |
| Total cells/cm$^2$ | 24,497 | 25,246 | 49,665 | 86,342 | 116,071 | 124,952 | 134,727 | 82,263 | 1,356,432 | 275,784 | 35,880 |
| No. of Species (t) | 37 | 15 | 18 | 22 | 16 | 24 | 24 | 13 | 36 | 36 | 30 |
| Shannon-Weaver Species Diversity Index ($\bar{d}$) | 2.44 | 1.38 | 1.30 | 2.22 | 0.63 | 1.30 | 2.03 | 1.26 | 2.73 | 2.17 | 1.94 |
| Equitability (e) | 0.19 | 0.20 | 0.17 | 0.27 | 0.13 | 0.13 | 0.21 | 0.23 | 0.25 | 0.17 | 0.17 |
| Biomass mg/m$^2$ | 1449.3 | 1464.6 | 374.7 | 1594.2 | 1072.3 | 775.2 | 1811.6 | 356.6 | 29565.2 | 3484.8 | 1206.7 |

(Continued)

TABLE 7. Continued.

MIDDLE STATION

| | June 16 P | June 16 G | July 15 N | July 15 P | July 13 G | Aug. 20 N | Aug. 20 P | Aug. 20 G | Sept 28 N | Sept 28 P | Sept 28 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chlorophyta | | | | | | | | | | | |
| *Ankistrodesmus convolutus* | | | 412 | 198 | | | 66 | | 2,569 | 790 | |
| *A. falcatus* var. *acicularis* | 198 | | | | | | | 366 | | 8,690 | 354 |
| *A. falcatus* | | | | | | | | | 12,845 | | 1,416 |
| *Carteria* sp. | | | | | | | | | | | |
| *Chlamydomonas* sp. | | | | | | | | | | | |
| *Cladophora* sp. | | | | | | | | | | | |
| *Cosmarium* sp. | | 183 | 412 | 1,778 | 4,750 | 12,845 | | 366 | 2,569 | | |
| *Coelastrum microporum* | | | | | | | | | | | 472 |
| *Closterium leibleinii* | | 91 | 103 | | 183 | 2,569 | | | 2,569 | | |
| *C. parvulum* | | | | | | | | | | | 354 |
| *Dictyosphaerium ehrenbergianum* | | | | | | | | | | | |
| *Euastropsis richteri* | | | | | | | | | | | |
| *Mougeotia* sp. | | | | | | | | | 7,707 | | |
| *Oocystis parva* | | | 206 | | | | | | | | |
| *Pediastrum tetras* | | | | | | | | | 20,552 | | |
| *Scenedesmus abundans* | | | | | | | | | 10,276 | | |
| *S. bijuga* | | | 617 | | | | | | | | |
| *S. obliquus* | | | | | | | | | | | |
| *S. quadricauda* | | | | | | | | | | 395 | 472 |
| *Spirogyra* sp. | | | | | | | | | 2,569 | 395 | 354 |
| *Stigeoclonium stagnatile* | | | | | | 97,070 | | | | | |
| *Stigeoclonium* sp. | | | | | | | | | | | 2,596 |
| *Tetraedron minimum* | | | | | | | | | | 395 | 118 |
| *Ulothrix* spp. | | | | | | | | | | | |
| *Zygnema* sp. | | | | | | | | | | | |

(Continued)

TABLE 7. Continued.

| | June 16 P | June 16 G | July 15 N | July 15 P | July 13 G | Aug. 20 N | Aug. 20 P | Aug. 20 G | Sept 28 N | Sept 28 P | Sept 28 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyanophyta | | | | | | | | | | | |
| *Anabaena inaequalis* | | | | | | | | | | | |
| *Anabaena* sp. | | 1,643 | | | | | | | 107,898 | | |
| *Chamaesiphon incrustans* | | | | | | | | | | | |
| *Chamaesiphon* sp. | 790 | | | | | | | | | | |
| *Calothrix braunii* | | | | | | | | | | | |
| *C. fusca* | | | | | | | | | | | |
| *Calothrix* sp. | | | | | | | | | 46,242 | | |
| *Chroococcus minutus* | | | | | | | | | | | |
| *Chroococcus* sp. | | | | | | | | | | | |
| *Gloeocapsa* sp. | | | | | | | | | | | |
| *Gomphosphaeria lacustris* | | | | | | | | | | | |
| *Lyngbya aerugineo-caerulea* | | | | | | | | | | | |
| *L. birgei* | | | | | | | | | | 8,690 | |
| *L. epiphytica* | | | | | | | | | | | |
| *Lyngbya* sp. | | | | | | | | | | | |
| *Merismopedia glauca* | | | | | | | | | | | |
| *Oscillatoria minnesotense* | | | | | | | | | | | |
| *O. splendida* | | | | | | 35,966 | | 21,199 | | | 2,124 |
| *O. tenuis* | | | | | | | | | | | |
| *Oscillatoria* spp. | | | | | | 51,380 | | | | | |
| *Phormidium* sp. | 14,622 | 8,765 | 3,910 | 29,838 | 77,618 | 400,764 | 1,186 | 20,103 | 310,849 | 53,325 | 7,434 |
| *Rivularia* spp. | | | | 1,186 | | | | | | | |
| *Spirulina princeps* | | | | | | | | | | | |
| *Tolypothrix limbata* | | | | | | | | | 102,760 | | |

(Continued)

TABLE 7. Continued.

| | June 16 P | June 16 G | July 15 N | July 15 P | July 13 G | Aug. 20 N | Aug. 20 P | Aug. 20 G | Sept 28 N | Sept 28 P | Sept 28 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chrysophyta | | | | | | | | | | | |
| Class Chrysophyceae | | | | | | | | | | | |
| *Chrysolykos planctonicus* | | | | | | | 66 | | | | |
| *Dinobryon sertularia* | | | | | | | | | | | |
| *D. sociale* | | | 103 | 99 | | | | | | | |
| *Epipyxis* sp. | | | | | | | | | | 395 | |
| *Ochromonas* spp. | | | | | | | | | | | |
| *Pseudokephyrion undulatissimum* | | | | | | | | | | | |
| *Salpingoeca frequentissima* | | | | | 183 | | 198 | 2,559 | 2,569 | 6,715 | 1,180 |
| *Stokesiella* sp. | | | | | | | | | | | 118 |
| Class Bacillariophyceae | | | | | | | | | | | |
| *Achnanthes exigua* | | | | | | | | | | | |
| *A. flexella* | | | | | | | | | | | |
| *A. lanceolata* | 99 | 365 | | 99 | | | 66 | | | | |
| *A. lanceolata* var. *dubia* | | | | | | 2,569 | | | | | |
| *A. linearis* var. *curta* | | | | | | | 132 | | | | |
| *A. minutissima* | | | | | | | 66 | | | | |
| *Achnanthes* spp. | 889 | 91 | 103 | 395 | 914 | | | 3,655 | 17,983 | 790 | 354 |
| *Amphipleura pellucida* | | | | | 183 | 2,569 | | | 5,138 | | 708 |
| *Amphora ovalis* | | | | | | | | 366 | | | |
| *Amphora* spp. | | | | | | | | | | | |
| *Cocconeis pediculus* | | | 206 | 198 | 183 | | 132 | 731 | 12,845 | 790 | 354 |
| *C. placentula* var. *lineata* | 6,521 | 15,795 | 206 | 12,548 | 24,482 | 5,138 | 8,831 | 39,109 | 7,707 | 13,430 | 14,868 |
| *Cymbella minuta* | | 91 | | | 183 | | | | | | |
| *C. postrata* var. *auerswaldii* | | | | | | | | | | | |
| *C. sinuata* | | | | | | | | | | | |
| *C. subaequalis* var. *krass* | | | | | | | | | | | |

(Continued)

TABLE 7. Continued.

| | June 16 P | June 16 G | July 15 N | July 15 P | July 13 G | Aug. 20 N | Aug. 20 P | Aug. 20 G | Sept 28 N | Sept 28 P | Sept 28 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cymbella* spp. | | | | | | | | | | | |
| *Cyclotella meneghiana* | | | | | | | | 366 | 2,569 | | |
| *Cyclotella* sp. | | | 1,338 | | 183 | 10,276 | | | | | |
| *Diatoma hiemale* | | | | | | | | | | | |
| *D. tenue* var. *elongatum* | | | | | | | | | | | |
| *D. tenue* | 99 | | 103 | | | | 66 | 731 | 5,138 | | 118 |
| *D. vulgare* | | | | | | 2,569 | | | | | |
| *Diatoma* spp. | | | | 99 | | | | | | | |
| *Epithemia emarginulata* | | | | | | | | | | | |
| *E. sorex* | | 548 | 206 | 2,470 | 2,010 | 310,849 | 659 | 1,462 | 267,176 | 40,290 | 12,154 |
| *E. turgida* | 99 | 639 | | 1,186 | 3,106 | | 66 | 366 | 25,690 | 4,345 | 1,180 |
| *Fragilaria vaucheriae* | | | | | | 15,414 | | 366 | 5,138 | | |
| *Fragilaria* spp. | | | 206 | | | 5,138 | | | | | |
| *Frustulia rhomboides* | | | | | | | | | | | |
| *Gomphonema angustatum* | | 365 | 103 | | | | | | | | |
| *G. intricatum* | | | | | | | | | | | |
| *G. olivaceum* | | | | | | | | | | | 118 |
| *G. parvulum* | 198 | 365 | | 198 | 183 | | | | 2,569 | | |
| *G. ventricosum* | 198 | | | | | | | | | | 118 |
| *Gomphonema* spp. | 99 | | | 99 | 914 | 5,138 | 132 | 366 | 10,276 | 1,580 | 590 |
| *Gyrosigma acuminatum* | | | | | | | | | | | 236 |
| *Gyrosigma* sp. | | | | | | | | | | | |
| *Hannaea arcus* | | | | | | | | | | | |
| *Melosira varians* | | | | | | | | | | | |
| *Melosira* sp. | | | | | | | | | | | |
| *Navicula angusta* | | | | 99 | | | | | | | |
| *N. arvensis* | 99 | | | | | | | | | | |
| *N. aurora* | | | | 99 | | | | | | | |
| *N. capitata* | | | | | | | | | | | |
| *N. cryptocephala* | | 457 | 206 | 395 | 548 | 20,552 | | 1,097 | 2,569 | 395 | 826 |
| *N. cryptocephala* var. *venter* | | | | | | 2,569 | | | | | |

(Continued)

TABLE 7. Continued.

| | June 16 P | June 16 G | July 15 N | July 15 P | July 13 G | Aug. 20 N | Aug. 20 P | Aug. 20 G | Sept 28 N | Sept 28 P | Sept 28 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *N. elginensis* | | | | | | | | | | | |
| *N. graciloides* | | | | | | | | | | | |
| *N. pupula* var. *capitata* | | | | | | | | | | | 118 |
| *N. pupula* var. *rectangularis* | | | | | | | | | | | |
| *N. radiosa* | | 274 | | | 183 | | | 731 | | | |
| *N. rhyncocephala* | | | | | | | | | | | |
| *N. salinarum* var. *intermedia* | | | | | | | | 366 | | 790 | |
| *N. tripunctata* | | | | | | 2,569 | | | 7,707 | | |
| *N. viridula* | | | | | | | | | | | |
| *N. viridula* var. *avenacea* | | | | | | | | | | | |
| *N. viridula* var. *linearis* | | | | | | | | | | | 118 |
| *Navicula* spp. | 494 | 457 | 309 | 494 | 1,096 | | | | 38,535 | 790 | 1,062 |
| *Neidium binode* | | | | | | | | | | | |
| *Neidium* sp. | | | | | | | | | | | |
| *Nitzschia acicularis* | | | 103 | | | | | | | | 118 |
| *N. dissipata* | | | | | | | | 366 | | | |
| *N. sigma* | | | | | | | | | | 395 | |
| *N. vermicularis* | | | | | | | | | | | |
| *Nitzschia* spp. | 1,877 | 1,552 | 617 | 3,952 | 6,395 | 23,121 | 330 | 366 | 89,915 | 18,170 | 4,366 |
| *Pinnularia* sp. | | | | | | | | | 2,569 | | |
| *Rhopalodia gibba* | | | | | | | | | 2,569 | | 118 |
| *Rhoicosphenia curvata* | | | | | | | | 366 | 5,138 | 395 | |
| *Stepharodiscus hantzschia* | | | | | 183 | | | | | | |
| *Surirella angustata* | | | | | | | | | | | |
| *S. ovalis* | | | | | | | | | | | |
| *Synedra delicatissima* | | | | | | | | | | | |
| *S. mazamaensis* | | | 103 | | | | | | | | |
| *S. rumpens* | | | | | | | | | | | |

(Continued)

TABLE 7. Continued.

| | June 16 P | June 16 G | July 15 N | July 15 P | July 13 G | Aug. 20 N | Aug. 20 P | Aug. 20 G | Sept 28 N | Sept 28 P | Sept 28 G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *S. ulna* | | | | | | | | | | | 118 |
| *S. ulna* var. *amphirhyncus* | | | | | | | | | | | |
| *S. ulna* var. *danica* | | | | | | | | | | | |
| *Synedra* sp. | | | 206 | | | | | | | | |
| *Tabellaria flocculosa* | | | | | | | | | | | |
| Euglenophyta | | | | | | | | | | | |
| *Euglena gracilis* | | | | | | | | | | | |
| *Phacus* sp. | | | | | | | | | | | |
| *Trachelomonas* spp. | | | | | | | | | | | |
| Cryptophyta | | | | | | | | | | | |
| *Cryptomonas* sp. | | | 103 | | | | | | | | |
| *Rhodomonas minuta* | | | 926 | | | | | | | | |
| Total cells/cm$^2$ | 26,381 | 31,681 | 10,807 | 55,430 | 123,750 | 1,009,065 | 11,996 | 95,408 | 1,143,205 | 161,950 | 54,634 |
| No. of Species (t) | 15 | 16 | 23 | 19 | 19 | 19 | 14 | 21 | 31 | 21 | 31 |
| Shannon-Weaver Species Diversity Index ($\bar{d}$) | 1.37 | 1.48 | 2.40 | 1.61 | 1.27 | 1.73 | 1.10 | 1.71 | 2.32 | 1.98 | 2.34 |
| Equitability (e) | 0.20 | 0.25 | 0.30 | 0.21 | 0.16 | 0.21 | 0.21 | 0.19 | 0.23 | 0.24 | 0.23 |
| Biomass mg/m$^2$ | 311.7 | 240.3 | 579.7 | 875.1 | 529.7 | 15543.5 | | 1054.3 | 19022.7 | 730.2 | 496.1 |

(Continued)

TABLE 7. Continued.

| | LOWER STATION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | May 11 N | July 18 N | July 15 P | July 15 G | Aug. 15 N | Aug. 15 P | Aug. 15 G | Sept 26 N | Sept 26 P | Sept 26 G |
| Chlorophyta | | | | | | | | | | |
| *Ankistrodesmus convolutus* | | | 264 | 46 | | | | 5,778 | 2,963 | 2,127 |
| *A. falcatus* var. *acicularis* | | 1,284 | | | | | | 10,272 | 5,530 | 9,216 |
| *A. falcatus* | | 642 | | | R | R | 47 | | | |
| *Carteria* sp. | | | | | | | | | | |
| *Chlamydomonas* sp. | | | | | | | | 1,284 | 198 | |
| *Cladophora* sp. | | | | | | | | 642 | | |
| *Cosmarium* sp. | | 7,704 | | 91 | R | | | | | 236 |
| *Coelastrum microporum* | | | | | | | | | | |
| *Closterium leibleinii* | | | | | R | | | | | |
| *C. parvulum* | | | | | | | | | | 945 |
| *Dictyosphaerium ehrenbergianum* | | | | | | | | | | |
| *Euastropsis richteri* | | | | | | | | | 395 | |
| *Mougeotia* sp. | | | | | | | | 642 | | 1,182 |
| *Oocystis parva* | | | | | | | | | | |
| *Pediastrum tetras* | | | | | | | | | | |
| *Scenedesmus abundans* | | | | | | | | | | |
| *S. bijuga* | | | | | | | | | | |
| *S. obliquus* | | | | | | | | | 790 | 945 |
| *S. quadricauda* | | | | | | | | | 790 | |
| *Spirogyra* sp. | | | | | | | | 1,284 | | 945 |
| *Stigeoclonium stagnatile* | | | | | | | | | | |
| *Stigeoclonium* sp. | | | | | | | | | | |
| *Tetraedron minimum* | | | | | | | | 642 | | |
| *Ulothrix* spp. | | | 659 | | | | | | | |
| *Zygnema* sp. | | | | | | | | | | 945 |

(Continued)

TABLE 7. Continued.

| | May 11 N | July 18 N | July 15 P | July 15 G | Aug. 15 N | Aug. 15 P | Aug. 15 G | Sept 26 N | Sept 26 P | Sept 26 G |
|---|---|---|---|---|---|---|---|---|---|---|
| Cyanophyta | | | | | | | | | | |
| *Anabaena inaequalis* | | | | | | | | | | |
| *Anabaena* sp. | | | | | | | | | | 10,161 |
| *Chamaesiphon incrustans* | | | | | | | | | | |
| *Chamaesiphon* sp. | | | | | | | | 2,568 | | |
| *Calothrix braunii* | | | | | | | | | | |
| *C. fusca* | | | | | | | | 29,964 | | |
| *Calothrix* sp. | | | | | | | | 44,298 | | |
| *Chroococcus minutus* | | | | | | | | | 1,580 | |
| *Chroococcus* sp. | | | | | | | | | | |
| *Gloeocapsa* sp. | | | | | | | | | | |
| *Gomphosphaeria lacustris* | | | | | | | | | | |
| *Lyngbya aerugineo-caerulea* | | 1,284 | | | | | | 17,976 | | |
| *L. birgei* | | | | | | | | | | |
| *L. epiphytica* | | | | | | | 568 | | | |
| *Lyngbya* sp. | | | | | | | | | | |
| *Merismopedia glauca* | | | | | | O | 378 | | | 15,123 |
| *Oscillatoria minnesotense* | | | | | | | | | 13,628 | |
| *O. splendida* | | | | | | | | | | |
| *O. tenuis* | 3,855 | | | | | | | | | |
| *Oscillatoria* spp. | | | | | | | | 26,322 | | |
| *Phormidium* sp. | | 24,396 | 6,722 | 3,245 | O | C | 11,800 | | | 64,983 |
| *Rivularia* spp. | 3,426 | | | | | | | | | |
| *Spirulina princeps* | | | | | | | | 642 | | |
| *Tolypothrix limbata* | | | | | | | | | | |

(Continued)

TABLE 7. Continued.

| | May 11 N | July 18 N | July 15 P | July 15 G | Aug. 15 N | Aug. 15 P | Aug. 15 G | Sept 26 N | Sept 26 P | Sept 26 G |
|---|---|---|---|---|---|---|---|---|---|---|
| Chrysophyta | | | | | | | | | | |
| Class Chrysophyceae | | | | | | | | | | |
| *Chrysolykos planctonicus* | | | | | | | | | | |
| *Dinobryon sertularia* | | | | | | | | | | |
| *D. sociale* | 428 | | | | | | | | | |
| *Epipyxis* sp. | | | | | | | | | 198 | |
| *Ochromonas* spp. | | | | | | | | 642 | | |
| *Pseudokephyrion undulatissimum* | | | | | | | | | | |
| *Salpingoeca frequentissima* | | | 66 | 46 | | O | 47 | | 988 | 473 |
| *Stokesiella* sp. | | | | | | | | | | |
| Class Bacillariophyceae | | | | | | | | | | |
| *Achnanthes exigua* | | | | | R | | 95 | | | |
| *A. flexella* | | | | | | | | | 198 | |
| *A. lanceolata* | 1,285 | 1,926 | 198 | | | | | | 988 | |
| *A. lanceolata* var. *dubia* | | | | | R | | 284 | | | |
| *A. linearis* var. *curta* | | | | | | | | | | |
| *A. minutissima* | | | | | R | | 189 | | | |
| *Achnanthes* spp. | | | 264 | 46 | | | | | 1,185 | 236 |
| *Amphipleura pellucida* | | | | | | | | 642 | | 1,182 |
| *Amphora ovalis* | | | | | | | | | 198 | |
| *Amphora* spp. | | | | | | | | | 198 | |
| *Cocconeis pediculus* | 428 | | 527 | | | | | 1,284 | 593 | |
| *C. placentula* var. *lineata* | 428 | 642 | 3,954 | 4,067 | | A | 1,892 | | 4,345 | 9,216 |
| *Cymbella minuta* | | | | | | | | | | |
| *C. postrata* var. *auerswaldii* | | | | | | | | | 198 | |
| *C. sinuata* | | | | | | | | | | |
| *C. subaequalis* var. *krass* | | | | | | | | | | |

(Continued)

TABLE 7. Continued.

| | May 11 N | July 18 N | July 15 P | July 15 G | Aug. 15 N | Aug. 15 P | Aug. 15 G | Sept 26 N | Sept 26 P | Sept 26 G |
|---|---|---|---|---|---|---|---|---|---|---|
| *Cymbella* spp. | | | 66 | 137 | | | | | | |
| *Cyclotella meneghiana* | | 3,210 | | | O | | | | 593 | 709 |
| *Cyclotella* sp. | 21,415 | | | 91 | | | | | | |
| *Diatoma hiemale* | | | | | | | | | 395 | |
| *D. tenue* var. *elongatum* | | | | | | | | 1,284 | | |
| *D. tenue* | 2,570 | | | | | | | 642 | | |
| *D. vulgare* | | | | | | | | | | |
| *Diatoma* spp. | | | | | | | | | | |
| *Epithemia emarginulata* | | | | | | | | | | |
| *E. sorex* | 428 | 1,926 | 330 | 183 | A | | 284 | 24,396 | 3,555 | 2,363 |
| *E. turgida* | | | 4,284 | 823 | O | C | 615 | | 1,185 | 2,836 |
| *Fragilaria vaucheriae* | | | | | | | | | | |
| *Fragilaria* spp. | 1,285 | | | | | | | | | |
| *Frustulia rhomboides* | | 642 | | | | | | | 198 | |
| *Gomphonema angustatum* | | | | | | | | | | |
| *G. intricatum* | | | | | | | | | | |
| *G. olivaceum* | | | | | | R | | | | |
| *G. parvulum* | | | | | R | | 237 | | 593 | 709 |
| *G. ventricosum* | | | | | | | | | | |
| *Gomphonema* spp. | 1,285 | 1,284 | | 137 | | | | | 2,370 | 945 |
| *Gyrosigma acuminatum* | | | | | | | | | | |
| *Gyrosigma* sp. | | | | 91 | | R | | | | |
| *Hannaea arcus* | | | | | | | | | | |
| *Melosira varians* | | | | | | | | | | |
| *Melosira* sp. | | | | | | | | | | |
| *Navicula angusta* | | | 264 | | | | | | | |
| *N. arvensis* | | 642 | | | | | | | 593 | |
| *N. aurora* | | | | | | | | | | |
| *N. capitata* | | | | | | | 95 | | | |
| *N. cryptocephala* | 428 | 1,926 | 725 | 2,468 | | R | | | 395 | 1,182 |
| *N. cryptocephala* var. *venter* | | | | | | | | | | 1,418 |

(Continued)

TABLE 7. Continued.

| | May 11 N | July 18 N | July 15 P | July 15 G | Aug. 15 N | Aug. 15 P | Aug. 15 G | Sept 26 N | Sept 26 P | Sept 26 G |
|---|---|---|---|---|---|---|---|---|---|---|
| *N. elginensis* | | | | | | | | | | |
| *N. graciloides* | | | | | | | | | | |
| *N. pupula* var. *capitata* | | | | | | | | | | |
| *N. pupula* var. *rectangularis* | | | | | | | | 642 | | |
| *N. radiosa* | | | | 91 | | | | | 198 | |
| *N. rhyncocephala* | | 642 | 66 | 274 | | | | | | |
| *N. salinarum* var. *intermedia* | | | | | | O | 95 | 642 | 593 | 2,836 |
| *N. tripunctata* | | | | | R | | | | | 473 |
| *N. viridula* | | | | | | | | | | |
| *N. viridula* var. *avenacea* | | | | | | R | | | | |
| *N. viridula* var. *linearis* | | | 66 | | | | | | | |
| *Navicula* spp. | | 8,346 | 791 | 686 | | O | | 3,852 | 2,765 | 473 |
| *Neidium binode* | | | | | | | | | | |
| *Neidium* sp. | | | | | R | | | | | |
| *Nitzschia acicularis* | 2,570 | 642 | | | | | | 2,568 | | 473 |
| *N. dissipata* | | | | | | | | 642 | | |
| *N. sigma* | | 642 | | | | | | | 198 | |
| *N. vermicularis* | | | | | | R | | | 198 | 236 |
| *Nitzschia* spp. | 4,283 | 5,136 | 923 | 1,280 | C | O | 4,588 | 12,840 | 5,530 | 7,325 |
| *Pinnularia* sp. | | | | | | | | | | |
| *Rhopalodia gibba* | | | | | | | | 2,568 | | |
| *Rhoicosphenia curvata* | 428 | 1,284 | 66 | | | | | 1,284 | 395 | |
| *Stepharodiscus hantzschia* | 428 | | | | | | | | | |
| *Surirella angustata* | | | | 46 | | | | | | |
| *S. ovalis* | 428 | | | | | | | | | |
| *Synedra delicatissima* | | | | | O | | | | | |
| *S. mazamaensis* | 428 | | | | | | | | | |
| *S. rumpens* | 1,713 | | | | | | | | | |

(Continued)

TABLE 7. Continued.

| | May 11 N | July 18 N | July 15 P | July 15 G | Aug. 15 N | Aug. 15 P | Aug. 15 G | Sept 26 N | Sept 26 P | Sept 26 G |
|---|---|---|---|---|---|---|---|---|---|---|
| *S. ulna* | 5,140 | | | | | | | | | |
| *S. ulna* var. *amphirhyncus* | | | | | | | | | | 236 |
| *S. ulna* var. *danica* | | | | | | | | | 593 | |
| *Synedra* sp. | | | | | | | | | | |
| *Tabellaria flocculosa* | | | | | | | 47 | | | |
| Euglenophyta | | | | | | | | | | |
| *Euglena gracilis* | 428 | | | | | | | | | |
| *Phacus* sp. | | | | | | | | | | |
| *Trachelomonas* spp. | | | 66 | | | | | | | |
| Cryptophyta | | | | | | | | | | |
| *Cryptomonas* sp. | | | | | | | | | 198 | |
| *Rhodomonas minuta* | | | | | | | | 1,284 | | |
| Total cells/cm$^2$ | 53,107 | 63,558 | 20,301 | 13,848 | - | - | 21,261 | 193,242 | 55,498 | 140,129 |
| No. of Species (t) | 21 | 19 | 19 | 18 | - | - | 16 | 28 | 36 | 30 |
| Shannon-Weaver Species Diversity Index ($\bar{d}$) | 2.23 | 2.20 | 2.00 | 1.98 | - | - | 1.46 | 2.45 | 2.80 | 2.10 |
| Equitability (e) | 0.29 | 0.32 | 0.32 | 0.28 | - | - | 0.19 | 0.25 | 0.28 | 0.20 |
| Biomass mg/m$^2$ | 5181.2 | 2424.5 | 540.7 | 273.9 | 3007.2 | 457.8 | 320.4 | 4420.3 | 379.0 | 428.9 |

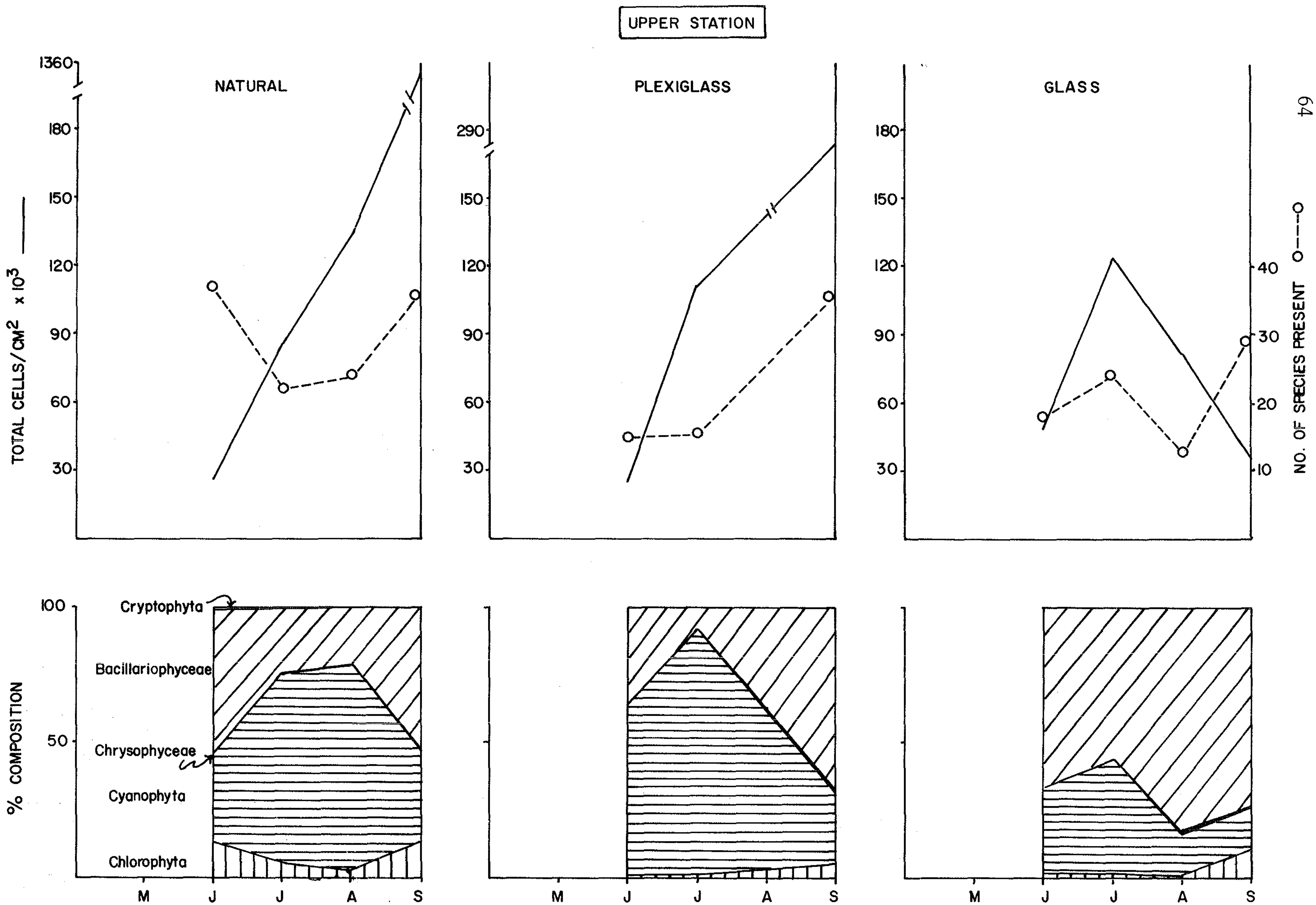


FIGURE 12. Standing crops (as cells/cm$^2$) and relative abundance of periphytic algae from three substrate types at the Upper Station on the MacKay River, June-September, 1977.

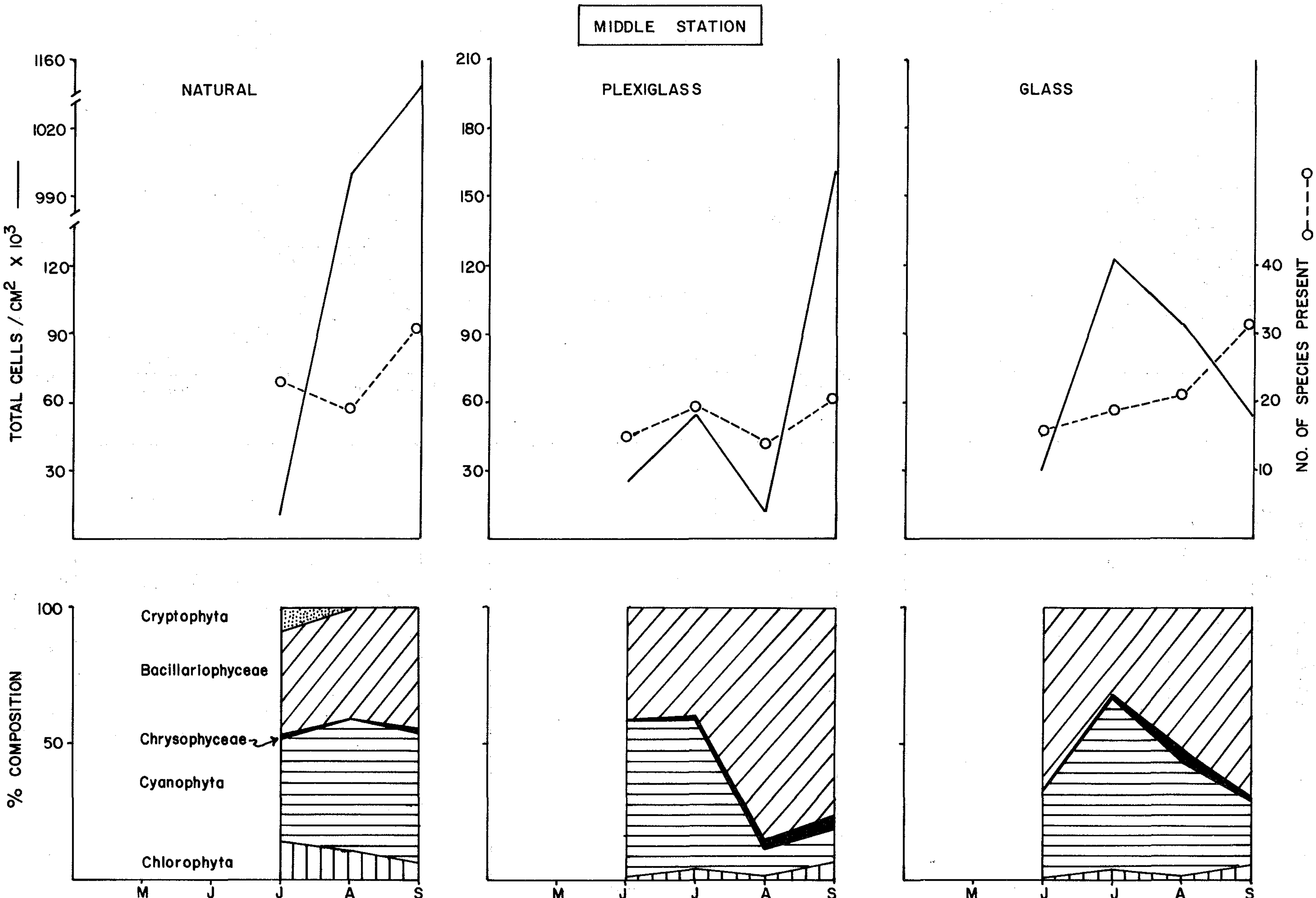


FIGURE 13. Standing crops (as cells/cm$^2$) and relative abundance of periphytic algae from three substrate types at the Middle Station on the MacKay River, June-September, 1977.

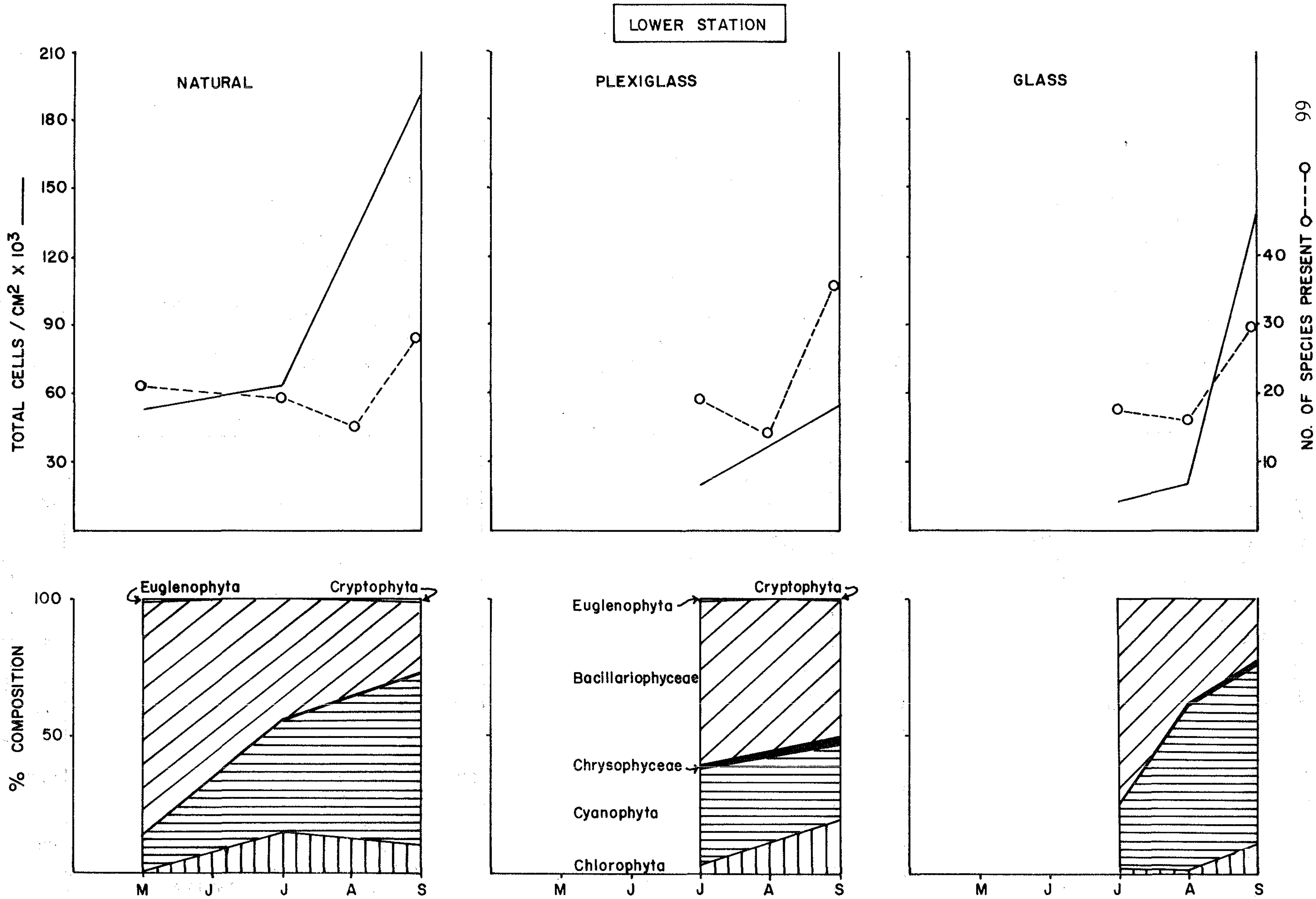


FIGURE 14. Standing crops (as cells/cm²) and relative abundance of periphytic algae from three substrate types at the Lower Station on the MacKay River, May-September, 1977.

The maximum densities on artificial substrates were $275.8 \times 10^3$ cells/cm$^2$ on plexiglass (Upper Station in September) and $140.1 \times 10^3$ cells/cm$^2$ on glass (Lower Station in September). In only three instances, at the Upper Station in June and July and at the Middle Station in July, were the densities recorded for artificial substrates higher than those for associated samples from natural substrates.

A comparison of the densities of periphyton on plexiglass and glass substrates, exposed at the same location and other the same time period, indicated that the densities on glass exceeded those on plexiglass in 5 of 8 instances. This difference is based on too small a sample to be statistically significant, but may indicate a real difference between the two substrates.

In general, the overall densities of periphyton were low throughout the summer (May through August) but increased in September (Figures 12 to 14). Exceptions were the glass substrates at the Middle and Upper Stations which produced peak densities in July. The number of species present on substrates tended to increase in September (Figures 12 to 14).

Biomass

Biomass (as mg/m$^2$) data are presented in Table 8 and Figure 15. The data are distinguished by location, date, and substrate type. The following general conclusions can be drawn:

1) biomass tended to be greatest in September (6 of 9 classes) when the densities of periphyton also tended to be greatest,

TABLE 8. Seasonal variation in periphyton biomass (mg/m$^2$) on natural, plexiglass, and glass substrates at three stations on the MacKay River, May to September, 1977.

| Substrate | Month | Lower | Middle | Upper | Mean |
|---|---|---|---|---|---|
| Natural | May | 5181.2 | 1865.9 | - | |
| | June | - | - | 1449.3 | |
| | July | 2427.5 | 579.7 | 1594.2 | |
| | August | 3007.2 | 15543.5 | 1811.6 | |
| | September | 4420.3 | 19021.7 | 29565.2 | |
| | Mean | 3759.1 | 9252.7 | 8605.1 | 7205.6 |
| Plexiglass | June | - | 317.7 | 1464.6 | |
| | July | 540.7 | 875.1 | 1072.3 | |
| | August | 457.8 | - | 326.3 | |
| | September | 379.0 | 730.2 | 3484.8 | |
| | Mean | 459.2 | 641.0 | 1587.0 | 964.9 |
| Glass | June | - | 240.3 | 374.7 | |
| | July | 273.9 | 529.7 | 775.2 | |
| | August | 320.4 | 1054.3 | 356.6 | |
| | September | 428.9 | 496.1 | 1206.7 | |
| | Mean | 341.1 | 580.1 | 678.3 | 550.6 |

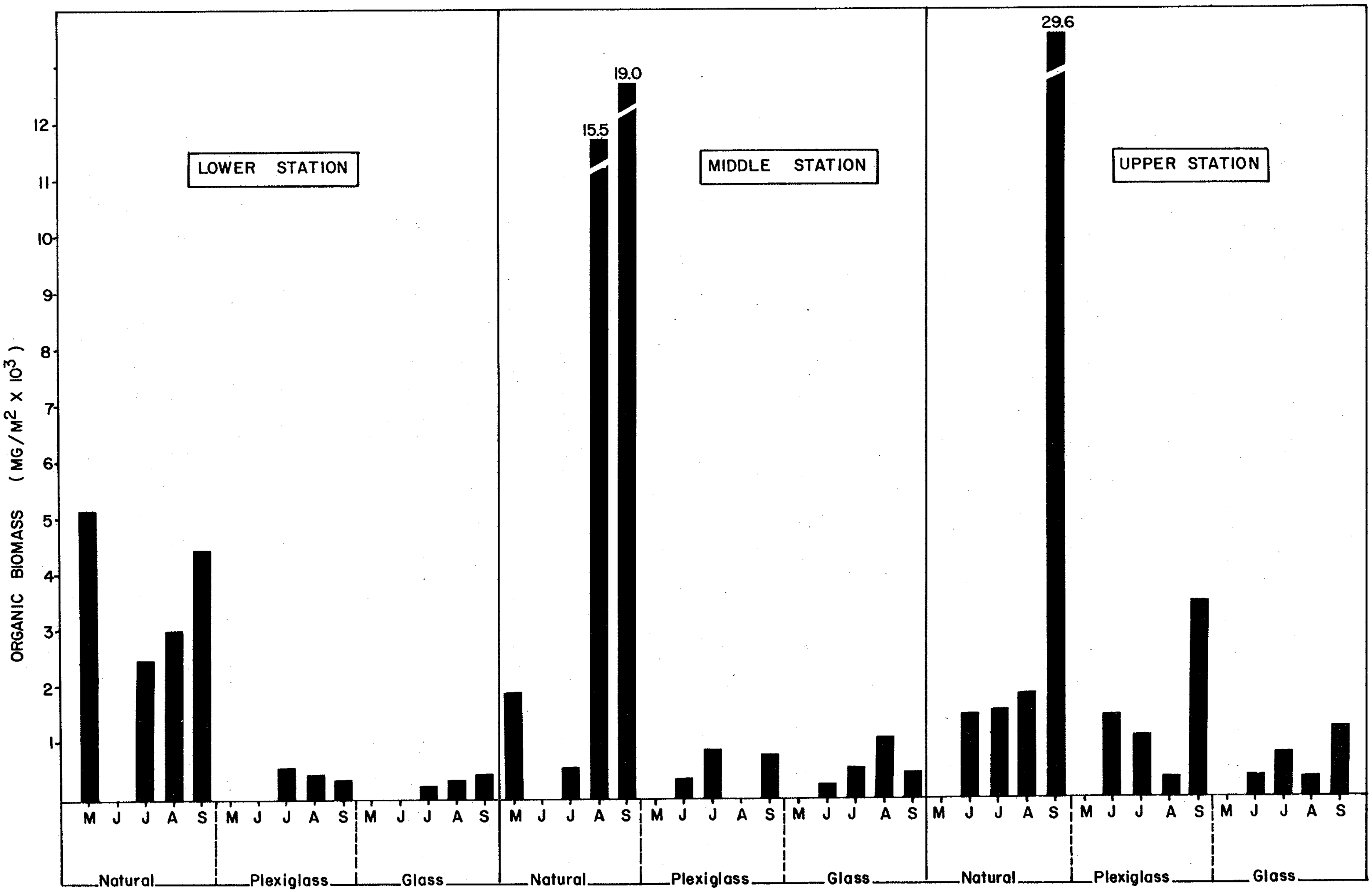


FIGURE 15. Seasonal variation in periphyton biomass ($mg/m^2$) on natural, plexiglass, and glass substrates at three stations on the MacKay River, May to September, 1977.

2) in September there was a definite longitudinal pattern, regardless of substrate, with biomass greatest at the Upper Station and lowest at the Lower Station,

3) biomass was almost always greater on natural substrates than on artificial substrates,

4) of the artificial substrates tested, biomass was usually greater on the plexiglass than on the glass substrates.

Relative Abundance and Seasonal Distribution of Major Groups

Data for the six major groups of periphytic algae in the MacKay River are summarized in Table 9 . Their seasonal distribution and relative abundance are shown in Figures 12 through 14 .

Of the total of 142 algal species recorded in the periphyton communities of the MacKay River, 80 (56.3%) were diatoms (Bacillariophyceae); 25 (17.6%) were green algae (Chlorophyta); 24 (16.9%) were blue-green algae (Cyanophyta); 8 (5.6%) were Chrysophyceae; 3 (2.1%) were euglenoids; and 2 (1.4%) were Cryptophyta.

A comparison (Table 10) of the total number of species and the per cent distribution of the major groups in the present study with data from previous stream studies in western Canada indicates that the periphyton communities of the streams are similar. The total number of species in the MacKay River was greater than that in two smaller streams in British

TABLE 9. Summary of information describing densities of periphyton in six major groups. N=natural substrate, P=plexiglass substrate, G=glass substrate. Data from Table 6. Densities as cells/cm$^2$.

| | | UPPER STATION | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | June 15 | June 15 | June 15 | July 14 | July 14 | July 14 | Aug. 17 | Aug. 17 | Sept 29 | Sept 29 | Sept 29 |
| Major Group | | N | P | G | N | P | G | N | G | N | P | G |
| Chlorophyta | % | 16.4 | 0.2 | 1.1 | 5.1 | 0.7 | 0.8 | 3.2 | 0.1 | 15.5 | 5.2 | 12.7 |
| | No. | 4,014 | 46 | 547 | 4,369 | 826 | 1,051 | 4,373 | 91 | 210,658 | 14,328 | 4,564 |
| Cyanophyta | % | 29.4 | 66.5 | 33.8 | 70.5 | 86.5 | 46.2 | 76.1 | 19.3 | 31.1 | 26.5 | 13.2 |
| | No. | 7,203 | 16,800 | 16,799 | 60,909 | 100,451 | 57,725 | 102,576 | 15,886 | 421,316 | 73,008 | 4,748 |
| Chrysophyceae | % | 0.4 | - | - | - | - | - | - | 0.6 | 0.8 | 1.3 | 0.3 |
| | No. | 103 | | | | | | | 457 | 10,276 | 3,582 | 91 |
| Bacillariophyceae | % | 52.9 | 33.3 | 65.1 | 23.8 | 12.8 | 53.0 | 20.4 | 80.0 | 52.6 | 67.0 | 73.8 |
| | No. | 12,971 | 8,400 | 32,319 | 20,560 | 14,794 | 66,176 | 27,521 | 65,829 | 714,182 | 184,866 | 26,477 |
| Euglenophyta | % | - | - | - | - | - | - | - | - | - | 0.01 | - |
| | No. | | | | | | | | | | 276 | |
| Cryptophyta | % | 0.8 | - | - | 0.6 | - | - | 0.2 | - | - | - | - |
| | No. | 206 | | | 504 | | | 257 | | | | |

(Continued)

TABLE 9. Continued.

| | | MIDDLE STATION | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | June 16 | June 16 | July 15 | July 15 | July 13 | Aug. 20 | Aug. 20 | Aug. 20 | Sept 28 | Sept 28 | Sept 28 |
| Major Group | | P | G | N | P | G | N | P | G | N | P | G |
| Chlorophyta | % | 0.8 | 0.9 | 16.2 | 3.6 | 4.0 | 11.1 | 0.6 | 0.8 | 5.4 | 6.6 | 11.2 |
| | No. | 198 | 274 | 1,750 | 1,976 | 4,933 | 112,484 | 66 | 732 | 61,656 | 10,665 | 6,136 |
| Cyanophyta | % | 58.4 | 32.9 | 36.2 | 56.0 | 62.7 | 48.4 | 9.9 | 43.3 | 49.7 | 38.3 | 17.5 |
| | No. | 15,412 | 10,408 | 3,910 | 31,024 | 77,618 | 488,110 | 1,186 | 41,307 | 567,749 | 62,015 | 9,558 |
| Chrysophyceae | % | - | - | 1.0 | 0.1 | 0.4 | - | 2.2 | 2.7 | 0.2 | 4.4 | 2.4 |
| | No. | | | 103 | 99 | 459 | | 264 | 2,559 | 2,569 | 7,110 | 1,298 |
| Bacillariophyceae | % | 40.8 | 66.3 | 37.1 | 40.3 | 32.9 | 40.5 | 87.4 | 53.2 | 44.7 | 50.7 | 68.9 |
| | No. | 10,771 | 20,999 | 4,015 | 22,331 | 40,740 | 408,471 | 10,480 | 50,810 | 511,231 | 82,160 | 37,642 |
| Euglenophyta | % | - | - | - | - | - | - | - | - | - | - | - |
| | No. | | | | | | | | | | | |
| Cryptophyta | % | - | - | 9.5 | - | - | - | - | - | - | - | - |
| | No. | | | 1,029 | | | | | | | | |

(Continued)

TABLE 9. Continued.

LOWER STATION

| Major Group | | May 11 N | July 18 N | July 15 P | July 15 G | Aug. 15 G | Sept 26 N | Sept 26 P | Sept 26 G |
|---|---|---|---|---|---|---|---|---|---|
| Chlorophyta | % | - | 15.2 | 4.5 | 1.0 | 0.2 | 10.6 | 19.2 | 11.8 |
| | No. | | 9,630 | 923 | 137 | 47 | 20,544 | 10,666 | 16,541 |
| Cyanophyta | % | 13.7 | 40.4 | 33.1 | 23.4 | 60.0 | 61.5 | 27.4 | 64.4 |
| | No. | 7,281 | 25,680 | 6,722 | 3,245 | 12,746 | 118,770 | 15,208 | 90,267 |
| Chrysophyceae | % | 0.8 | - | 0.3 | 0.3 | 0.2 | 0.3 | 2.1 | 0.3 |
| | No. | 428 | | 66 | 46 | 47 | 642 | 1,186 | 473 |
| Bacillariophyceae | % | 84.7 | 44.4 | 61.7 | 75.2 | 39.6 | 26.9 | 50.9 | 23.4 |
| | No. | 44,970 | 28,248 | 12,524 | 10,420 | 8,421 | 52,002 | 28,250 | 32,848 |
| Euglenophyta | % | 0.8 | - | 0.3 | - | - | - | - | - |
| | No. | 428 | | 66 | | | | | |
| Cryptophyta | % | - | - | - | - | - | 0.7 | 0.4 | - |
| | No. | | | | | | 1,284 | 188 | |

TABLE 10. Per cent distribution of species among major algal groups from selected rivers in western Canada.

| | This Study | Athabasca River* | South Saskatchewan River** | Yoho-Kicking Horse Rivers*** | Connaught-Beaver Watershed*** |
|---|---|---|---|---|---|
| Number of Taxa | 142 | 191 | 192 | 124 | 123 |
| Chlorophyta | 17.6 | 17.8 | 21.9 | 13.7 | 10.6 |
| Cyanophyta | 16.9 | 11.0 | 14.1 | 11.3 | 13.8 |
| Chrysophyceae | 5.6 | 8.9 | 6.7 | 12.9 | 9.0 |
| Bacillariophyceae | 56.3 | 61.3 | 57.3 | 61.3 | 65.0 |
| Euglenophyta | 2.1 | - | - | 0.8 | 0.8 |
| Cryptophyta | 1.4 | 1.0 | - | - | 0.8 |

*Artificial substrates (glass). From McCart *et al.* (1977).

**Natural substrates (epilithic) only. From Davies *et al.* (1977).

***Artificial (glass) and natural substrates (epilithic) combined. From Den Beste *et al.* (1977).

Columbia (Den Beste *et al.*, 1977a, 1977b) but less than that in the larger Athabasca River (McCart *et al.*, 1977) and South Saskatchewan River (Davies *et al.*, 1977).

Though the total number of species differed, the relative abundance of the major groups was similar. In each of the studies, including the present one, diatoms were the most common group, followed by either the green or blue-green algae. The remaining groups, the Chrysophyceae, Euglenophyta, and Cryptophyta, account for less than 10% of the total species.

In the following, the seasonal distribution of major groups is discussed by location and by substrate type.

Upper Station

Though diatoms (Bacillariophyceae) and blue-green algae (Cyanophyta) together dominated the periphyton community throughout the season on all substrate types (Figure 12), the relative abundance of the two groups fluctuated both seasonally and among substrate types. On natural substrates, diatoms were more important than blue greens in June and September but less important in July and August. On plexiglass substrates, the June and July samples were dominated by blue-greens (66.5 and 86.5%, respectively) but the September one by diatoms (67%). On glass substrates, diatoms were the most important group in each of four sampling periods (53 to 80%).

Green algae (Chlorophyta) were common but did not exceed a maximum of

16.4% in any sample. Over the season, they were most abundant on natural substrates. On all substrates, the relative abundance of greens was greater in September than in samples taken in mid-summer in July and August.

The Chrysophyceae occurred on all substrates but were absent from over half the samples taken. They were most widespread late in the sampling period but they never exceeded 1.3% of any sample. Euglenophyta were found on only one sample (plexiglass, September) where they constituted only 0.01% of the total cells. Cryptophyta occurred on natural substrates only and their numbers never exceeded 0.8% of the total.

Middle Station

Diatoms and blue-green algae dominated periphyton populations on all three substrates at the Middle Station (Figure 13). On natural substrates, the relative abundance of the two groups was similar throughout the summer although in August and September there was a slight preponderance of blue-greens (7.9 and 5.0%, respectively). In contrast to natural substrates, both artificial substrates produced peak blue-green populations by July and were diatom dominated thereafter.

Green algae were present on all three substrates throughout the sampling period. Their representation fluctuated between 0.6 and 16.2% of the total depending on substrate and time period. Their relative abundance declined seasonally on natural substrates but on both plexiglass and glass, the relative abundance of green algae was highest at the end of the sampling period in September.

Cryptophyta were relatively abundant on natural substrates in July (9.5% of total count) but were absent thereafter. This group did not appear on artificial substrates at this station.

The Chrysophyceae appeared in small numbers on all substrates but reached their greatest importance on artificial substrates in August and September (2.2-4.4% of total counts). Euglenophyta did not occur at the Middle Station.

Lower Station

Diatoms dominated the periphyton communities on all three substrates at the Lower Station through July but declined in relative importance later (Figure 14). Blue-green were second in relative abundance early in the season but by September, their numbers exceeded 50% of the total on both natural and glass substrates. On plexiglass substrates, in contrast, they became relatively less important as the season progressed and constituted only 27.4% of the total cells in September. Green algae were never as important as diatoms and blue-green algae but they did have maximums of 15.2% on natural substrates (July), 19.2% on plexiglass (September), and 11.8% on glass (September). On the artificial substrates there was a definite increase in the importance of green algae from July through September. The other groups, Chrysophyceae, Euglenophyta, and Cryptophyta, were rare at the Lower Station, each group seldom exceeding 1% of the total count.

In summary, of the six major groups, the diatoms and blue-green algae were most important and one or the other dominated every sample.

The green algae were rarely absent but were clearly less important than the diatoms and blue-greens. The green algae never exceeded 20% of any sample and in most instances constituted less than 10%. They tended to reach their greatest relative abundance in September. The other three major groups, the Chrysophyceae, Euglenophyta, and Cryptophyta, were not important overall. The representation of Chrysophyceae ranged from 0 to 4.4% of individual samples and the Euglenophyta, the rarest group, from 0 to 0.8%. Chryptophyta constituted 9.5% of one sample but were absent from most.

## Dominant Species

Only 19 of the 142 species observed in the present study were classified as dominant species (i.e., constituting more than 10% of the total cells/$cm^2$) in samples from either artificial or natural substrates (Table 11). In the following, the dominant species within each major group are discussed.

### Chlorophyta

Only one green alga, *Ulothrix*, was recorded as a dominant species in the MacKay River. This species was a dominant on natural substrates at the Upper Station in June, but did not occur on artificial substrates at this location. *Ulothrix* was, however, present (though not dominant) on plexiglass substrates at the Lower Station in July, indicating that the species can become established on artificial substrates.

TABLE 11 . Seasonal variation in occurrence of dominant species (those consisting of more than 10% of the total cell/$cm^2$ in any sample) in the MacKay River, May to September, 1977. N=natural substrate, P=plexiglass, G=glass substrate, A=all.

| Station: | Lower | | | | | Middle | | | | Upper | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | M | J | J | A | S | J | J | A | S | J | J | A | S |
| Chlorophyta | | | | | | | | | | | | | |
| *Ulothrix* sp. | | | | | | | | | | N | | | |
| Cyanophyta | | | | | | | | | | | | | |
| *Anabaena* spp. | | | | | | | | | | | N | | |
| *Calothrix fusca* | | | | | | | | | | | | | N |
| *Calothrix* spp. | | | | | | | | | | | | | N |
| *Gomphosphaeria lacustris* | | | | | | | | | | | N | | |
| *Lyngbya aerugino-caerulea* | | | | | | | | | | | | | N |
| *Merismopedia glauca* | | | | | G | | | | | | | | |
| *Oscillatoria minnesotense* | | | | | P | | | | | | | | |
| *O. splendida* | | | | | | | | G | | | | | |
| *O. tenuis* | | | | | | | | | | | | | N |
| *Oscillatoria* sp. | | | | | N | | | | | | | | |
| *Phormidium* spp. | | | A | G | G | A | A | P-G | A | A | A | A | A |
| Bacillariophyceae | | | | | | | | | | | | | |
| *Cocconeis placentula* var. *lineata* | | | P-G | | | P-G | P-G | P-G | G | P-G | G | G | |
| *Cyclotella* spp. | N | | | | | | | | | | | | |
| *Epithemia sorex* | | | | | N | | | N | A | | | | N |
| *E. turgida* | | | P | | | | | | N | | | | |
| *Navicula cryptocephala* | | | G | | | | | | | | | | |
| *Navicula* sp. | | | N | | | | | | | | | | |
| *Nitzschia* spp. | | | | G | | | | | P | N | | | A |

Cyanophyta

Overall, 11 species of blue-green algae were classified as dominants. Of these, *Phormidium* was the most commonly recorded from the MacKay River. This filamentous alga was found at almost every site on every date and was a dominant species on all substrate types. *Phormidium* has been previously recorded as a dominant form in the South Saskatchewan watershed (Davies *et al.*, 1977) and the Connaught-Beaver River watershed (Den Beste *et al.*, 1977).

Other species of blue-green algae frequently dominated natural substrates at the Upper Station. They also dominated an August sample from the Middle Station and three September samples from the Lower Station. With the exception of *Phormidium* spp., the dominant blue-green species were different at each site (Table 11). They included the genera *Anabaena*, *Calothrix*, *Gomphosphaeria*, *Lyngbya*, *Merismopedia*, and *Oscillatoria*. Previous studies (Blum, 1957, Squires *et al.*, 1973; Den Beste *et al.*, 1977b) have demonstrated that some species of blue-green algae (e.g., *Oscillatoria* and *Phormidium*) found in high densities on natural substrates are nearly absent from artificial substrates.

Bacillariophyceae

The diatom community included fewer dominant species than the blue-green algae (7 and 11 species, respectively). *Cocconeis placentula* var. *lineata*, an epiphytic species, was one of the most common diatoms but, as a dominant species, was restricted to the artificial substrates. This species generally reached its highest densities on glass substrates

(Table 10) and was a common dominant in previous studies on the Athabasca River where these substrates were used (McCart *et al.*, 1977). It appears to be a species that can rapidly colonize new areas. One other species of *Cocconeis*, *C. pediculus*, was observed from the MacKay River, although not as a dominant species. *C. pediculus* invariably reached its greatest densities on natural substrates.

Of the six other species of dominant diatoms, only *Epithemia sorex* was widespread in its distribution. The species was recorded from all sites and had its highest densities during the August-September period, on natural substrates. *E. sorex* had previously been recorded as abundant in late summer and early fall in the South Saskatchewan River (Davies *et al.*, 1977). *Epithemia turgida* appeared as a dominant diatom on only two occasions and on different substrates (natural and plexiglass). The *Navicula* spp. were restricted to the Lower Station but appeared as a dominant on both natural and glass substrates. *Nitzschia* was an occasional dominant on all substrates. The centric diatom, *Cyclotella*, was only observed as a dominant species during May at the Lower Station. All of the dominant diatom genera except *Cyclotella* are widespread in Alberta and have been previously identified as dominants in the South Saskatchewan River (Davies *et al.*, 1977).

No dominant species occurred among the other three major groups, the Chrysophyceae, Euglenophyta, and Cryptophyta.

Species Diversity

The diversity of the periphytic communities at the MacKay River was characterized by:

1) the taxonomic diversity (t);
2) the Shannon-Weaver Species Diversity Index ($\bar{d}$); and
3) MacArthur's Equitability Index (e).

The results are summarized in Tables 12 and 13 and Figure 16.

For natural substrates, taxonomic diversity (t) seemed to be higher at the Upper Station than at the Middle or Lower Stations. However, for the plexiglass substrate, taxonomic diversity was higher at the Lower Station than at the others. The glass substrate, on the whole, supported a similar number of taxa at all the stations. In general, species diversity ($\bar{d}$) and equitability (e) were higher for the periphytic communities on natural substrates and lower for those on artificial substrates, indicating the occurrence of a more complex and stable community on the natural substrate.

All sites and substrate types had similar seasonal variations in the species diversity and taxonomic diversity with peak values generally occurring during September, coinciding with the peak standing crops. Lowest diversity values commonly occurred in July and August. Equitability values showed little variation, ranging from 0.13 to 0.32. Natural substrates tended to produce higher species diversity values than either

TABLE 12. Variations in the means and ranges of the taxonomic diversity (t), Shannon-Weaver Species Diversity Index ($\bar{d}$), and equitability (e) of the periphyton communities on various substrate types in the MacKay River. May to September, 1977.

| | | STATIONS | | | | | |
|---|---|---|---|---|---|---|---|
| | | Upper | | Middle | | Lower | |
| Substrate Type | Parameter | Mean | Range | Mean | Range | Mean | Range |
| Natural | t | 31.67 | 22-37 | 24.33 | 19-31 | 22.67 | 19-28 |
| | $\bar{d}$ | 2.36 | 2.03-2.73 | 2.15 | 1.73-2.4 | 2.29 | 2.20-2.45 |
| | e | 0.23 | 0.19-0.27 | 0.25 | 0.21-0.3 | 0.29 | 0.25-0.32 |
| Plexiglass | t | 22.33 | 15-36 | 17.25 | 14-21 | 27.50 | 19-36 |
| | $\bar{d}$ | 1.39 | 0.63-2.17 | 1.54 | 1.10-1.98 | 2.40 | 2.00-2.80 |
| | e | 0.17 | 0.13-0.20 | 0.22 | 0.20-0.24 | 0.30 | 0.28-0.32 |
| Glass | t | 21.25 | 13-30 | 21.75 | 16-31 | 21.33 | 16-30 |
| | $\bar{d}$ | 1.51 | 1.26-1.94 | 1.70 | 1.27-2.34 | 1.85 | 1.46-2.10 |
| | e | 0.18 | 0.13-0.23 | 0.21 | 0.16-0.23 | 0.22 | 0.19-0.28 |

TABLE 13. Comparison of mean values and ranges for various parameters describing periphyton on natural, plexiglass, and glass substrates. Data from Table 7. N=8 in every case.

| | Natural | | Plexiglass | | Glass | |
|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range |
| Species (t) | 26.9 | 19-37 | 22.2 | 14-36 | 23.9 | 18-31 |
| Diversity ($\bar{d}$) | 2.31 | 1.73-2.73 | 1.71 | 0.63-2.80 | 1.74 | 1.30-2.34 |
| Equitability (e) | 0.25 | 0.19-0.32 | 0.22 | 0.13-0.32 | 0.19 | 0.13-0.28 |
| Density (1000 cells/$cm^2$) | 485.6 | 10.8-1356.4 | 90.1 | 12.0-275.8 | 79.9 | 13.8-124.9 |
| Biomass (mg/$m^2$) | 7757.8 | 579.7-29565.2 | 1125.6 | 379.0-3484.8 | 550.7 | 273.9-1206.7 |
| Diatoms/Blue-Greens | 1.01 | 0.33-1.79 | 2.22 | 0.14-8.82 | 2.24 | 0.36-5.59 |

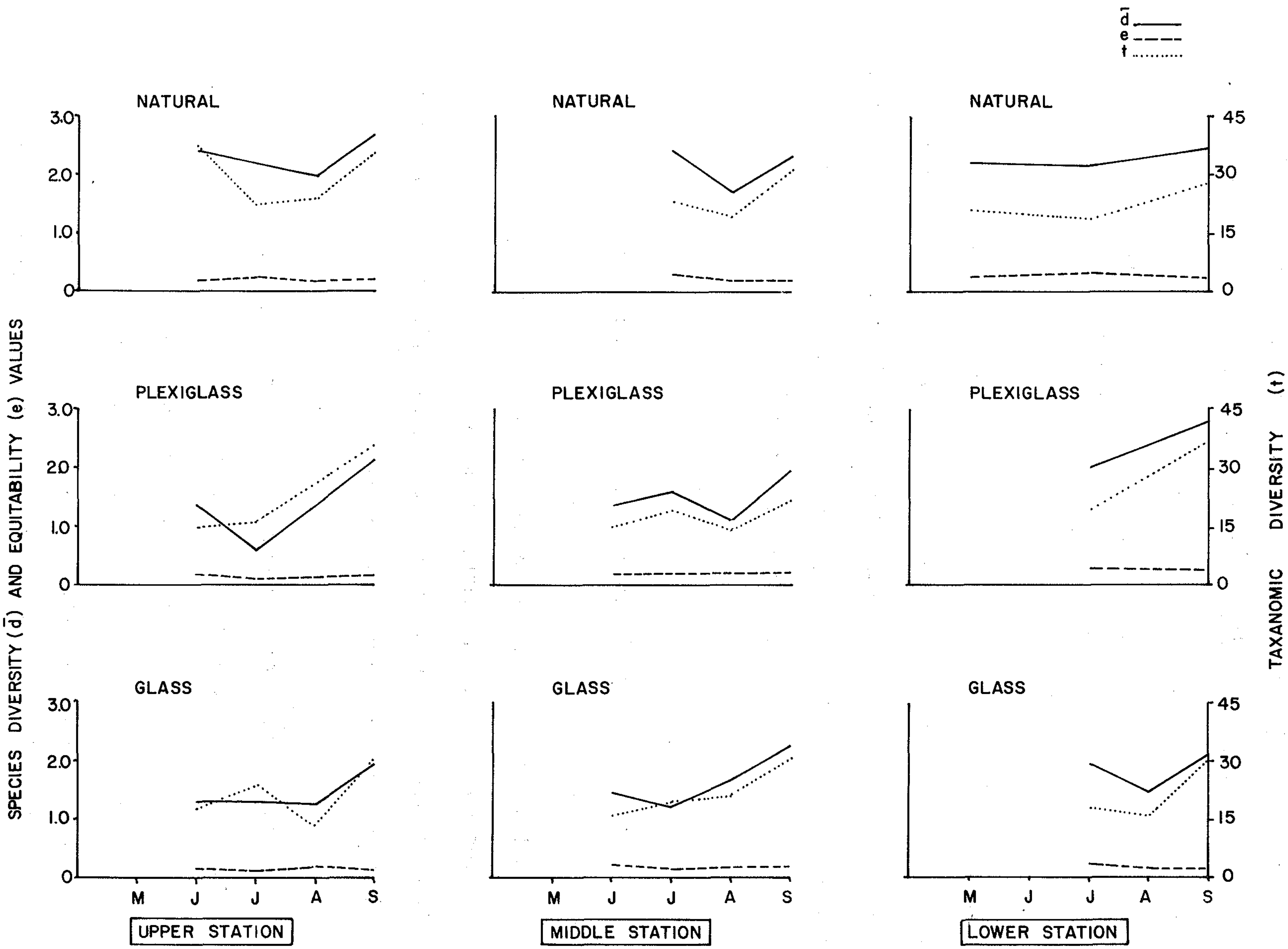


FIGURE 16. Seasonal variation in species diversity ($\bar{d}$), equitability (e), and taxonomic diversity on natural, plexiglass, and glass substrates at three sites in the MacKay River, May-September, 1977.

type of artificial substrate, with most values above 2.0 (range 1.73-2.73). Species diversity was generally less than 2.0 on both glass and plexiglass (ranges 1.26-2.34 and 0.63-2.80, respectively). Taxonomic diversity values ranged from 14-36 with similar values yielded by all three substrates.

The generally higher species diversity values on natural substrates probably resulted from the failure of some species to rapidly colonize the artificial substrates. It was not necessary for natural substrates to recolonize after each sampling, since a periphyton community existed on the substrate prior to each 30 day sampling period.

Comparison of Substrates

Data comparing the performance of the three substrates are presented in Table 13. The comparisons have been confined to samples which are similar in location and sampling period (N=8 in every case). While the sample sizes are too small to permit any meaningful tests of statistical significance, there are indications of very real differences between the communities present on the three substrates.

Mean values for natural substrates exceed those for either artificial substrates in the number of species (t), species diversity ($\bar{d}$), equitability (e), density, and biomass. The greatest discrepancies are in density and biomass which are, respectively, 5 to 6 and 7 to 14 times greater than the means recorded for artificial substrates. On natural substrates, the ratio of diatoms to blue-green algae, the two most important groups in all samples, averages only half that on artificial substrates.

In most respects, the values for the two artificial substrates are similar. The only major difference is in biomass. The mean for plexiglass substrates is approximately twice that for glass. There is also a difference, though a small one, in the density of cells on the two artificial substrates. The mean for plexiglass is 11% higher than that for glass.

The differences in the communities on natural and artificial substrates are probably due to two factors: habitat diversity and length of exposure. A rock, with its rough surface, presents a greater variety of microhabitats for unicellular organisms than does the smooth surface of plexiglass or glass. It can, therefore, accommodate the habitat requirements of a wider range of organisms. In addition, because they are exposed to colonization and community development over a longer period of time, natural substrates would be expected to develop a more complex algal community than artificial substrates exposed for a relatively short period. The 30 day exposure period used in this study is based on Weber's (1973) recommendations for streams in the continental United States. It may not be applicable to streams at higher latitudes. It is suggestive that diatoms were, on the average, more abundant on artificial substrates than were blue-greens whereas, on natural substrates, the mean ratio of densities of the two groups were approximately equal. Diatoms, particularly *Cocconeis*, frequently have their highest densities in new habitats, while blue-greens, particularly *Phormidium*, often characterize well developed climax communities in streams (Bloom, 1957, Squires *et al.*, 1973; Den Beste *et al.*, 1977b). Certainly, further studies are necessary to determine the optimum exposure time for artificial substrates in this area.

These studies do not indicate any great advantage to one or the other of the two artificial substrates though with longer exposure, the density and biomass differences may increase. There may be an advantage to having a larger population on which to base analyses.

Natural Stress

As previously indicated, the equitability values (e) of the periphyton community were low, ranging from 0.13 to 0.32, regardless of substrate type, sampling location, or sampling period. These values are substantially lower than 0.5, a value generally regarded as the lower limit for stream communities in unstressed habitats. Since the species diversity was also relatively low (range 1.51 to 2.40, Table 12), it appears that the periphyton community of the MacKay River is subjected to some natural stress even in the absence of any man-made disturbance.

There are no data indicating what the cause of the stress is, if any. The phenomenon appears to be real, however, and not an artifact of sampling technique. The species composition of periphyton on glass slides collected from the MacKay River in 1977 and on slides from the Athabasca River in 1975 (McCart *et al.*, 1977) were similar for the same sampling period (June to September) and exposure time (30 days). Species diversity (range 1.08-4.26) and equitability (range 0.05-1.10) were, however, higher in the Athabasca River and biomass lower (range 85.0-777.7 $mg/m^2$) than in the MacKay River (range 240.2-1206.7 $mg/m^2$).

The structure of periphyton communities in the MacKay River resembles the periphyton community in streams with mild organic loading (Patrick, 1973). Such streams often have high periphyton densities that are dominated by a few species with a resultant decrease in species diversity. Margale (1961) suggests that this decrease is related to different reproductive capacities in an enriched environment. Certain species reproduce more rapidly than others and dominate the community, thereby reducing diversity.

Other than outcroppings of tar sands and other natural sources such as leaf drop, bog drainage, etc., there are no known sources of organic loading in the MacKay River. There is, therefore, no obvious explanation for the status of the periphyton community in the river. Naturally occurring values for oil and grease, phenols, boron, iron, lead, mercury, total organic carbon, nitrogen, and cadmium (Table 6) exceed the limits recommended in Alberta Surface Water Quality Objectives, Alberta Environment (1977). Possibly they are at levels high enough to affect periphyton growth in the MacKay River but not high enough to affect benthic invertebrates.

Current and substrate composition are important factors influencing periphyton species composition and growth. Provided there are no other limiting factors, stable substrates composed of rubble in a slow moving current are ideal conditions for periphyton growth (Blum, 1956).

Filamentous forms in particular may achieve their greatest growth under these conditions. These conditions are common in the upper and middle reaches of the MacKay River but with progressively more gravel, sand, and mud-silt downstream. Periphyton biomass showed a similar longitudinal trend, i.e., generally highest at the Upper Station and lowest at the Lower Station (Table 8).

# BENTHIC MACROINVERTEBRATES

## Introduction

This study was undertaken to determine the qualitative and quantitative characteristics of the benthic macroinvertebrate communities of the MacKay River and to assess the relationship of these communities to existing environmental conditions. Specifically, the objectives were to:

1) describe the structure of the benthic animal communities at three selected stations (Upper, Middle, and Lower Stations);

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

3) determine the efficiency of the rock-basket sampler in collecting benthos from the MacKay River;

4) characterize the diel benthic invertebrate drift rate and drift density.

## Materials and Methods

### Sample Collection

The benthic macroinvertebrate fauna at each station was sampled at monthly intervals from May to September, 1977, using a standard Surber sampler (mesh size 600 microns). For each sampling period, three replicate samples were taken from stone and gravel substrates in riffle areas and preserved in 10% formalin for later analysis.

Artificial substrates made from wire baskets and quarry rock as described by McCart *et al.* (1977) were also used to sample aquatic invertebrates. At each station, three samplers were suspended 10 cm above the substrate. Each month, the samplers were retrieved, cleaned of all invertebrates and accumulated debris, and placed back in position. A 600 micron mesh sieve bucket was held under the baskets to capture any invertebrates dislodged during retrieval. Samples were preserved in 10% formalin for later enumeration and identification.

Three additional samplers filled with tar sand were placed at the Middle Station on the MacKay River from June to September to check possible variability in benthic colonization due to substrate differences. Tar sand was a common feature of the bottom substrate of the Middle Station and the pieces used were similar in size and shape to rocks in the other samplers.

Drift

Twenty-four hour drift studies were conducted at the Lower Station on the MacKay River on July 15 and 16 and August 21 and 22, 1977. During each 24 hour sampling period, three nets were placed in the stream for one hour, every two to four hours, for a total of seven, one hour drift samples of three replicates each. Sampling was more frequent from dusk to dawn when drift rates were highest and less frequent during the day when drift rates were low. The drift nets had an opening of 30 cm x 45 cm and a 250 μ mesh net 90 cm long. Records were kept of water depth and current at the mouth of each net.

### Sample Analysis

In the laboratory, samples were washed through a 600 micron mesh sieve and the invertebrates sorted out under a stereoscopic dissecting microscope. Organisms were counted, identified, and further preserved in 75% isopropanol.

The major taxonomic references used include Allen and Edmunds (1961a, 1961b, 1965), Jensen (1966), Needham *et al.* (1935), Pennak (1953), Usinger (1963), and Ward and Whipple (1959). The Chironomidae were identified according to the provisional key by Hamilton and Saether[1], and Saether (1969, 1975, 1976, 1977).

Shannon-Weaver species diversity indices and MacArthur equitability indices were computed for each station as previously described for periphyton.

## Results and Discussion

### Species Composition

During this study, a total of 80 benthic macroinvertebrate taxa was collected from the three sampling stations. Because of differences in substrate composition and flow rates at the three stations (Table 2), the species composition of their benthic communities varied considerably.

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

The longitudinal distribution of the various benthic taxa are summarized in Table 14. A total of 59 taxa was found at the Upper Station, whereas 56 and 49 taxa were found at the Middle and Lower Stations, respectively. Taxonomic diversity of five major insect Orders at the three stations is shown in Figure 17. It appeared that the Upper Station supported a comparatively diverse fauna of Chironomidae (midges), Trichoptera (caddisflies), and Plecoptera (stoneflies), whereas the Middle Station supported a more diverse Ephemeroptera (mayfly) and chironomid fauna. In contrast, the Lower Station was comparatively rich in mayfly species, but the other major Orders were not as well represented.

Table 15, based on data from Clifford *et al.* (1973) is a comparison of the relative abundance of mayfly, stonefly, and caddisfly species in the MacKay River and other stream types in Alberta. On the whole, the relative abundance of these groups in the MacKay River is similar to that of other brown-water streams in Alberta.

Species Dominance

The percentage composition of the standing crop of each benthic taxon has been used as the basis of a classification of benthic invertebrates in the MacKay River (Tables 16 - 18), following the method of Ulfstrand (1968). Such a classification provides an overall impression of the benthic community structure of the study area. Five categories of dominance were designated on the basis of the per cent composition of the total standing crop:

TABLE 14. Longitudinal distribution of benthic macroinvertebrate taxa at the Upper, Middle, and Lower Stations of the MacKay River, May-September, 1977.

| Taxa | Upper | Middle | Lower |
|---|---|---|---|
| Oligochaeta | + | + | + |
| Nematoda | + | | + |
| Hirudinea | | | + |
| Hydracarina | + | + | |
| Amphipoda | | | |
| *Hyalella* | | + | |
| Mollusca | | | |
| *Ferrissia* | + | | + |
| *Lymnaea* | + | | |
| Insecta | | | |
| Collembola | | + | + |
| Ephemeroptera | | | |
| *Ameletus* | + | + | + |
| *Baetis* sp. A | + | + | + |
| *Baetis* sp. B | + | + | + |
| *Brachycercus* | + | + | + |
| *Caenis* | + | + | + |
| *Centroptilum* | + | + | + |
| *Ephemerella* | + | + | + |
| *Rhithrogena* | + | + | + |
| *Tricorythodes* | + | + | + |
| *Paraleptophlebia* | + | + | + |
| *Heptagenia* | + | + | + |
| *Baetisca* | | + | + |
| *Leptophlebia* | | + | + |
| *Neocloeon* | | + | + |
| *Ametropus* | | | + |
| *Stenonema* | | | + |
| *Hexagenia* | | | + |
| Odonata | | | |
| *Ophiogomphus* | + | + | + |
| *Aeshna* | | + | |
| *Calopteryx* | | | + |
| Plecoptera | | | |
| *Isogenus* | + | + | + |
| *Pteronarcys* | + | + | + |
| *Taeniopteryx* | + | + | + |
| *Hastaperla* | + | | + |
| *Acroneuria* | + | | |
| *Arcynopteryx* | + | | |
| Trichoptera | | | |
| *Arctopsyche* | + | + | + |
| *Hydropsyche* | + | + | + |
| *Mayatrichia* | + | + | + |
| *Glossosoma* | + | + | |
| *Brachycentrus* | + | | |
| *Athripsodes* | + | | |

(Continued)

TABLE 14. Continued.

| Taxa | Upper | Middle | Lower |
|---|---|---|---|
| *Neureclipsis* | + | | |
| *Rhyacophila* | + | | |
| *Oxyethira* | | + | |
| *Drusinus* | + | | + |
| Hemiptera | | | |
| Corixidae | + | + | + |
| Coleoptera | | | |
| Elmidae | + | | + |
| Dytiscidae | | | + |
| Diptera | | | |
| Simuliidae | + | + | + |
| Empididae | + | + | + |
| Rhagionidae | + | | |
| Dolichopodidae | + | | |
| Ceratopogonidae | | + | + |
| Chironomidae | | | |
| *Cricotopus* | + | + | + |
| *Orthocladius* | + | + | + |
| *Micropsectra* | + | + | + |
| *Polypedilum* | + | + | + |
| *Rheotanytarsus* | + | + | + |
| *Ablabesmyia* | + | + | + |
| *Conchapelopia* | + | + | + |
| *Tanytarsus* | + | + | + |
| *Eukiefferiella* | + | + | + |
| *Cladotanytarsus* | + | + | |
| *Microtendipes* | + | + | |
| *Cardiocladius* | + | + | |
| *Endochironomus* | + | + | |
| *Smittia* | + | + | |
| *Psectrocladius* | + | + | |
| *Thienemanniella* | + | + | |
| *Paralauterborniella* | + | + | |
| *Brillia* | + | | |
| *Cryptotendipes* | + | | |
| *Labrundinia* | + | | |
| *Paratendipes* | + | | + |
| *Cryptochironomus* | | + | + |
| *Cryptocladopelma* | | + | |
| *Coelotanypus* | | + | |
| *Procladius* | | + | |
| *Tribelos* | | + | |
| *Trichocladius* | | + | |
| *Chironomus* | | | + |
| Total Number of Taxa | 59 | 56 | 49 |

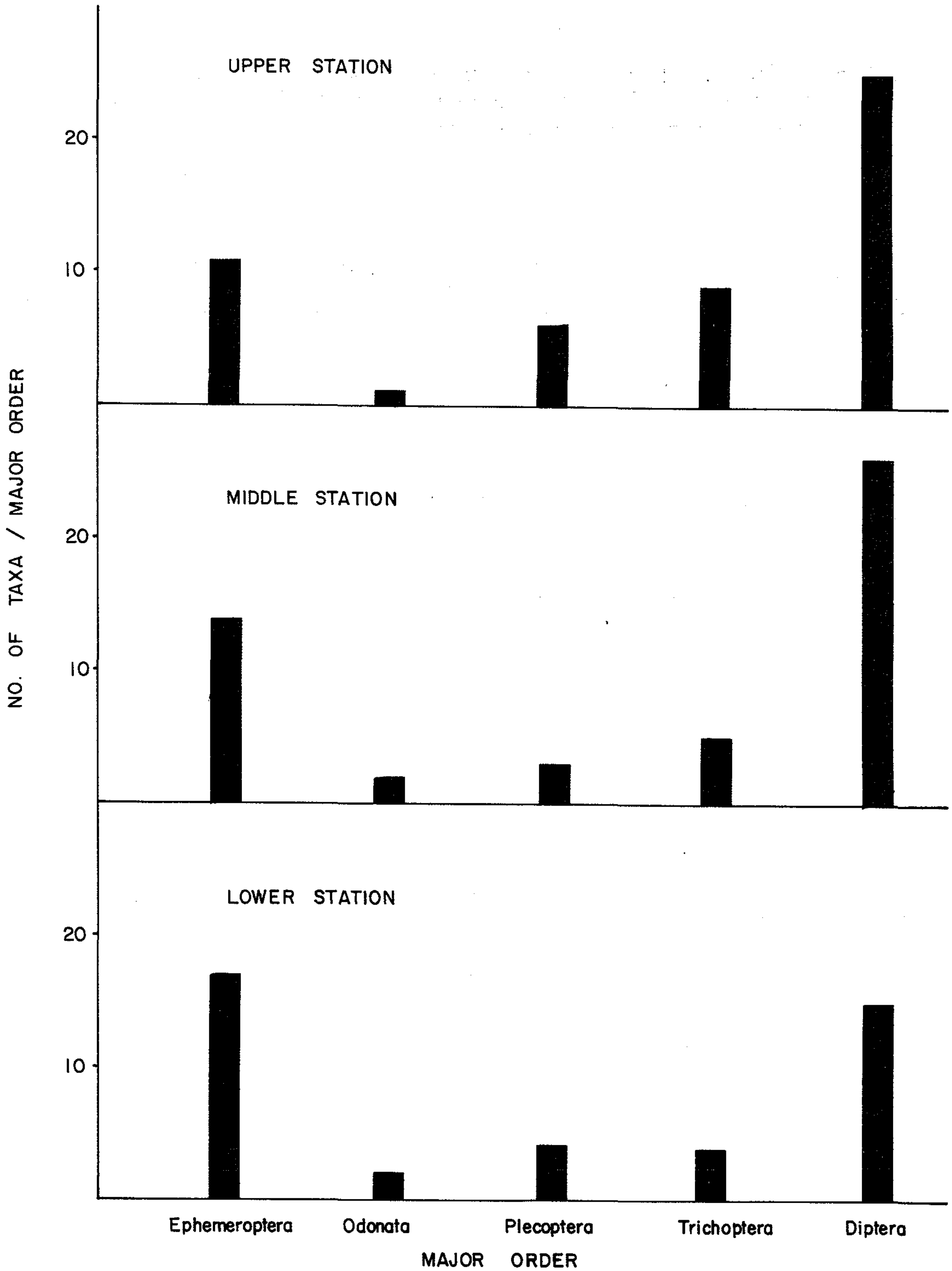



FIGURE 17. Comparison of the number of taxa per major invertebrate group at the Upper, Middle, and Lower Stations. MacKay River, May-September, 1977.

TABLE 15. Comparison of the relative composition in terms of Ephemeroptera, Plecoptera, and Trichoptera species from the MacKay River and various stream types in Alberta.

| Stream Type | Ephem. % | Plecop. % | Trichop. % | Total Species | Source |
|---|---|---|---|---|---|
| Foothills Stream | 28 | 48 | 24 | 61 | Zelt (1970) |
| Boreal Forest Stream | 43 | 14 | 43 | 23 | Robertson (1967) |
| Brown-Water Stream | 45 | 10 | 45 | 33 | Clifford (1969) |
| MacKay River | 52 | 18 | 30 | 33 | |

TABLE 16. Species composition, species diversity, equitability, and standing crop (number per square metre) of benthic macroinvertebrates collected in Surber samples at the Upper Station of MacKay River, May-September, 1977.

| Taxa | May No./m$^2$ | % | June No./m$^2$ | % | July No./m$^2$ | % | Aug No./m$^2$ | % | Sept No./m$^2$ | % |
|---|---|---|---|---|---|---|---|---|---|---|
| Oligochaeta | 50.23 | 19.17 | 21.53 | 9.52 | 7.18 | 1.27 | | | | |
| Nematoda | 10.76 | 4.11 | | | 3.59 | 0.64 | | | | |
| Hirudinea | | | | | | | | | | |
| Amphipoda | | | | | | | | | | |
| *Hyalella* | | | | | | | | | | |
| Collembola | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | |
| *Ameletus* | 3.59 | 1.37 | 3.59 | 1.59 | | | | | 28.70 | 1.52 |
| *Baetis* sp.A | | | | | 161.46 | 28.67 | 104.05 | 4.36 | | |
| *Baetis* sp. B | 25.12 | 9.59 | | | 157.87 | 28.04 | 61.00 | 2.56 | 21.53 | 1.14 |
| *Baetisca* | | | | | | | | | | |
| *Brachycercus* | | | 25.12 | 11.10 | | | | | | |
| *Caenis* | | | | | 14.35 | 2.55 | | | | |
| *Centroptilum* | | | 46.64 | 19.03 | | | 86.11 | 3.61 | | |
| *Ephemerella* | 14.35 | 5.48 | 17.94 | 7.94 | | | | | 3.59 | 0.19 |
| *Heptagenia* | 7.18 | 2.74 | 32.29 | 14.28 | 78.94 | 14.01 | 419.80 | 17.61 | 287.04 | 15.21 |
| *Isonychia* | | | | | | | | | | |
| *Leptophlebia* | | | | | | | | | | |
| *Neocleon* | | | | | | | | | | |
| *Paraleptophlebia* | | | 3.59 | 1.59 | | | | | | |
| *Rhithrogena* | 7.18 | 2.74 | | | | | 57.41 | 2.41 | 136.34 | 7.22 |
| *Stenonema* | | | | | | | | | | |
| *Tricorythodes* | | | | | 17.94 | 3.18 | 14.35 | 0.60 | | |
| Baetidae | | | | | | | | | | |
| Odonata | | | | | | | | | | |
| *Aeshna* | | | | | | | | | | |
| *Ophiogomphus* | 3.59 | 1.37 | 3.59 | 1.59 | | | 7.18 | 0.30 | 7.18 | 0.38 |
| *Calopteryx* | | | | | | | | | | |
| Gomphidae | | | | | | | | | | |
| Plecoptera | | | | | | | | | | |
| *Acroneuria* | | | | | | | | | | |
| *Arcynopteryx* | | | | | | | | | | |

(Continued)

TABLE 16. Continued.

| Taxa | May No./m² | % | June No./m² | % | July No./m² | % | Aug No./m² | % | Sept No./m² | % |
|---|---|---|---|---|---|---|---|---|---|---|
| *Hastaperla* | | | 3.59 | 1.59 | | | | | 3.59 | 0.19 |
| *Isogenus* | 7.18 | 2.74 | | | | | 28.70 | 1.20 | 53.82 | 2.85 |
| *Pteronarcys* | 3.59 | 1.37 | | | | | 25.12 | 1.05 | 25.12 | 1.33 |
| *Taeniopteryx* | | | | | | | | | | |
| Trichoptera | | | | | | | | | | |
| *Arctopsyche* | | | | | 7.18 | 1.27 | 710.42 | 29.81 | 46.64 | 2.47 |
| *Athripsodes* | | | | | | | 3.59 | 0.15 | | |
| *Brachycentrus* | | | 17.94 | 7.94 | 3.59 | 0.64 | 46.64 | 1.95 | 172.22 | 9.13 |
| *Drusinus* | | | | | | | 14.35 | 0.60 | | |
| *Glossosoma* | | | | | | | 10.76 | 0.45 | 200.93 | 10.65 |
| *Hydropsyche* | 3.59 | 1.37 | | | | | 175.81 | 7.36 | 649.43 | 34.42 |
| *Mayatrichia* | | | | | 3.59 | 0.64 | | | | |
| *Neureclipsis* | | | | | | | 17.94 | 0.75 | | |
| *Oxyethira* | | | | | | | | | | |
| *Rhyacophila* | | | | | | | 78.94 | 3.31 | 43.06 | 2.28 |
| unid. pupae | | | | | | | 3.59 | 0.15 | 10.76 | 0.57 |
| Hemiptera | | | | | | | | | | |
| Corixidae | | | | | | | | | 32.29 | 1.71 |
| Coleoptera | | | | | | | | | | |
| Dytiscidae | | | | | | | | | | |
| Elmidae | | | | | | | 3.59 | 0.15 | | |
| Diptera | | | | | | | | | | |
| Ceratopogonidae | | | | | | | | | | |
| Chironomidae | | | | | | | | | | |
| *Ablabesmyia* | | | 3.59 | 1.59 | 7.18 | 1.27 | 3.59 | 0.15 | | |
| *Brillia* | | | | | | | | | | |
| *Cardiocladius* | 3.59 | 1.37 | | | 7.18 | 1.27 | | | | |
| *Cladotanytarsus* | | | | | 7.18 | 1.27 | 10.76 | 0.45 | | |
| *Conchapelopia* | | | | | | | | | | |
| *Cricotopus* | 96.88 | 36.99 | 14.35 | 6.35 | 21.53 | 3.82 | 125.58 | 5.26 | | |
| *Cryptotendipes* | | | | | | | | | | |
| Orthocladiinae | | | | | | | | | | |
| *Endochironomus* | | | 3.59 | 1.59 | | | | | | |

(Continued)

TABLE 16. Continued.

| Taxa | May No./m$^2$ | May % | June No./m$^2$ | June % | July No./m$^2$ | July % | Aug No./m$^2$ | Aug % | Sept No./m$^2$ | Sept % |
|---|---|---|---|---|---|---|---|---|---|---|
| *Eukiefferiella* | | | | | | | 21.53 | 0.90 | | |
| *Labrundinia* | | | | | | | | | | |
| *Micropsectra* | 7.18 | 2.74 | | | 14.35 | 2.55 | 35.88 | 1.50 | 17.94 | 0.95 |
| *Microtendipes* | | | | | | | 93.29 | 3.91 | 75.35 | 3.99 |
| *Orthocladius* | 3.59 | 1.37 | | | 21.53 | 3.82 | 39.47 | 1.65 | 43.06 | 2.28 |
| *Paralauterborniella* | | | 3.59 | 1.59 | | | | | | |
| *Paratendipes* | | | 3.59 | 1.59 | | | | | | |
| *Polypedilum* | 7.18 | 2.74 | 3.59 | 1.59 | | | 10.76 | 0.45 | | |
| *Psectrocladius* | | | | | | | | | | |
| *Rheotanytarsus* | | | | | 7.18 | 1.27 | 32.29 | 1.35 | | |
| *Smittia* | | | | | 14.35 | 2.55 | | | | |
| *Tanytarsus* | | | | | 7.18 | 1.27 | 14.35 | 0.60 | | |
| *Thienemanniella* | | | | | | | | | | |
| Dolichopodidae | | | | | | | | | | |
| *Hydrophorus* | | | | | | | | | | |
| Empididae | | | | | | | 39.47 | 1.65 | 21.53 | 1.14 |
| Rhagionidae | | | | | | | | | 7.18 | 0.38 |
| Simuliidae | | | 17.94 | 7.94 | | | | | | |
| Tipulidae | | | | | | | | | | |
| unid. pupae | 7.18 | 2.74 | 3.59 | 1.59 | | | 89.70 | 3.75 | | |
| Arachnida | | | | | | | | | | |
| Hydracarina | | | | | | | | | | |
| Mollusca | | | | | | | | | | |
| Ferrissia | | | | | | | | | | |
| Lymnaea | | | | | | | | | | |

(Continued)

TABLE 16. Continued.

| | May No./m² | % | June No./m² | % | July No./m² | % | Aug No./m² | % | Sept No./m² | % |
|---|---|---|---|---|---|---|---|---|---|---|
| No. Individuals/m² | 261.92 | | 226.04 | | 563.32 | | 2386.02 | | 1887.29 | |
| No. Taxa (s) | 17 | | 18 | | 19 | | 31 | | 21 | |
| Shannon-Weaver Species Diversity Index ($\bar{d}$) | 3.09 | | 3.60 | | 3.05 | | 3.83 | | 3.21 | |
| Equitability (e) | 0.71 | | 0.94 | | 0.63 | | 0.68 | | 0.62 | |

TABLE 17. Species composition, species diversity, equitability, and standing crop (number per square metre) of benthic macroinvertebrates collected in Surber samples at the Middle Station of MacKay River, May-September, 1977.

| Taxa | May No./m² | May % | June No./m² | June % | July No./m² | July % | August No./m² | August % | September No./m² | September % |
|---|---|---|---|---|---|---|---|---|---|---|
| Oligochaeta | 28.70 | 27.58 | 32.29 | 10.11 | | | 10.76 | 1.00 | 17.94 | 1.23 |
| Nematoda | | | | | | | | | | |
| Hirudinea | | | | | | | | | | |
| Amphipoda | | | | | | | | | | |
| *Hyalella* | | | | | | | | | | |
| Collembola | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | |
| *Ameletus* | | | | | | | | | 3.59 | 0.25 |
| *Baetis* sp. A | | | 3.59 | 1.12 | 208.10 | 27.36 | 251.16 | 23.41 | 32.29 | 2.22 |
| *Baetis* sp. B | 7.18 | 6.90 | 10.76 | 3.37 | 50.23 | 6.60 | 182.99 | 17.06 | 229.63 | 15.76 |
| *Baetisca* | | | | | | | | | | |
| *Brachycercus* | | | 7.18 | 2.25 | | | | | | |
| *Caenis* | | | 3.59 | 1.12 | 139.93 | 18.40 | | | | |
| *Centroptilum* | | | 118.40 | 37.09 | | | | | | |
| *Ephemerella* | | | | | | | | | 333.68 | 20.45 |
| *Heptagenia* | 10.76 | 10.34 | 50.23 | 15.74 | 64.58 | 8.49 | 182.99 | 17.06 | 290.63 | 19.96 |
| *Isonychia* | | | | | | | | | | |
| *Leptophlebia* | | | | | | | | | | |
| *Neocloeon* | | | | | | | 10.76 | 1.00 | | |
| *Paraleptophlebia* | | | | | | | | | 3.59 | 0.25 |
| *Rhithrogena* | | | | | | | | | | |
| *Stenonema* | | | | | | | | | | |
| *Tricorythodes* | | | | | 39.47 | 5.19 | 17.94 | 1.67 | 3.59 | 0.25 |
| Baetidae | | | | | | | | | | |
| Odonata | | | | | | | | | | |
| *Aeshna* | | | | | | | | | | |
| *Ophiogomphus* | 7.18 | 6.90 | 3.59 | 1.12 | 14.35 | 1.89 | 25.12 | 2.34 | 3.59 | 0.25 |
| *Calopteryx* | | | | | | | | | | |
| Gomphidae | | | | | | | | | | |
| Plecoptera | | | | | | | | | | |
| *Acroneuria* | | | | | | | | | | |
| *Arcynopteryx* | | | | | | | | | | |

(Continued)

TABLE 17. Continued.

| Taxa | May No./m² | May % | June No./m² | June % | July No./m² | July % | August No./m² | August % | September No./m² | September % |
|---|---|---|---|---|---|---|---|---|---|---|
| *Hastaperla* | | | | | | | | | | |
| *Isogenus* | | | | | | | | | 50.23 | 3.45 |
| *Pteronarcys* | 3.59 | 3.45 | | | | | 7.18 | 0.67 | 10.76 | 0.74 |
| *Taeniopteryx* | | | | | | | | | 89.70 | 6.16 |
| Trichoptera | | | | | | | | | | |
| *Arctopsyche* | | | 3.59 | 1.12 | | | 7.18 | 0.67 | | |
| *Athripsodes* | | | | | | | | | | |
| *Brachycentrus* | | | | | | | | | | |
| *Drusinus* | | | | | | | | | | |
| *Glossosoma* | | | | | | | 3.59 | 0.33 | | |
| *Hydropsyche* | | | | | | | | | 43.06 | 2.95 |
| *Mayatrichia* | | | | | | | | | | |
| *Neureclipsis* | | | | | | | | | | |
| *Oxyethira* | | | 3.59 | 1.12 | | | | | | |
| *Rhyacophila* | | | | | | | | | | |
| unid. pupae | | | | | | | | | | |
| Hemiptera | | | | | | | | | | |
| Corixidae | | | 3.59 | 1.12 | | | | | | |
| Coleoptera | | | | | | | | | | |
| Dytiscidae | | | | | | | | | | |
| Elmidae | | | | | | | | | | |
| Diptera | | | | | | | | | | |
| Ceratopogonidae | | | 3.59 | 1.12 | | | | | | |
| Chironomidae | | | | | | | | | | |
| *Ablabesmyia* | | | | | 7.18 | 0.94 | | | | |
| *Cardiocladius* | | | | | | | 7.18 | 0.67 | | |
| *Cladotanytarsus* | 14.35 | 13.79 | | | | | 3.59 | 0.33 | | |
| *Coelotanypus* | | | | | | | | | | |
| *Conchapelopia* | | | 10.76 | 3.37 | | | 7.18 | 0.67 | 86.11 | 5.91 |
| *Cricotopus* | 14.35 | 13.79 | 50.23 | 15.74 | | | | | | |
| *Cryptocladopelma* | | | | | | | | | | |
| *Cryptochironomus* | | | | | 3.59 | 0.47 | | | | |
| *Endochironomus* | | | | | | | | | | |
| *Eukiefferiella* | | | | | | | 21.53 | 2.01 | | |
| *Micropsectra* | 7.18 | 6.90 | | | 14.35 | 1.89 | | | 14.35 | 0.98 |

(Continued)

TABLE 17. Continued.

| Taxa | May No./$m^2$ | May % | June No./$m^2$ | June % | July No./$m^2$ | July % | August No./$m^2$ | August % | September No./$m^2$ | September % |
|---|---|---|---|---|---|---|---|---|---|---|
| *Microtendipes* | | | | | | | | | 17.94 | 1.23 |
| *Orthocladius* | 3.59 | 3.45 | | | | | 114.82 | 10.70 | 226.04 | 15.52 |
| *Paralauterborniella* | | | | | | | | | | |
| *Polypedilum* | | | | | | | | | 17.94 | 1.23 |
| *Procladius* | | | | | | | | | | |
| *Psectocladius* | | | | | | | | | | |
| *Rheotanytarsus* | 3.59 | 3.45 | 10.76 | 3.37 | | | 3.59 | 0.33 | | |
| *Smittia* | | | | | 14.35 | 1.89 | | | | |
| *Tanytarsus* | | | 3.59 | 1.12 | | | | | 7.18 | 0.49 |
| *Thienemaniella* | | | | | | | | | | |
| *Tribelos* | | | | | | | | | | |
| *Trichocladius* | | | | | | | | | | |
| Dolichopodidae | | | | | | | | | | |
| *Hydrophorus* | | | | | | | | | | |
| Empididae | | | | | | | 10.76 | 1.00 | 10.76 | 0.74 |
| Rhagionidae | | | | | | | | | | |
| Simuliidae | 3.59 | 3.45 | | | 200.93 | 26.41 | 175.81 | 16.39 | | |
| unid. pupae | | | | | 3.59 | 0.47 | 28.70 | 2.67 | | |
| Arachnida | | | | | | | | | | |
| Hydracarina | | | | | | | | | | |
| Mollusca | | | | | | | | | | |
| Ferrissia | | | | | | | | | | |
| Lymnaea | | | | | | | | | | |
| No. Individuals/$m^2$ (t) | 104.05 | | 319.33 | | 760.66 | | 1072.81 | | 1456.73 | |
| No. Taxa (s) | 11 | | 16 | | 12 | | 19 | | 20 | |
| Shannon-Weaver Species Diversity Index ($\bar{d}$) | 3.11 | | 2.90 | | 2.71 | | 3.09 | | 3.23 | |
| Equitability (e) | 1.09 | | 0.63 | | 0.75 | | 0.63 | | 0.65 | |

TABLE 18. Species composition, species diversity, equitability, and standing crop (number per square metre) of benthic macroinvertebrates collected in Surber samples at the Lower Station of MacKay River, May-September, 1977.

| Taxa | May No./m$^2$ | May % | June No./m$^2$ | June % | July No./m$^2$ | July % | August No./m$^2$ | August % | September No./m$^2$ | September % |
|---|---|---|---|---|---|---|---|---|---|---|
| Oligochaeta | 53.82 | 75.00 | 14.35 | 9.75 | 28.70 | 32.00 | 7.18 | 2.94 | 61.00 | 7.11 |
| Nematoda | | | | | 3.59 | 4.00 | | | | |
| Hirudinea | | | | | 3.59 | 4.00 | | | | |
| Amphipoda | | | | | | | | | | |
| *Hyalella* | | | | | | | | | | |
| Collembola | | | | | 3.59 | 4.00 | | | | |
| Ephemeroptera | | | | | | | | | | |
| *Ameletus* | | | 17.94 | 12.19 | 3.59 | 4.00 | | | | |
| *Baetis* sp. A | 3.59 | 5.00 | 17.94 | 12.19 | 14.35 | 16.00 | 61.00 | 25.01 | | |
| *Baetis* sp. B | 3.59 | 5.00 | 25.12 | 17.07 | 3.59 | 4.00 | 78.94 | 32.36 | 111.23 | 12.97 |
| *Baetisca* | | | | | | | | | 3.59 | 0.41 |
| *Brachycercus* | | | | | | | | | | |
| *Caenis* | | | | | | | | | 3.59 | 0.41 |
| *Centroptilum* | | | 21.53 | 14.71 | | | | | | |
| *Ephemerella* | | | | | | | | | 68.17 | 7.94 |
| *Heptagenia* | | | 10.76 | 7.31 | 7.18 | 8.00 | 43.06 | 17.64 | 247.57 | 28.97 |
| *Isonychia* | | | | | | | | | | |
| *Leptophlebia* | | | | | | | | | 21.53 | 2.51 |
| *Neocloeon* | | | | | | | | | | |
| *Paraleptophlebia* | 3.59 | 5.00 | | | | | | | 7.18 | 0.83 |
| *Rhithrogena* | | | | | | | 3.59 | 1.47 | 121.99 | 14.24 |
| *Stenonema* | | | | | | | | | 17.94 | 2.09 |
| *Tricorythodes* | | | | | | | 7.18 | 2.94 | 3.59 | 0.41 |
| Baetidae | | | | | | | | | | |
| Odonata | | | | | | | | | | |
| *Aeshna* | | | | | | | | | | |
| *Ophiogomphus* | | | 3.59 | 2.43 | | | | | 7.18 | 0.83 |
| *Calopteryx* | | | | | | | | | | |
| Gomphidae | | | | | | | | | | |
| Plecoptera | | | | | | | | | | |
| *Acroneuria* | | | | | | | | | | |
| *Arcynopteryx* | | | | | | | | | | |

(Continued)

TABLE 18. Continued.

| Taxa | May No./m² | % | June No./m² | % | July No./m² | % | Aug No./m² | % | Sept No./m² | % |
|---|---|---|---|---|---|---|---|---|---|---|
| *Hastaperla* | | | | | | | | | 17.94 | 2.09 |
| *Isogenus* | | | | | | | | | 35.88 | 4.18 |
| *Pteronarcys* | | | | | | | | | | |
| *Taeniopteryx* | | | | | | | | | 3.59 | 0.41 |
| Trichoptera | | | | | | | | | | |
| *Arctopsyche* | | | | | | | 3.59 | 1.47 | | |
| *Athripsodes* | | | | | | | | | | |
| *Brachycentrus* | | | | | | | | | | |
| *Drusinus* | | | | | | | | | 7.18 | 0.83 |
| *Glossosoma* | | | | | | | | | | |
| *Hydropsyche* | | | | | | | | | 32.29 | 3.76 |
| *Mayatrichia* | | | | | 3.59 | 4.0 | | | | |
| *Neureclipsis* | | | | | | | | | | |
| *Oxyethira* | | | | | | | | | | |
| *Rhyacophila* | | | | | | | | | | |
| unid. pupae | | | | | | | | | | |
| Hemiptera | | | | | | | | | | |
| Corixidae | | | | | | | | | | |
| Coleoptera | | | | | | | | | | |
| Dytiscidae | 3.59 | 5.00 | | | | | | | | |
| Elmidae | | | | | 3.59 | 4.0 | | | | |
| Diptera | | | | | | | | | | |
| Ceratopogonidae | 3.59 | 5.00 | | | | | | | | |
| Chironomidae | | | | | | | | | | |
| *Ablabesmyia* | | | | | | | | | | |
| *Chironomus* | | | | | | | | | 25.12 | 2.92 |
| *Cladotanytarsus* | | | | | | | | | | |
| *Conchapelopia* | | | 3.59 | 2.43 | | | | | 7.18 | 0.83 |
| *Cricotopus* | | | | | 3.59 | 4.0 | 7.18 | 2.94 | | |
| *Cryptochironomus* | | | | | | | 3.59 | 1.47 | | |
| *Eukiefferiella* | | | | | | | 3.59 | 1.47 | | |
| *Micropsectra* | | | | | | | | | 32.29 | 3.76 |
| *Orthocladius* | | | | | | | 3.59 | 1.47 | | |

(Continued)

TABLE 18. Continued.

| Taxa | May No./m² | % | June No./m² | % | July No./m² | % | Aug No./m² | % | Sept No./m² | % |
|---|---|---|---|---|---|---|---|---|---|---|
| *Paratendipes* | | | 7.18 | 4.87 | | | | | | |
| *Polypedilum* | | | 7.18 | 4.87 | 7.18 | 8.00 | 10.76 | 4.41 | | |
| *Rheotanytarsus* | | | 10.76 | 7.31 | | | 7.18 | 2.94 | 7.18 | 0.83 |
| *Tanytarsus* | | | | | | | | | 10.76 | 1.25 |
| Dolichopodidae | | | | | | | | | | |
| *Hydrophorus* | | | | | | | | | | |
| Empididae | | | | | | | | | 3.59 | 0.41 |
| Rhagionidae | | | | | | | | | | |
| Simuliidae | | | 7.18 | 4.87 | 3.59 | 4.00 | | | | |
| unid. pupae | | | | | | | | | | |
| Arachnida | | | | | | | | | | |
| Hydracarina | | | | | | | | | | |
| Mollusca | | | | | | | | | | |
| Ferrissia | | | | | | | 3.59 | 1.47 | | |
| Lymnaea | | | | | | | | | | |
| No. Individuals/m² | 71.76 | | 147.11 | | 89.70 | | 243.98 | | 857.53 | |
| No. Taxa (s) | 6 | | 12 | | 13 | | 14 | | 23 | |
| Shannon-Weaver Species Diversity Index ($\bar{d}$) | 1.39 | | 3.36 | | 3.20 | | 2.80 | | 3.07 | |
| Equitability (e) | 0.50 | | 1.25 | | 1.00 | | 0.71 | | 0.52 | |

1) Dominant taxon (D)--at least 25%;

2) Sub-dominant taxon (S)--at least 10%, but less than 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%.

Each of the five categories was given an arbitrary numerical value:

D=16

S=8

C=4

R=2

1=1

Based on the per cent composition data for the taxa (Tables 16-18 ), their dominance values were summed to form a "dominance index". These indices were used to group the invertebrate taxa into dominance classes (Tables 19-22).

The data suggest that, as a whole, the dominant benthos at the MacKay River (Table 19) are the oligochaete worms; the mayflies *Baetis* spp. and *Heptagenia* sp.; the dragonfly *Ophiogomphus* sp.; the caddisflies *Arctopsyche* sp. and *Hydropsyche* spp.; the blackfly *Simulium* spp.; and the orthocladiinid chironomids *Cricotopus* spp. and *Orthocladius* spp.

At the Upper Station (Table 20) the dominant benthos are the mayflies

TABLE 19. Grouping of the benthic macroinvertebrate taxa from the MacKay River in dominance classes based on their dominance index values.

| Index: 104-88 | 52-32 | 28-20 | 18-12 | 10-2 |
|---|---|---|---|---|
| Oligochaeta | Ephemeroptera | Ephemeroptera | Ephemeroptera | Nematoda |
| Ephemeroptera | *Centroptilum* | *Ephemerella* | *Ameletus* | Hirudinea |
| *Baetis* sp. A | Odonata | *Rhithrogena* | *Brachycercus* | Collembola |
| *Baetis* sp. B | *Ophiogomphus* | *Tricorythodes* | *Caenis* | Ephemeroptera |
| *Heptagenia* | Trichoptera | Plecoptera | *Paraleptophlebia* | *Baetisca* |
| | *Arctopsyche* | *Isogenus* | Trichoptera | *Leptophlebia* |
| | *Hydropsyche* | *Pteronarcys* | *Brachycentrus* | *Neocloeon* |
| | Diptera | Diptera | *Glossosoma* | *Stenonema* |
| | *Cricotopus* | *Micropsectra* | Diptera | Plecoptera |
| | *Orthocladius* | *Polypedilum* | *Ablabesmyia* | *Hastaperla* |
| | Simuliidae | *Rheotanytarsus* | *Cladotanytarsus* | *Taeniopteryx* |
| | | | *Conchapelopia* | Trichoptera |
| | | | *Microtendipes* | *Athripsodes* |
| | | | *Tanytarsus* | *Drusinus* |
| | | | Empididae | *Mayatrichia* |
| | | | | *Neureclipsis* |
| | | | | *Oxyethira* |
| | | | | *Rhyacophila* |
| | | | | Hemiptera |
| | | | | Corixidae |
| | | | | Coleoptera |
| | | | | Dytiscidae |
| | | | | Elmidae |
| | | | | Diptera |
| | | | | Ceratopogonidae |
| | | | | *Cardiocladius* |
| | | | | *Chironomus* |
| | | | | *Endochironomus* |
| | | | | *Eukiefferiella* |
| | | | | *Paralauterborniella* |
| | | | | *Paratendipes* |
| | | | | *Smittia* |
| | | | | Rhagionidae |
| | | | | Mollusca |
| | | | | *Ferrissia* |

TABLE 20. Grouping of the benthic macroinvertebrate taxa from the upper station of the MacKay River in dominance classes based on their dominance index values.

| Index: 36-28 | 24-20 | 16-10 | 8-2 |
|---|---|---|---|
| Ephemeroptera | Ephemeroptera | Oligochaeta | Nematoda |
| *Baetis* sp. B | *Baetis* sp. A | Ephemeroptera | Ephemeroptera |
| *Heptagenia* | Trichoptera | *Ameletus* | *Brachycercus* |
| Diptera | *Arctopsyche* | *Centroptilum* | *Caenis* |
| *Cricotopus* | *Hydropsyche* | *Ephemerella* | *Paraleptophlebia* |
| | | *Rhithrogena* | *Tricorythodes* |
| | | Odonata | Plecoptera |
| | | *Ophiogomphus* | *Hastaperla* |
| | | Plecoptera | Trichoptera |
| | | *Isogenus* | *Athripsodes* |
| | | *Pteronarcys* | *Drusinus* |
| | | Trichoptera | *Mayatrichia* |
| | | *Brachycentrus* | *Neureclipsis* |
| | | *Glossosoma* | *Rhyacophila* |
| | | Diptera | Hemiptera |
| | | *Ablabesmyia* | Corixidae |
| | | *Micropsectra* | Coleoptera |
| | | *Orthocladius* | Elmidae |
| | | *Polypedilum* | Diptera |
| | | | *Cardiocladius* |
| | | | *Cladotanytarsus* |
| | | | *Endochironomus* |
| | | | *Eukiefferiella* |
| | | | *Microtendipes* |
| | | | *Paralauterborniella* |
| | | | *Paratendipes* |
| | | | *Rheotanytarsus* |
| | | | *Smittia* |
| | | | *Tanytarsus* |
| | | | Empididae |
| | | | Rhagionidae |
| | | | Simuliidae |

TABLE 21. Grouping of the benthic macroinvertebrate taxa from the middle station of the MacKay River in dominance classes based on their dominance index values.

| Index: 36-28 | 20-16 | 12-10 | 8-2 |
|---|---|---|---|
| Oligochaeta | Ephemeroptera | Ephemeroptera | Ephemeroptera |
| Ephemeroptera | *Centroptilum* | *Caenis* | *Ameletus* |
| *Baetis* sp. A | Odonata | *Tricorythodes* | *Brachycercus* |
| *Baetis* sp. B | *Ophiogomphus* | Diptera | *Ephemerella* |
| *Heptagenia* | Diptera | *Cladotanytarsus* | *Neocloeon* |
| Diptera | *Cricotopus* | *Conchapelopia* | *Paraleptophlebia* |
| Simuliidae | *Orthocladius* | *Micropsectra* | Plecoptera |
| | | *Rheotanytarsus* | *Isogenus* |
| | | | *Pteronarcys* |
| | | | *Taeniopteryx* |
| | | | Trichoptera |
| | | | *Arctopsyche* |
| | | | *Glossosoma* |
| | | | *Hydropsyche* |
| | | | *Oxyethira* |
| | | | Hemiptera |
| | | | Corixidae |
| | | | Diptera |
| | | | Ceratopogonidae |
| | | | *Ablabesmyia* |
| | | | *Cardiocladius* |
| | | | *Cryptochironomus* |
| | | | *Eukiefferiella* |
| | | | *Microtendipes* |
| | | | *Polypedilum* |
| | | | *Smittia* |
| | | | *Tanytarsus* |
| | | | Empididae |

TABLE 22. Grouping of the benthic macroinvertebrate taxa from the lower station of the MacKay River in dominance classes based on their dominance index values.

| Index: 44-40 | 36-32 | 12-10 | 8-2 |
|---|---|---|---|
| Oligochaeta | Ephemeroptera | Ephemeroptera | Nematoda |
| Ephemeroptera | *Baetis* sp. A | *Ameletus* | Hirudinea |
| *Baetis* sp. B | *Heptagenia* | *Rhithrogena* | Collembola |
| | | Diptera | Ephemeroptera |
| | | *Polypedilum* | *Baetisca* |
| | | *Rheotanytarsus* | *Caenis* |
| | | | *Centroptilum* |
| | | | *Ephemerella* |
| | | | *Leptophlebia* |
| | | | *Paraleptophlebia* |
| | | | *Stenonema* |
| | | | *Tricorythodes* |
| | | | Odonata |
| | | | *Ophiogomphus* |
| | | | Plecoptera |
| | | | *Hastaperla* |
| | | | *Isogenus* |
| | | | *Taeniopteryx* |
| | | | Trichoptera |
| | | | *Arctopsyche* |
| | | | *Drusinus* |
| | | | *Hydropsyche* |
| | | | *Mayatrichia* |
| | | | Coleoptera |
| | | | Dytiscidae |
| | | | Elmidae |
| | | | Diptera |
| | | | Ceratopogonidae |
| | | | *Chironomus* |
| | | | *Conchapelopia* |
| | | | *Cricotopus* |
| | | | *Cryptochironomus* |

(Continued)

TABLE 22. Continued.

Index:

| 44-40 | 36-32 | 12-10 | 8-2 |
|---|---|---|---|
| | | | *Eukiefferiella* |
| | | | *Micropsectra* |
| | | | *Orthocladius* |
| | | | *Paratendipes* |
| | | | *Tanytarsus* |
| | | | Empididae |
| | | | Simuliidae |
| | | | Mollusca |
| | | | *Ferrissia* |

*Baetis* spp. and *Heptagenia* sp.; the caddisflies *Arctopsyche* sp. and *Hydropsyche* spp.; and the chironomid *Cricotopus* spp. Other common forms include the riffle mayflies *Ameletus* sp., *Ephemerella* spp., and *Rhithrogena* sp., and the stoneflies *Isogenus* sp. and *Pteronacys* sp. The diverse caddisfly fauna is dominated by the *Brachycentrus* sp. and *Glossosoma* sp. According to Barton and Wallace (1977), such a benthic community structure is characteristic of the Type (or Zone) IV Streams, i.e., "large, high gradient streams which cut through glacial till and thus have substrates consisting of boulders and gravels."

At the Middle Station, where exposed tar sand is a common feature of the substratum, the benthic community (Table 21) is dominated by the oligochaete worms; the blackfly *Simulium*; and the mayflies *Baetis* spp. and *Heptagenia*. Other common benthic invertebrates include the mayfly *Centroptilum* sp.; the dragonfly *Ophiogomphus* sp.; and the Orthocladiinae midges *Cricotopus* spp. and *Orthocladius* spp. This benthic association appears to conform to the Type (or Zone) VI Streams of Barton and Wallace (1977), i.e., "streams cutting through oil sands deposits."

At the Lower Station (Table 22), the dominant benthos are the oligochaetes and the mayflies *Baetis* spp. and *Heptagenia* sp. Several slow-water forms seem to be restricted to the Lower Station (Tables 12 and 16), e.g., the mayflies *Stenonema* and *Hexagenia;* the damselfly *Calopteryx*; a predaceous dytiscid beetle; and the bloodworm *Chironomus* sp.

Species Diversity

The diversity of the benthic communities at the MacKay River was characterized by:

1) the Shannon-Weaver Species Diversity Index ($\bar{d}$);
2) taxonomic diversities (t); and
3) MacArthur's Equitability Index (e).

The results are summarized in Table 23.

On the whole, benthic diversity ($\bar{d}$ and t) was greatest at the Upper Station, lowest at the Lower Station, and intermediate at the Middle Station. This variation is most likely correlated with the difference in substrate types at the three stations. The predominantly rubble substrate at the Upper Station provided a more complex and stable habitat for the invertebrates and hence a more diverse fauna (Percival and Whitehead, 1929; Sprules, 1947; Hynes, 1970). The predominantly gravel and exposed tar sand substrates at the Middle Station are more subject to movement and wash-out than rubble and hence the reduced benthic diversity.

The Lower Station, which is situated in the depositional zone, has a substrate which includes large amounts of silt and sand and, consequently, a reduced faunal diversity (Hynes, 1970).

Seasonally, species diversities ($\bar{d}$) fluctuated considerably at the three stations (Figure 18). There seemed, however, to be a general increase

TABLE 23. Seasonal variations in the species diversity ($\bar{d}$), taxonomic diversity (t), and equitability (e) of the benthic macroinvertebrate communities at the MacKay River. May-September, 1977.

| Station | Parameter | May | June | July | August | September | Mean | Standard Deviation |
|---|---|---|---|---|---|---|---|---|
| Upper | $\bar{d}$ | 3.09 | 3.60 | 3.05 | 3.85 | 3.21 | 3.36 | 0.3497 |
| | t | 17 | 18 | 19 | 31 | 21 | 21.20 | 5.6745 |
| | e | 0.71 | 0.94 | 0.63 | 0.68 | 0.62 | 0.716 | 0.1305 |
| Middle | $\bar{d}$ | 3.11 | 2.90 | 2.71 | 3.09 | 3.23 | 3.00 | 0.2043 |
| | t | 11 | 16 | 12 | 19 | 20 | 15.60 | 4.0373 |
| | e | 1.09 | 0.63 | 0.75 | 0.63 | 0.65 | 0.75 | 0.1965 |
| Lower | $\bar{d}$ | 1.39 | 3.36 | 3.20 | 2.80 | 3.07 | 2.76 | 0.7950 |
| | t | 6 | 12 | 13 | 14 | 23 | 13.60 | 6.1074 |
| | e | 0.50 | 1.25 | 1.00 | 0.71 | 0.52 | 0.796 | 0.3236 |

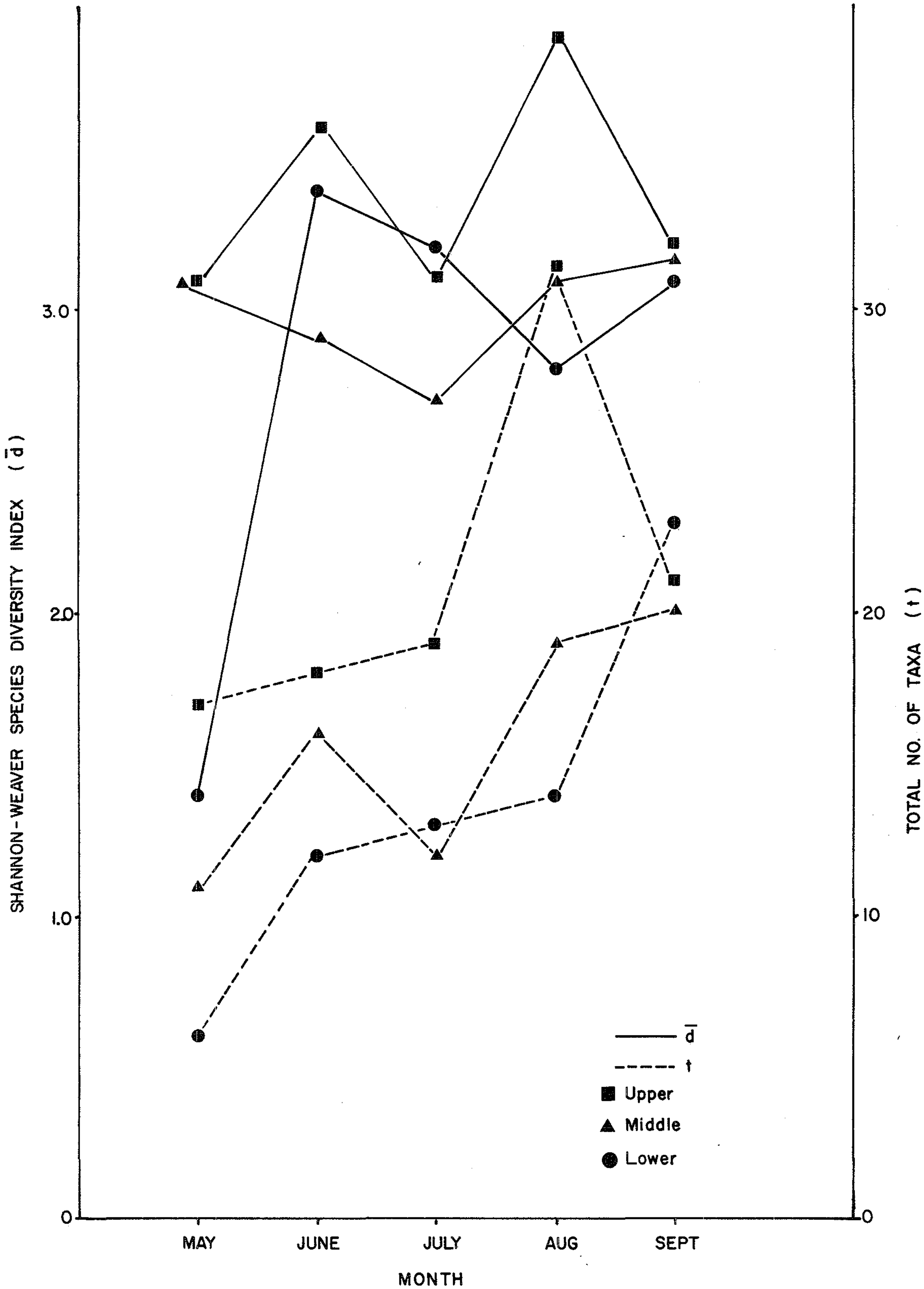



FIGURE 18. Seasonal variation of the taxonomic diversity (t) and Shannon-Weaver Species Diversity (d̄) at the Upper, Middle, and Lower Stations of the MacKay River, May-September, 1977.

in taxonomic diversity (t) from spring to fall (Table 23 and Figure 18). An analysis of the seasonal distribution of the benthic taxa indicated that out of the 80 taxa found in the MacKay River, 23 taxa were found in May, 34 in June, 44 in July, 55 in August, and 46 in September. The greater taxonomic diversity in August and September is probably related to the "winter species" type of life cycles found in the majority of the benthos in northern latitudes (Hartland-Rowe, 1964; Clifford, 1969; Clifford *et al.*, 1973). Most of these species hatch from eggs in summer and fall and persist through the winter (with or without growth) to emerge the following spring or summer.

Standing Crop

Both temporal and spatial variations in benthic macroinvertebrate standing crops (number/$m^2$) have been examined (Figure 19 and Tables 16-18).

Seasonally, it appears that the standing crop of benthos increased from May to September. The increment was greatest between July and August. Again, this phenomenon probably reflects:

1) The dominant life-history pattern (i.e., winter species type) that occurs in the benthic community of most brown-water streams (Clifford, 1969; Clifford *et al.*, 1973). Spring and summer emergence can probably account for the lower observed standing crop in May and June and the hatching (from eggs) in late summer and fall can account for the increase in August and September.

2) Suspended sediment concentrations were generally higher in spring than in late summer and fall and increased sedimentation tends to

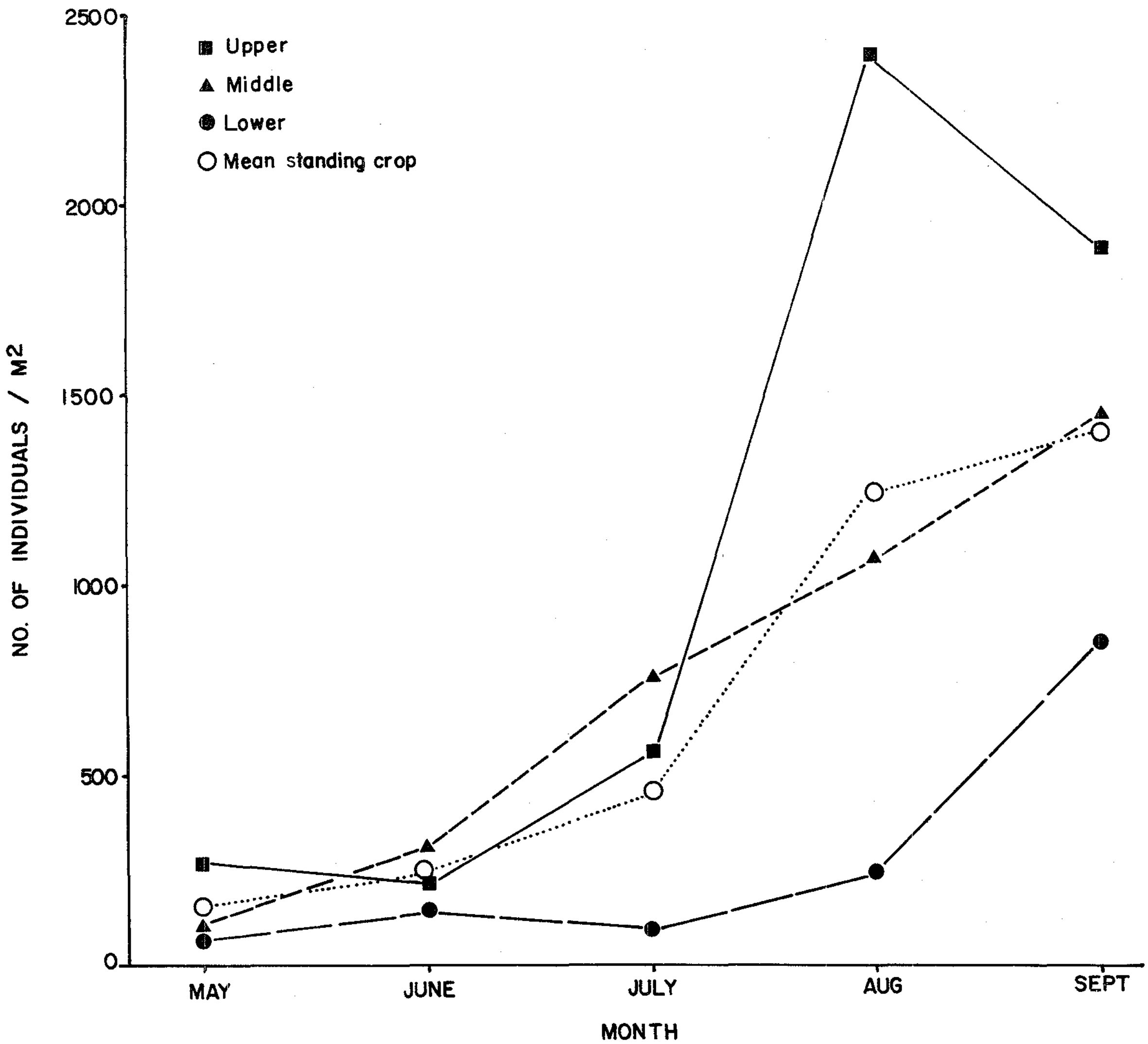



FIGURE 19. Seasonal variations in benthos standing crop (No./$m^2$) at the Upper, Middle, and Lower Stations of the MacKay River, May-September, 1977.

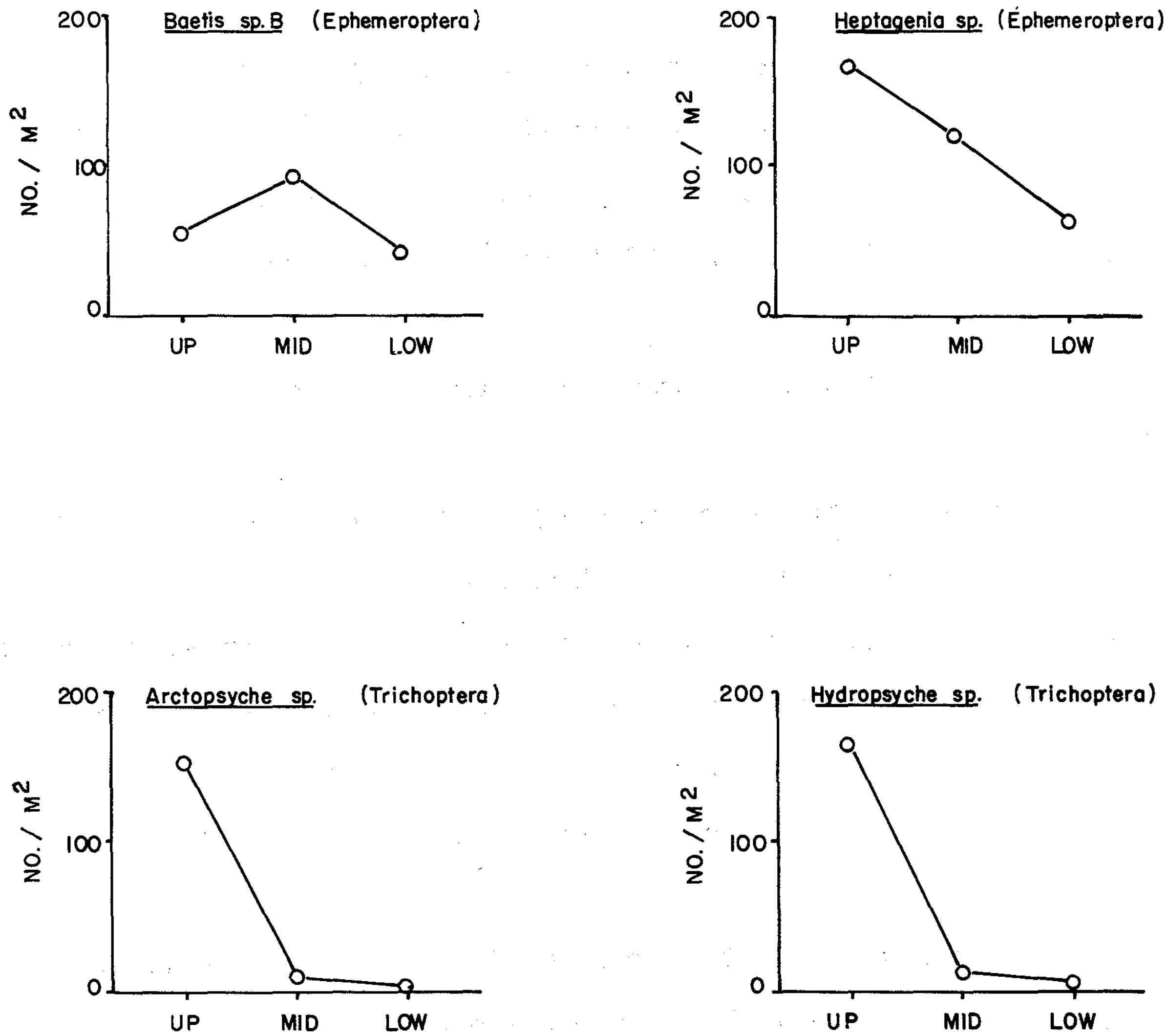
lower benthic density.

Spatially, the mean standing crop declined from the Upper to the Lower Station (Table 24). This variation can probably be attributed to: 1) substrate size, and 2) sedimentation. The larger substrates (mainly cobble) at the Upper Station probably provided a greater diversity of habitat particularly for dipterans and caddisfly larvae. The larger substrates also provided the stability needed for colonization. Barber and Kevern (1973) investigated the influence of substrate on macroinvertebrate standing crop (numbers and biomass). They found that the biomass of dipteran larvae (primarily chironomids and simuliids) was positively correlated with substrate size, and that higher numbers and greater biomass of trichopterans were associated with larger substrates.

The substrate-standing crop relationship at the MacKay River can be demonstrated by examining the standing crop of several of the dominant benthos at the Upper, Middle, and Lower Stations (Figure 20). The slightly higher mean standing crop of *Baetis* sp. B at the Middle Station is probably best explained by the smaller size of the *Baetis* nymphs (as compared with *Heptagenia* sp. nymphs). Smaller nymphs are usually associated with smaller substrates (Macan, 1957), and, generally, gravel is the common substrate type found at the Middle Station. *Heptagenia* sp. and *Cricotopus* sp. showed a more gradual decline in mean standing crop from the Upper to the Lower Stations; however, the trichopterans (*Arctopsyche* sp. and *Hydropsyche* sp.) showed a rapid decline from Upper to Middle and Lower Stations.

TABLE 24. Variation of benthos mean standing crop (number/$m^2$) at the Upper, Middle, and Lower Stations of the MacKay River. May to September, 1977.

| Station | Dominant Substrate Types | Mean Standing Crop | Range |
|---|---|---|---|
| Upper | rubble, boulder | 1064.92 | (226.04-2386.02) |
| Middle | gravel, rubble | 742.72 | (104.05-1456.73) |
| Lower | gravel, sand, mud silt | 282.02 | (71.76-857.53) |



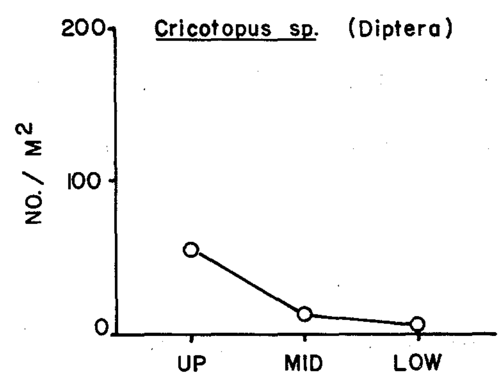




FIGURE 20. Mean standing crop (No./$m^2$) of several dominant benthos at the Upper, Middle, and Lower Stations of the MacKay River, 1977.

The longitudinal variation in benthos standing crop can also be explained by the increase of sedimentation downstream (Table 24). The inverse relation of sediment concentration and benthos standing crop is well documented (Gaufin, 1959; Cordone and Kelley, 1961).

Proficiency of Rock Basket Sampler in Collecting Benthos from the MacKay River

Substrate variability in the MacKay River is one of the main problems in locating ecologically comparable habitats for benthic sampling. One method of overcoming this problem is to use an artificial substrate sampler which will ensure substrate uniformity. In this study, the rock-basket sampler, as described in McCart *et al.* (1977) was used to collect benthos at the three stations. The objectives of this experiment were:

1) to compare the benthic species collected by the rock-basket sampler to those collected by the Surber sampler;

2) to compare the number of taxa and individuals collected by the two methods (i.e., rock-basket sampler and the Surber sampler); and

3) to compare the diversity and evenness of the benthic communities which developed on the artificial substrates to those of the natural population.

The data resulting from this study are presented in Tables 25 to 27.

TABLE 25. Species composition, species diversity, equitability, and total number of benthic macroinvertebrates collected by the rock basket samplers at the Upper Station of MacKay River, June-September, 1977.

| Taxa | June No. | June % | July No. | July % | Aug No. | Aug % | Sept No. | Sept % |
|---|---|---|---|---|---|---|---|---|
| Oligochaeta | | | 1 | 0.03 | | | | |
| Nematoda | | | | | | | | |
| Hirudinea | | | | | | | | |
| Amphipoda | | | | | | | | |
| *Hyalella* | | | | | | | | |
| Collembola | | | | | | | | |
| Ephemeroptera | | | | | | | | |
| *Ameletus* | | | 2 | 0.06 | 8 | 0.19 | 2 | 0.38 |
| *Baetis* sp.A | 2 | 0.12 | 88 | 2.84 | 710 | 16.74 | | |
| *Baetis* sp. B | 10 | 0.60 | 133 | 4.30 | 144 | 3.40 | 83 | 15.93 |
| *Baetisca* | | | | | | | | |
| *Brachycercus* | | | | | | | | |
| *Caenis* | | | | | | | | |
| *Centroptilum* | | | | | 4 | 0.09 | | |
| *Ephemerella* | 15 | 0.90 | 2 | 0.06 | | | 3 | 0.58 |
| *Heptagenia* | 24 | 1.44 | 92 | 2.97 | 78 | 1.84 | 36 | 6.91 |
| *Isonychia* | | | | | | | | |
| *Leptophlebia* | | | | | | | | |
| *Neocloeon* | | | | | | | | |
| *Paraleptophlebia* | | | | | | | | |
| *Rhithrogena* | 5 | 0.30 | | | | | 23 | 4.41 |
| *Stenonema* | | | | | | | | |
| *Tricorythodes* | | | 70 | 2.26 | 9 | 0.21 | | |
| Baetidae | 4 | 0.24 | | | | | 3 | 0.58 |
| Odonata | | | | | | | | |
| *Aeshna* | | | | | | | | |
| *Ophiogomphus* | | | | | 1 | 0.02 | | |
| *Calopteryx* | | | | | | | | |
| Gomphidae | | | | | | | | |
| Plecoptera | | | | | | | | |
| *Acroneuria* | | | | | | | 2 | 0.38 |
| *Arcynopteryx* | | | | | 5 | 0.12 | | |

(Continued)

TABLE 25. Continued.

| Taxa | June No. | June % | July No. | July % | Aug No. | Aug % | Sept No. | Sept % |
|---|---|---|---|---|---|---|---|---|
| *Hastaperla* | 1 | 0.06 | | | | | | |
| *Isogenus* | | | 20 | 0.64 | 223 | 5.26 | 8 | 1.54 |
| *Pteronarcys* | 13 | 0.78 | 41 | 1.32 | 42 | 0.99 | 10 | 1.92 |
| *Taeniopteryx* | | | | | | | 7 | 1.34 |
| Trichoptera | | | | | | | | |
| *Arctopsyche* | 268 | 16.06 | 223 | 7.21 | 89 | 2.10 | | |
| *Athripsodes* | | | | | | | | |
| *Brachycentrus* | 909 | 54.45 | 593 | 19.17 | 66 | 1.56 | 22 | 4.22 |
| *Drusinus* | | | | | 5 | 0.12 | | |
| *Glossosoma* | | | | | | | 99 | 19.01 |
| *Hydropsyche* | 33 | 1.98 | 246 | 7.95 | 758 | 17.87 | 140 | 26.88 |
| *Mayatrichia* | | | 1 | 0.03 | | | | |
| *Neureclipsis* | | | | | | | | |
| *Oxyethira* | | | | | | | | |
| *Rhyacophila* | | | | | 3 | 0.07 | | |
| unid. pupae | 1 | 0.06 | | | | | 2 | 0.38 |
| Hemiptera | | | | | | | | |
| Corixidae | | | | | | | | |
| Coleoptera | | | | | | | | |
| Dytiscidae | | | | | | | | |
| Elmidae | | | | | | | | |
| Diptera | | | | | | | | |
| Ceratopogonidae | | | | | | | | |
| Chironomidae | | | | | | | | |
| *Ablabesmyia* | | | 1 | 0.03 | | | | |
| *Brillia* | | | 27 | 0.87 | | | | |
| *Cardiocladius* | | | | | | | | |
| *Cladotanytarsus* | | | 4 | 0.13 | | | | |
| *Conchapelopia* | | | 2 | 0.06 | 30 | 0.71 | 1 | 0.19 |
| *Cricotopus* | 3 | 0.18 | 64 | 2.07 | 170 | 4.01 | | |
| *Cryptotendipes* | | | 15 | 0.49 | | | | |
| Orthocladiinae | | | | | 71 | 1.67 | | |
| *Endochironomus* | | | | | 10 | 0.24 | | |

(Continued)

TABLE 25. Continued.

| Taxa | June No. | June % | July No. | July % | Aug No. | Aug % | Sept No. | Sept % |
|---|---|---|---|---|---|---|---|---|
| *Eukiefferiella* | 2 | 0.12 | | | 170 | 4.01 | | |
| *Labrundinia* | | | | | 10 | 0.24 | | |
| *Micropsectra* | | | | | | | | |
| *Microtendipes* | | | | | | | | |
| *Orthocladius* | 11 | 0.66 | 392 | 12.67 | 1017 | 23.98 | 76 | 14.59 |
| *Paralauterborniella* | | | | | | | | |
| *Paratendipes* | | | | | | | | |
| *Polypedilum* | 1 | 0.06 | 49 | 1.58 | 56 | 1.32 | | |
| *Psectrocladius* | | | | | 71 | 1.67 | | |
| *Rheotanytarsus* | | | 62 | 2.00 | 211 | 4.98 | 2 | 0.38 |
| *Smittia* | | | | | | | | |
| *Tanytarsus* | | | | | | | | |
| *Thienemanniella* | | | | | 73 | 1.72 | | |
| Dolichopodidae | | | | | | | | |
| *Hydrophorus* | | | | | | | | |
| Empididae | | | | | 6 | 0.14 | 2 | 0.38 |
| Rhagionidae | | | | | | | | |
| Simuliidae | 367 | 21.99 | 958 | 30.97 | 152 | 3.58 | | |
| Tipulidae | | | | | 2 | 0.05 | | |
| unid. pupae | | | 8 | 0.26 | 46 | 1.08 | | |
| Arachnida | | | | | | | | |
| Hydracarina | | | 1 | 0.03 | | | | |
| Mollusca | | | | | | | | |
| Ferrissia | | | | | | | | |
| Lymnaea | | | | | 1 | 0.02 | | |

(Continued)

TABLE 25. Continued.

| | June No. | June % | July No. | July % | Aug No. | Aug % | Sept No. | Sept % |
|---|---|---|---|---|---|---|---|---|
| No. Individuals | 1669 | | 3095 | | 4241 | | 521 | |
| No. Taxa (s) | 17 | | 25 | | 31 | | 18 | |
| Shannon-Weaver Species Diversity Index ($\bar{d}$) | 1.90 | | 3.16 | | 3.54 | | 2.99 | |
| Equitability (e) | 0.29 | | 0.52 | | 0.54 | | 0.61 | |

TABLE 26. A comparison of benthic macroinvertebrates collected by basket samplers with rock and tar sand substrates from the Middle Station of the MacKay River. June-September, 1977.

| | Rock Substrate | | | | | | | | Tar Sand Substrate | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June | | July | | Aug | | Sept | | July | | Aug | | Sept | |
| Taxa | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| Oligochaeta | 4 | 1.38 | | | 2 | 0.76 | 9 | 4.19 | | | 1 | 0.32 | 7 | 2.15 |
| Nematoda | | | | | | | | | | | | | | |
| Hirudinea | | | | | | | | | | | | | | |
| Amphipoda | | | | | | | | | | | | | | |
| *Hyalella* | | | | | | | 1 | 0.46 | | | | | | |
| Collembola | | | | | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | | | | | |
| *Ameletus* | 2 | 0.69 | | | 13 | 4.94 | 5 | 2.33 | | | 1 | 0.32 | 7 | 2.15 |
| *Baetis* sp. A | 51 | 17.60 | 70 | 19.34 | 39 | 14.83 | 4 | 1.86 | 85 | 26.07 | 31 | 9.87 | 25 | 7.69 |
| *Baetis* sp. B | | | 3 | 0.83 | 12 | 4.56 | 4 | 1.86 | | | 4 | 1.27 | 3 | 0.92 |
| *Baetisca* | | | | | | | | | 1 | 0.31 | | | 1 | 0.31 |
| *Brachycercus* | | | | | | | | | | | | | | |
| *Caenis* | | | 37 | 10.22 | 6 | 2.28 | | | 9 | 2.76 | 1 | 0.32 | 9 | 2.77 |
| *Centroptilum* | 42 | 14.48 | | | 31 | 11.79 | | | | | 12 | 3.82 | | |
| *Ephemerella* | 7 | 2.41 | 1 | 0.28 | | | 3 | 1.39 | | | | | | |
| *Heptagenia* | 48 | 16.55 | 84 | 23.19 | 58 | 22.05 | 44 | 20.47 | 115 | 35.28 | 53 | 16.88 | 63 | 19.38 |
| *Isonychia* | | | | | | | | | 1 | 0.31 | | | | |
| *Leptophlebia* | | | | | | | 11 | 5.12 | | | | | 7 | 2.15 |
| *Neocloeon* | | | | | | | | | | | 1 | 0.32 | | |
| *Paraleptophlebia* | | | 1 | 0.28 | 14 | 5.32 | 4 | 1.86 | 6 | 1.84 | 34 | 10.83 | 21 | 6.46 |
| *Rithrogena* | | | | | | | 1 | 0.46 | | | | | | |
| *Stenonema* | | | | | | | | | | | | | | |
| *Tricorythodes* | | | 22 | 6.08 | 1 | 0.38 | | | 8 | 2.45 | 4 | 1.27 | | |
| Baetidae | | | | | 10 | 3.81 | | | 3 | 0.92 | 3 | 0.96 | | |
| Odonata | | | | | | | | | | | | | | |
| *Aeshna* | | | | | 2 | 0.76 | 1 | 0.46 | | | 6 | 1.91 | 6 | 1.86 |
| *Ophiogomphus* | | | 1 | 0.28 | | | | | | | | | 2 | 0.62 |
| *Calopteryx* | | | | | | | | | | | | | | |
| Gomphidae | | | | | | | | | | | | | | |
| Plecoptera | | | | | | | | | | | | | | |
| *Acroneuria* | | | | | | | | | | | | | | |
| *Arcynopteryx* | | | | | | | | | | | | | | |

(Continued)

TABLE 26. Continued.

| | Rock Substrate | | | | | | | | Tar Sand Substrate | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June | | July | | Aug | | Sept | | July | | Aug | | Sept | |
| Taxa | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| *Hastaperla* | | | | | | | | | | | | | | |
| *Isogenus* | | | 1 | 0.28 | | | 59 | 27.45 | | | 1 | 0.32 | 57 | 17.54 |
| *Pteronarcys* | | | 6 | 1.66 | | | | | | | 2 | 0.64 | 1 | 0.31 |
| *Taeniopteryx* | | | | | | | 39 | 18.14 | | | | | 26 | 8.00 |
| Trichoptera | | | | | | | | | | | | | | |
| *Arctopsyche* | | | | | 1 | 0.38 | | | | | | | | |
| *Athripsodes* | | | | | | | | | | | | | | |
| *Brachycentrus* | | | | | | | | | | | | | | |
| *Drusinus* | | | | | | | | | | | | | | |
| *Glossosoma* | | | | | | | | | | | | | | |
| *Hydropsyche* | | | | | | | | | | | | | | |
| *Mayatrichia* | | | 55 | 15.19 | 1 | 0.38 | 2 | 0.93 | 51 | 15.64 | | | | |
| *Neureclipsis* | | | | | | | | | | | | | | |
| *Oxyethira* | | | | | 3 | 1.14 | | | | | | | | |
| *Rhyacophila* | | | | | | | | | | | | | | |
| unid. pupae | | | | | 1 | 0.38 | | | | | | | | |
| Hemiptera | | | | | | | | | | | | | | |
| Corixidae | | | | | | | 4 | 1.86 | | | | | 5 | 1.54 |
| Coleoptera | | | | | | | | | | | | | | |
| Dytiscidae | | | | | | | | | | | | | | |
| Elmidae | | | | | | | | | | | | | | |
| Diptera | | | | | | | | | | | | | | |
| Ceratopogonidae | | | | | | | | | 1 | 0.31 | | | | |
| Chironomidae | | | | | | | | | | | | | | |
| *Ablabesmyia* | | | | | | | | | | | 19 | 6.05 | | |
| *Cardiocladius* | | | | | | | | | | | | | | |
| *Cladotanytarsus* | 4 | 1.38 | | | | | 2 | 0.93 | | | | | | |
| *Coelotanypus* | | | 2 | 0.55 | | | | | | | | | | |
| *Conchapelopia* | 11 | 3.79 | 13 | 3.59 | 6 | 2.28 | 17 | 7.91 | 5 | 1.53 | 9 | 2.87 | 69 | 21.24 |
| *Cricotopus* | 26 | 8.96 | 3 | 0.83 | 10 | 3.81 | | | | | 2 | 0.64 | | |
| *Cryptocladopelma* | | | | | | | | | 1 | 0.31 | | | | |
| *Cryptochironomus* | | | | | | | | | | | | | | |
| *Endochironomus* | | | | | | | | | 2 | 0.61 | | | | |
| *Eukiefferiella* | | | | | 9 | 3.42 | 1 | 0.46 | | | | | | |
| *Micropsectra* | | | | | 1 | 0.38 | | | | | 19 | 6.05 | 4 | 1.23 |

(Continued)

TABLE 26. Continued.

| Taxa | Rock Substrate June No. | % | July No. | % | Aug No. | % | Sept No. | % | Tar Sand Substrate July No. | % | Aug No. | % | Sept No. | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Microtendipes* | | | | | 1 | 0.38 | 4 | 1.86 | | | 6 | 1.91 | 4 | 1.23 |
| *Orthocladius* | | | 2 | 0.55 | | | | | | | | | | |
| *Paralauterborniella* | | | | | 1 | 0.38 | | | | | 2 | 0.64 | | |
| *Polypedilum* | | | 8 | 2.21 | | | | | 3 | 0.92 | 4 | 1.27 | | |
| *Procladius* | | | | | | | | | | | 2 | 0.64 | 7 | 2.15 |
| *Psectocladius* | | | | | 5 | 1.90 | | | 3 | 0.92 | 17 | 5.41 | | |
| *Rheotanytarsus* | 25 | 8.62 | 4 | 1.10 | 10 | 3.81 | | | 1 | 0.31 | 3 | 0.96 | | |
| *Smittia* | | | | | | | | | | | | | | |
| *Tanytarsus* | | | | | 1 | 0.38 | | | 1 | 0.31 | 35 | 11.14 | | |
| *Thienemaniella* | | | | | 3 | 1.14 | | | | | 1 | 0.32 | | |
| *Tribelos* | | | | | | | | | | | 2 | 0.64 | | |
| *Trichocladius* | | | | | | | | | | | 1 | 0.32 | | |
| Dolichopodidae | | | | | | | | | | | | | | |
| *Hydrophorus* | | | | | | | | | | | | | 1 | 0.31 |
| Empididae | | | | | | | | | | | | | | |
| Rhagionidae | | | | | | | | | | | | | | |
| Simuliidae | 45 | 15.52 | 48 | 13.26 | | | | | 30 | 9.20 | 1 | 0.32 | | |
| unid. pupae | 25 | 8.62 | 1 | 0.28 | 22 | 8.36 | | | | | 37 | 11.77 | | |
| Arachnida | | | | | | | | | | | | | | |
| Hydracarina | | | | | | | | | | | | | | |
| Mollusca | | | | | | | | | | | | | | |
| Ferrissia | | | | | | | | | | | | | | |
| Lymnaea | | | | | | | | | | | | | | |
| No. Individuals | 290 | | 362 | | 263 | | 215 | | 326 | | 314 | | 325 | |
| No. Taxa | 12 | | 19 | | 26 | | 19 | | 18 | | 29 | | 20 | |
| Shannon-Weaver Species Diversity Index ($\bar{d}$) | 3.14 | | 3.11 | | 3.76 | | 3.14 | | 2.63 | | 3.93 | | 3.37 | |
| Equitability (e) | 1.00 | | 0.63 | | 0.77 | | 0.68 | | 0.50 | | 0.76 | | 0.75 | |

TABLE 27. Species composition, species diversity, equitability, and total number of benthic macroinvertebrates collected by the rock basket samplers at the Lower Station of MacKay River, June-September, 1977.

| Taxa | June No. | June % | July No. | July % | Aug No. | Aug % | Sept No. | Sept % |
|---|---|---|---|---|---|---|---|---|
| Oligochaeta | 1 | 0.49 | | | 1 | 0.69 | 6 | 2.69 |
| Nematoda | | | | | | | | |
| Hirudinea | | | 1 | 0.95 | | | | |
| Amphipoda | | | | | | | | |
| *Hyalella* | | | | | | | | |
| Collembola | | | | | | | | |
| Ephemeroptera | | | | | | | | |
| *Ameletus* | 9 | 4.47 | | | 3 | 2.08 | 3 | 1.34 |
| *Baetis* sp. A | | | 6 | 5.71 | 3 | 2.08 | 14 | 6.28 |
| *Baetis* sp. B | | | | | 2 | 1.39 | 6 | 2.69 |
| *Baetisca* | | | | | | | | |
| *Brachycercus* | 1 | 0.49 | | | | | | |
| *Caenis* | | | | | | | 1 | 0.45 |
| *Centroptilum* | 3 | 1.49 | | | 18 | 12.51 | | |
| *Ephemerella* | 1 | 0.49 | | | | | | |
| *Heptagenia* | 73 | 36.34 | 53 | 50.49 | 89 | 61.85 | 68 | 30.49 |
| *Isonychia* | | | | | | | | |
| *Leptophlebia* | | | | | | | 1 | 0.45 |
| *Neocloeon* | | | | | 1 | 0.69 | | |
| *Paraleptophlebia* | | | | | | | 18 | 8.07 |
| *Rhithrogena* | | | | | | | | |
| *Stenonema* | | | | | | | | |
| *Tricorythodes* | | | 12 | 11.43 | | | | |
| Baetidae | 1 | 0.49 | | | | | 2 | 0.90 |
| Odonata | | | | | | | | |
| *Aeshna* | | | | | | | | |
| *Ophiogomphus* | | | | | | | | |
| *Calopteryx* | | | | | 1 | 0.69 | 27 | 12.11 |
| Gomphidae | | | | | | | | |
| Plecoptera | | | | | | | | |
| *Acroneuria* | | | | | | | | |
| *Arcynopteryx* | | | | | | | | |

(Continued)

TABLE 27. Continued.

| Taxa | June No. | June % | July No. | July % | Aug No. | Aug % | Sept No. | Sept % |
|---|---|---|---|---|---|---|---|---|
| *Hastaperla* | | | | | | | | |
| *Isogenus* | 1 | 0.49 | 1 | 0.95 | 1 | 0.69 | 27 | 12.11 |
| *Pteronarcys* | | | 5 | 4.76 | 5 | 3.47 | 1 | 0.45 |
| *Taeniopteryx* | | | | | | | 36 | 16.14 |
| Trichoptera | | | | | | | | |
| *Arctopsyche* | | | | | | | | |
| *Athripsodes* | | | | | | | | |
| *Brachycentrus* | | | | | | | | |
| *Drusinus* | | | | | | | | |
| *Glossosoma* | | | | | | | | |
| *Hydropsyche* | | | | | | | | |
| *Mayatrichia* | | | 27 | 25.71 | 1 | 0.69 | 4 | 1.79 |
| *Neureclipsis* | | | | | | | | |
| *Oxyethira* | | | | | | | | |
| *Rhyacophila* | | | | | | | | |
| unid. pupae | | | | | | | | |
| Hemiptera | | | | | | | | |
| Corixidae | 1 | 0.49 | | | | | | |
| Coleoptera | | | | | | | | |
| Dytiscidae | | | | | | | | |
| Elmidae | | | | | | | | |
| Diptera | | | | | | | | |
| Ceratopogonidae | | | | | | | | |
| Chironomidae | | | | | | | | |
| *Ablabesmyia* | | | | | 1 | 0.69 | 1 | 0.45 |
| *Chironomus* | | | | | | | | |
| *Cladotanytarsus* | | | | | 1 | 0.69 | | |
| *Conchapelopia* | 1 | 0.49 | | | | | 1 | 0.45 |
| *Cricotopus* | | | | | | | | |
| *Cryptochironomus* | | | | | | | | |
| *Eukiefferiella* | | | | | | | | |
| *Micropsectra* | | | | | | | 7 | 3.14 |
| *Orthocladius* | | | | | | | | |

(Continued)

TABLE 27. Continued.

| Taxa | June No. | June % | July No. | July % | Aug No. | Aug % | Sept No. | Sept % |
|---|---|---|---|---|---|---|---|---|
| *Paratendipes* | | | | | | | | |
| *Polypedilum* | | | | | | | | |
| *Rheotanytarsus* | 89 | 44.33 | | | 12 | 8.33 | | |
| *Tanytarsus* | | | | | | | | |
| Dolichopodidae | | | | | | | | |
| *Hydrophorus* | | | | | | | | |
| Empididae | 1 | 0.49 | | | | | | |
| Rhagionidae | | | | | | | | |
| Simuliidae | 16 | 7.96 | | | | | | |
| unid. pupae | 3 | 1.49 | | | 2 | 1.39 | | |
| Arachnida | | | | | | | | |
| Hydracarina | | | | | | | | |
| Mollusca | | | | | | | | |
| Ferrissia | | | | | 3 | 2.08 | | |
| Lymnaea | | | | | | | | |
| No. Individuals (t) | 201 | | 105 | | 144 | | 223 | |
| No. Taxa (s) | 14 | | 7 | | 16 | | 17 | |
| Shannon-Weaver Species Diversity Index ($\bar{d}$) | 2.03 | | 1.93 | | 2.14 | | 3.09 | |
| Equitability (e) | 0.43 | | 0.71 | | 0.38 | | 0.71 | |

Species Similarity

To determine how well the benthic communities on rock-basket samplers approximated those in samples from natural substrates, the benthic taxa collected by the two methods were compared. Four major insect Orders--the Ephemeroptera, Plecoptera, Trichoptera, and Diptera--were compared. For each Order, the number of benthic species (or taxa) collected during a particular period was divided into three groups: Group I, species (or taxa) that were collected by both the basket and the Surber sampler; Group II, species that were collected by the basket sampler only; and Group III, species that were collected by the Surber sampler only. The results are summarized in Tables 28 to 31.

The results of this study (Table 28) indicate that 32-34% of the benthic taxa were collected by both techniques; 29-43% of the benthic taxa were only collected by the rock-basket sampler; and 23-38% of the taxa were only found in Surber samples. Selectivity of the basket sampler seemed to be highest at the Upper Station and decreased downstream. The reverse was true for the Surber sampler.

At the Upper Station (Table 29), the basket sampler was most efficient in collecting Plecoptera, Trichoptera, and the Diptera (mostly chironomids and simuliids). Overall, three basket samplers at the Upper Station were capable of collecting 65-85% of the total benthic species found at that station.

At the Middle Station (Table 30), the basket sampler collected slightly

TABLE 28. Mean per cent composition of benthic species (or taxa) collected by both the basket and Surber sampler (Group I), those collected by the basket sampler only (Group II), and those collected by the Surber sampler only (Group III) at the Upper, Middle, and Lower Stations of MacKay River. May-September, 1977.

| Station | Group I | Group II | Group III |
|---|---|---|---|
| Upper | 32.30 | 42.66 | 23.26 |
| Middle | 32.80 | 36.42 | 30.80 |
| Lower | 33.80 | 28.49 | 37.72 |

TABLE 29. A comparison of the number of benthic species (or taxa) collected by both the basket and Surber samplers (Group I) with those collected by the basket sampler only (Group II), or those collected by the Surber sampler only (Group III) for several Orders at the Upper Station of the MacKay River, June-September, 1977.

| | June | | | July | | | August | | | September | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Order | I | II | III | I | II | III | I | II | III | I | II | III |
| Ephemeroptera | | | | | | | | | | | | |
| No. Species | 3 | 2 | 3 | 4 | 2 | 1 | 4 | 2 | 1 | 4 | 1 | 2 |
| % | 37.5 | 25.0 | 37.5 | 57.14 | 28.57 | 14.29 | 57.14 | 28.57 | 14.29 | 57.14 | 14.29 | 28.57 |
| Plecoptera | | | | | | | | | | | | |
| No. Species | 0 | 2 | 0 | 0 | 2 | 0 | 1 | 2 | 0 | 3 | 1 | 0 |
| % | | 100.0 | | | 100.0 | | 33.33 | 66.67 | | 75.0 | 25.0 | |
| Trichoptera | | | | | | | | | | | | |
| No. Species | 1 | 2 | 1 | 0 | 4 | 0 | 1 | 3 | 1 | 1 | 2 | 0 |
| % | 25.0 | 50.0 | 25.0 | | 100.0 | | 20.0 | 60.0 | 20.0 | 33.33 | 66.67 | |
| Diptera | | | | | | | | | | | | |
| No. Species | 1 | 4 | 4 | 2 | 8 | 3 | 5 | 9 | 3 | 3 | 1 | 4 |
| % | 11.11 | 44.44 | 44.44 | 15.39 | 61.54 | 23.08 | 29.41 | 52.94 | 17.65 | 37.5 | 12.5 | 50.0 |
| Total | | | | | | | | | | | | |
| No. Species | 5 | 10 | 8 | 6 | 16 | 4 | 11 | 16 | 5 | 11 | 5 | 6 |
| % | 21.74 | 43.48 | 34.78 | 23.08 | 61.54 | 15.39 | 34.38 | 50.0 | 15.62 | 50.0 | 15.63 | 27.27 |

TABLE 30. A comparison of the number of benthic species (or taxa) collected by both the basket and Surber samplers (Group I) to those collected by the basket sampler only (Group II) or by the Surber sampler only (Group III) for several Orders at the Middle Station of the MacKay River. June-September, 1977.

| | June | | | July | | | August | | | September | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Order | I | II | III | I | II | III | I | II | III | I | II | III |
| Ephemeroptera | | | | | | | | | | | | |
| No. Species | 3 | 2 | 3 | 5 | 2 | 2 | 4 | 4 | 1 | 6 | 4 | 1 |
| % | 37.5 | 25.0 | 37.5 | 55.56 | 22.22 | 22.22 | 44.44 | 44.44 | 11.11 | 54.55 | 36.36 | 9.09 |
| Plecoptera | | | | | | | | | | | | |
| No. Species | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 2 | 0 | 1 |
| % | | | | | 100.0 | | | | 100.0 | 66.67 | | 33.33 |
| Trichoptera | | | | | | | | | | | | |
| No. Species | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 2 | 1 | 0 | 1 | 1 |
| % | | | 100.0 | | 100.0 | | 25.0 | 50.0 | 25.0 | | 50.0 | 50.0 |
| Diptera | | | | | | | | | | | | |
| No. Species | 3 | 2 | 1 | 1 | 6 | 4 | 3 | 7 | 5 | 2 | 2 | 5 |
| % | 50.0 | 33.33 | 16.67 | 9.09 | 54.55 | 36.36 | 20.0 | 46.67 | 33.33 | 22.22 | 22.22 | 55.55 |
| Total | | | | | | | | | | | | |
| No. Species | 6 | 4 | 6 | 6 | 11 | 6 | 8 | 13 | 8 | 10 | 7 | 8 |
| % | 37.5 | 25.0 | 37.5 | 26.09 | 47.83 | 26.09 | 27.59 | 44.83 | 27.59 | 40.0 | 28.0 | 32.0 |

TABLE 31. A comparison of the number of benthic species (or taxa) collected by both the basket and Surber sampler (Group I) to those collected by the basket sampler only (Group II) or those collected by the Surber sampler only (Group III) for several Orders at the Lower Station of the MacKay River. June-September, 1977.

| Order | June I | June II | June III | July I | July II | July III | August I | August II | August III | September I | September II | September III |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ephemeroptera | | | | | | | | | | | | |
| No. Species | 3 | 2 | 2 | 2 | 1 | 2 | 3 | 3 | 2 | 7 | 1 | 3 |
| % | 42.86 | 28.57 | 28.57 | 40.0 | 20.0 | 40.0 | 37.5 | 37.5 | 25.0 | 63.64 | 9.09 | 27.27 |
| Plecoptera | | | | | | | | | | | | |
| No. Species | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 2 | 1 | 1 |
| % | | 100.0 | | | 100.0 | | | 100.0 | | 50.0 | 25.0 | 25.0 |
| Trichoptera | | | | | | | | | | | | |
| No. Species | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 |
| % | | | | 100.0 | | | | 100.0 | | | 33.33 | 66.67 |
| Diptera | | | | | | | | | | | | |
| No. Species | 3 | 1 | 2 | 0 | 0 | 3 | 1 | 2 | 5 | 2 | 1 | 4 |
| % | 50.0 | 16.67 | 33.33 | | | 100.0 | 12.5 | 25.0 | 62.5 | 28.57 | 14.29 | 57.14 |
| Total | | | | | | | | | | | | |
| No. Species | 6 | 4 | 4 | 3 | 3 | 5 | 4 | 8 | 7 | 11 | 4 | 10 |
| % | 42.86 | 28.57 | 28.57 | 27.27 | 27.27 | 45.46 | 21.06 | 42.10 | 36.84 | 44.0 | 16.0 | 40.0 |

more Ephemeroptera and Diptera taxa than did the Surber sampler. Three basket samplers at the Middle Station were capable of collecting 63-74% of the total benthic taxa found at that station.

At the Lower Station, the basket samplers were more efficient than the Surber only in collecting Plecoptera and Trichoptera. In contrast, the Surber sampler collected more species of Ephemeroptera and Diptera. Three basket samplers at the Lower Station were capable of collecting 55-72% of the total benthic taxa found at that station (Table 31).

Factors which might affect the performance of the basket sampler are: 1) current, 2) faunal compositions at the sampling site, and 3) artificial substrate and fauna compatibility.

Number of Taxa and Individuals

Figure 21 is a comparison of the number of invertebrate taxa and individuals collected by the three Surber samples and three rock-basket samples at the Upper, Middle, and Lower Stations during June to September, 1977. The results indicate that, on the whole, the basket sampler collected more benthic taxa at the Upper and Middle Stations, but that, at the Lower Station, the Surber sampler collected more different taxa than the basket. In terms of the number of individuals collected, the basket samplers, on the average, collected more individuals than the Surbers.

Species Diversity

Table 32 summarizes $\bar{d}$ and e values for benthic samples collected by the two different methods. It appears that, except at the Middle Station,

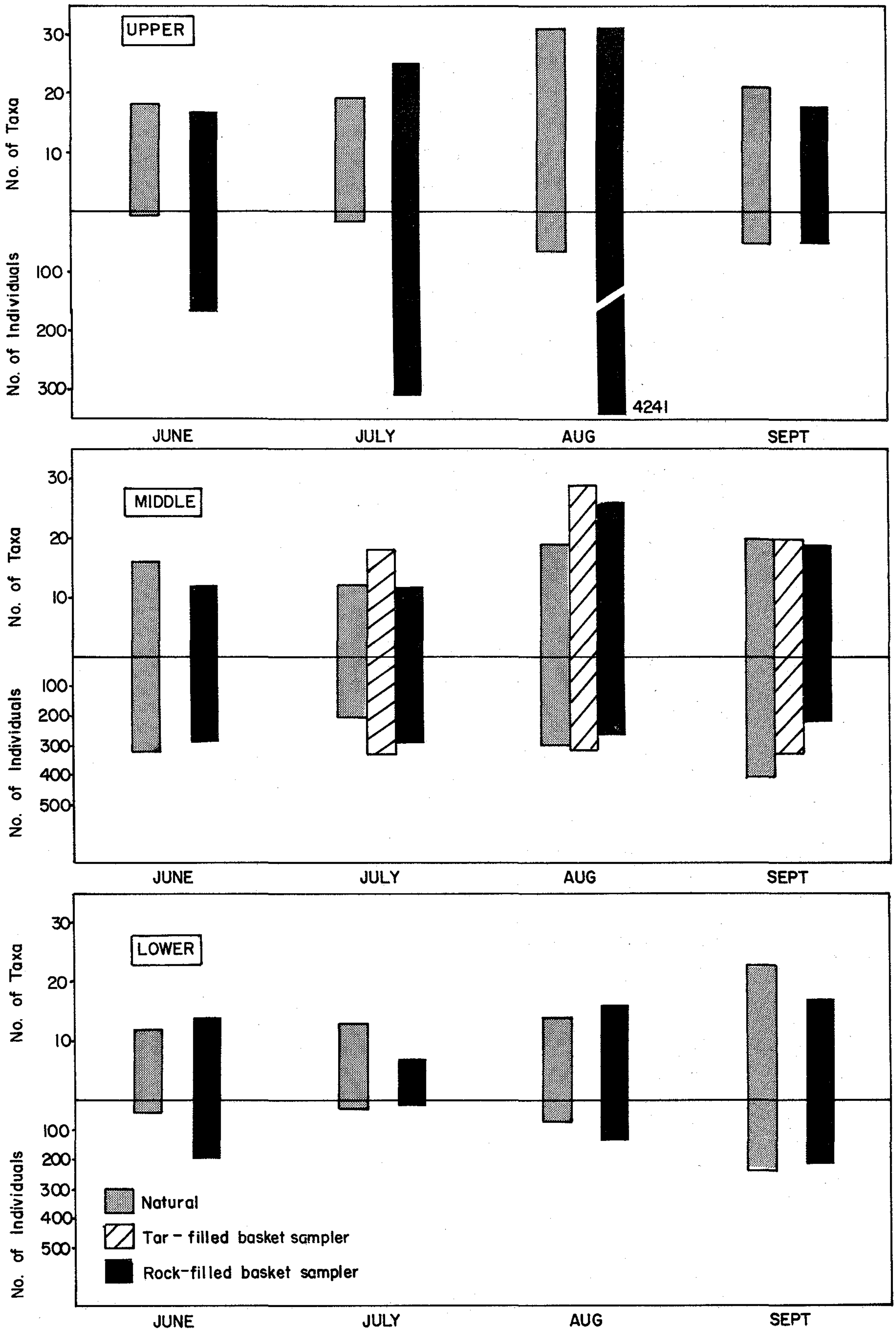



FIGURE 21. Comparison of the number of invertebrate taxa and individuals collected by the basket and Surber samplers.

TABLE 32. A comparison of the Shannon-Weaver Species Diversity Indices ($\bar{d}$) and MacArthur's Equitability Indices (e) for the rock-basket samples (B) and the Surber samples (S) at the Upper, Middle, and Lower Stations of the MacKay River. June-September, 1977.

| Station | Parameters | June B | June S | July B | July S | August B | August S | September B | September S | Means B | Means S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Upper | $\bar{d}$ | 1.90 | 3.60 | 3.16 | 3.05 | 3.54 | 3.83 | 2.99 | 3.21 | 2.90 | 3.42 |
| | e | 0.29 | 0.94 | 0.52 | 0.63 | 0.54 | 0.68 | 0.61 | 0.62 | 0.49 | 0.72 |
| Middle | $\bar{d}$ | 3.14 | 2.90 | 3.11 | 2.70 | 3.76 | 3.09 | 3.14 | 3.23 | 3.29 | 2.98 |
| | e | 1.00 | 0.63 | 0.63 | 0.75 | 0.77 | 0.63 | 0.68 | 0.65 | 0.77 | 0.67 |
| Lower | $\bar{d}$ | 2.03 | 3.36 | 1.93 | 3.20 | 2.14 | 2.80 | 3.09 | 3.07 | 2.30 | 3.11 |
| | e | 0.43 | 1.25 | 0.71 | 1.00 | 0.38 | 0.71 | 0.71 | 0.52 | 0.56 | 0.87 |

samples taken from natural substrates (by the Surber) have higher $\bar{d}$ and e values than those taken by the basket samplers. This indicates that the benthic communities developed on the artificial substrates were less diverse and equitable (or less even) than those in the natural streambed. Insufficient colonization time is the most likely cause of the lower $\bar{d}$ and e values for the basket samples. Future benthic studies involving artificial substrate samplers should include trial studies to determine the optimum exposure period for colonization by northern benthos, i.e., the time required to establish a dynamically stable benthic community on the artificial substrates.

## Exposed Tar Sand

Exposed tar sand is a common feature of the substratum at the Middle Station. A study was conducted to compare the utilization of the tar sand and rock as substrates by the benthos. The results are presented in Table 26. The results indicated that the characteristics of benthic communities (in terms of density, taxonomic and species diversities, equitability) on the two types of substrates were very similar. Some minor differences in species composition (chironomids in particular) were, however, observed. Of the 10 species of chironomids found in July, four species (40%) were restricted to the tar sand substrate. In all likelihood, the exposed tar sand is non-toxic and inert.

## Invertebrate Drift

Invertebrate drift studies were conducted on July 15-16 and August 19-20, 1977. The objectives of these studies were:

1) to determine the qualitative composition of the drift, and

2) to quantify total drift density (number/$m^3$) and drift rate (number/second) at the Lower MacKay River.

Drift Composition

Data on the drifting invertebrates collected from seven one-hour drift samples from each sampling period are summarized in Table 33. The results indicate that the drift fauna in July was dominated by trichopterans (mainly one species of *Mayatrichia*), mayflies (mainly *Baetis* spp. and *Heptagenia* sp.), blackflies (*Simulium* spp.), and chironomids.

In August, the drift was mainly composed of *Baetis* spp. and *Heptagenia, Simulium* sp. and the chironomids.

Drift Rate and Density

Discharge, water depth, and current data were used to compute the benthic drift rate (number of organisms/second) and drift density (number of organisms/$m^3$) at the Lower Station of the MacKay River. The results are presented in Table 34. In this study, drift rate is defined as the quantity of organisms passing through the entire width transect per unit time at the Lower Station of the MacKay River. Drift density is defined as the quantity of organisms per unit-volume of water.

The results indicate that drift densities and drift rates were highest at night for both study periods. This probably reflects the preponderance of night active species in the benthic community of the MacKay River.

TABLE 33. Total number of drifting invertebrates collected and their relative frequencies at the Lower Station of the MacKay River. July-August, 1977.

| Taxa | July 15-16 No. | July 15-16 % | August 19-20 No. | August 19-20 % |
|---|---|---|---|---|
| Oligochaeta | 36 | 0.83 | 1 | 0.02 |
| Crustacea | | | | |
| Copepoda | 4 | 0.09 | - | - |
| Ostracoda | 6 | 0.14 | - | - |
| Cladocera | 34 | 0.79 | 13 | 0.21 |
| Branchiura | 1 | 0.02 | - | - |
| Amphipoda | 1 | 0.02 | - | - |
| Collembola | 3 | 0.07 | 1 | 0.02 |
| Odonata | - | - | 1 | 0.02 |
| Ephemeroptera | 1157 | 26.73 | 4826 | 76.60 |
| Plecoptera | 39 | 0.90 | 45 | 0.71 |
| Trichoptera | 1683 | 38.89 | 47 | 0.75 |
| Hemiptera | 4 | 0.09 | 1 | 0.02 |
| Diptera | | | | |
| Chironomidae | 248 | 5.73 | 504 | 8.00 |
| Simuliidae | 1104 | 25.51 | 826 | 13.11 |
| Empididae | 2 | 0.05 | 2 | 0.04 |
| Tipulidae | 1 | 0.02 | - | - |
| Hydracarina | 5 | 0.12 | 33 | 0.52 |
| Total | 4328 | | 6300 | |

TABLE 34. Fluctuations in total benthic drift densities and drift rates for a single diel period in July and in August at the Lower Station of the MacKay River, 1977.

| | | | DUSK- | ------DARK | ------ | -DAWN | |
|---|---|---|---|---|---|---|---|
| Time (MDT): | 1130-1230 | 1630-1730 | 2030-2130 | 2330-0030 | 0230-0330 | 0630-0730 | 1030-1130 |
| JULY 15-16 | | | | | | | |
| Total Drift Density (No./m$^3$) | 8.47 | 6.16 | 5.51 | 78.89 | 80.37 | 12.36 | 8.61 |
| Total Drift Rate (No./hr) | 45,770.4 | 33,285.6 | 29,775.6 | 426,290.4 | 434,286.0 | 66,787.2 | 46,526.4 |

| | | | DUSK- | ------DARK | ------ | -DAWN | |
|---|---|---|---|---|---|---|---|
| Time (MDT): | 1100-1200 | 1600-1700 | 2000-2100 | 2300-2400 | 0200-0300 | 0530-0630 | 0900-1000 |
| AUGUST 19-20 | | | | | | | |
| Total Drift Density (No/m$^3$) | 4.64 | 4.46 | 2.06 | 65.90 | 48.59 | 64.67 | 3.41 |
| Total Drift Rate (No./hr) | 5,680.8 | 5,457.6 | 2,520.0 | 80,661.6 | 59,475.6 | 79,156.8 | 4,172.4 |

# FISH

## Introduction

Fisheries studies on the MacKay River began in May, 1977, to provide baseline data for comparison with future studies. The specific objectives were:

1) to describe on a seasonal basis the species composition and relative abundance of fish in the MacKay River;

2) to describe the life histories of major species;

3) to locate potential spawning and overwintering areas within the study area;

4) to describe the use of the MacKay River by fishermen;

5) to assess the relative importance of the MacKay River to the fisheries of the region.

## Materials and Methods

### Collection of Samples

Standard gangs of monofilament gillnets consisting of two 15 m x 2.4 m panels of stretched mesh 6.4 and 8.9 cm (2.5 and 3.5 inch) were set monthly from May to September at the Lower and Middle Stations and from June to September at the Upper Station (Figure 1). In most cases, nets were set for approximately 24 hour periods. When this was not feasible, nets were set in the evening and picked up the following morning. Catch by species and the length of the gillnetting effort were recorded.

Inshore habitats were sampled with a fine mesh nylon marquissette minnow seine, 6 m in length. Seine hauls averaged approximately 5 m parallel to shore. Subsamples were collected for life history analysis. Very large collections of small species and young-of-the-year were also subsampled (i.e., 1/4, 1/5, 1/10, etc.) and counted immediately or preserved in 10% formalin for later identification and enumeration. Records were kept of the number of seine hauls and the numbers of each species taken to determine species distribution and relative abundance. Similar methods were used in sampling nearshore habitats at various locations on the MacKay River during the August float trip.

During winter studies (December, 1977, and January, 1978), shortened gillnets (15 m x 1 m) of either 6.4 cm (2.5 inch) or 8.9 cm (3.5 inch) stretched mesh were set under the ice at the Lower and Middle Stations for 44 to 72 hours. The Upper Station was not sampled because of low water levels.

Life History Analysis

Fish sampled for life history analysis in May and September were dissected fresh in a field laboratory. At other times, fish were shipped frozen to AEL's Calgary laboratory for analysis.

Fish retained for life history analysis were measured to the nearest millimetre (fork length for all species except sculpins, burbot, and sticklebacks) and weighed to the nearest 0.1 g on a triple beam balance. Sex and gonad weight were recorded and the state of maturity assessed according to McCart *et al.* (1972). Egg size was determined by aligning ten typical eggs on a millimetre scale and dividing by 10 to calculate an average diameter.

Fecundities were determined for trout-perch *(Percopsis omiscomaycus)* by direct counts of eggs in ovaries preserved in 10% formalin. The eggs of other species were insufficiently developed for accurate enumeration.

Otoliths and scales were removed from all species with the exception of northern pike and examined for age determination under a binocular microscope (otoliths) or scale enlarger. After a preliminary examination the best method for aging purposes was selected. Scales only were removed from pike since their otoliths are generally accepted to be unreadable. Criteria for the identification of annuli were similar to those of Lagler (1956)(scales), and Nordeng (1961)(otoliths).

Stomach contents were identified to major taxa during dissection and listed without regard to proportionate volume. These data indicate the frequency of occurrence and range of food items consumed.

# Results and Discussion

## Species Composition and Abundance

During the course of the study, 19 species of fish representing 10 families were collected at permanent sampling stations on the MacKay River (Table 35). The number of species decreased from 18 at the Lower Station to 11 at the Middle Station and 9 at the Upper Station. Eight species including northern pike, lake chub, longnose dace, longnose sucker, white sucker, trout-perch, walleye, and slimy sculpin were found at all stations, while seven were evidently restricted to the Lower Station. These were: lake whitefish, mountain whitefish, emerald shiner, flathead chub, burbot, yellow perch, and spoonhead sculpin. With the exception of yellow perch, these species were uncommon and all are probably more properly identified with the Athabasca River than with the MacKay River.

Pearl dace (*Semotilus margarita* [Cope]) was the only species previously reported from the MacKay River drainage (Griffiths, 1973) not captured in this study.

Walleye was the most abundant of eight fish species collected in gillnets, constituting 34% of the total gillnet catch at all sampling stations (Table 36). Other species commonly sampled included white suckers (19.4%), longnose suckers (16.5%), goldeye (16.0%), and northern pike (10.7%). Lake whitefish, Arctic grayling, and flathead chub together accounted for only 3.5% of the total catch.

TABLE 35. Distribution of fish species collected at permanent sampling stations on the MacKay River, 1977. Overall relative abundance is indicated as follows: A=abundant, C=common, R=rare.

| Common Name | Scientific Name | Code | Upper Station | Middle Station | Lower Station | Relative Abundance |
|---|---|---|---|---|---|---|
| lake whitefish | *Coregonus clupeaformis* (Mitchill) | LKWT | | | + | R |
| mountain whitefish | *Prosopium williamsoni* (Girard) | MTWT | | | + | R |
| Arctic grayling | *Thymallus arcticus* (Pallas) | GRAY | | + | + | R |
| goldeye | *Hiodon alosoides* (Rafinesque) | GOLD | | + | + | C |
| northern pike | *Esox lucius* Linnaeus | PIKE | + | + | + | C |
| lake chub | *Couesius plumbeus* (Agassiz) | LKCB | + | + | + | A |
| emerald shiner | *Notropis atherinoides* Rafinesque | EMSH | | | + | R |
| spottail shiner | *Notropis hudsonius* (Clinton) | SPSH | | + | + | R |
| flathead chub | *Platygobio gracilis* (Richardson) | FLCB | | | + | R |
| longnose dace | *Rhinichthys cataractae* (Valenciennes) | LNDC | + | + | + | C |
| longnose sucker | *Catostomus catostomus* (Forster) | LNSK | + | + | + | A |
| white sucker | *Catostomus commersonii* (Lacépède) | WTSK | + | + | + | A |
| burbot | *Lota lota* (Linnaeus) | BURB | | | + | R |
| brook stickleback | *Culaea inconstans* (Kirtland) | BRST | + | | | R |
| trout-perch | *Percopsis omiscomaycus* (Walbaum) | TRPH | + | + | + | A |
| yellow perch | *Perca flavescens* (Mitchill) | YWPH | | | + | C |
| walleye | *Stizostedion vitreum* (Mitchill) | WALL | + | + | + | A |
| slimy sculpin | *Cottus cognatus* Richardson | SLSC | + | + | + | C |
| spoonhead sculpin | *Cottus ricei* (Nelson) | SPSC | | | + | R |
| Total Number of Species | | | 9 | 11 | 18 | |

TABLE 36. Summary of data for fish collections at all permanent gillnet and seining stations on the MacKay River, 1977, indicating numbers of each species captured by each method and per cent of the total catch.

| Species | Gillnetting N | Gillnetting % of Total | Seining N | Seining % of Total |
|---|---|---|---|---|
| lake whitefish | 3 | 1.5 | 1 | <0.1 |
| mountain whitefish | - | - | 1 | <0.1 |
| Arctic grayling | 1 | 0.5 | 3 | <0.1 |
| goldeye | 33 | 16.0 | - | - |
| northern pike | 22 | 10.7 | 3 | <0.1 |
| lake chub | - | - | 2121 | 45.5 |
| emerald shiner | - | - | 10 | 0.2 |
| spottail shiner | - | - | 9 | 0.2 |
| flathead chub | 3 | 1.5 | - | - |
| longnose dace | - | - | 165 | 3.5 |
| longnose sucker | 34 | 16.5 | 807 | 17.3 |
| white sucker | 40 | 19.4 | 504 | 10.8 |
| burbot | - | - | 2 | <0.1 |
| brook stickleback | - | - | 1 | <0.1 |
| trout-perch | - | - | 908 | 19.5 |
| yellow perch | - | - | 74 | 1.6 |
| walleye | 70 | 34.0 | 5 | 0.1 |
| slimy sculpin | - | - | 42 | 0.9 |
| spoonhead sculpin | - | - | 1 | <0.1 |
| Totals | 206 | | 4657 | |

Among the species collected at permanent seining stations, lake chub was by far the most common species overall, accounting for 45.5% of the fish sampled (Table 36). Other common species included trout-perch (19.5%), longnose sucker (17.3%), and white sucker (10.8%). The seine samples of the latter two species were primarily young-of-the-year.

A station by station comparison shows that the lake chub is the dominant species at the Upper and Middle Stations but less abundant downstream (Table 37). Similarly, sucker young-of-the-year (both species) are much more abundant upstream than they are downstream. Trout-perch replace lake chub as the dominant species at the Lower Station.

Fish collected during the float trip (August 17-19, 1977), show a pattern of relative abundance and longitudinal distribution similar to that described above (Table 38).

Slimy sculpins are probably more abundant than otherwise indicated. Because of their bottom-dwelling habits, they often escape detection in seine samples. This is particularly true with rocky substrates.

## Life Histories of Fish Species

### Goldeye

Goldeye are distributed in major rivers throughout the Great Plains area, extending as far north as Aklavik on the Mackenzie River Delta (Scott and Crossman, 1973). They prefer either the quiet, muddy waters of large rivers and associated lakes and ponds or the shallows of larger

TABLE 37. Summary of catches at permanent seining sites on the MacKay River, 1977. Data are expressed as catch per unit effort (number of fish per seine) with the numbers of fish actually captured in brackets.

UPPER STATION

| | May 14 | June 15 | Aug. 17 | Sept 29 | Total | % of Total |
|---|---|---|---|---|---|---|
| Effort (seines): | 3 | 9 | 3 | 4 | 19 | |
| lake whitefish | - | - | - | - | - | |
| mountain whitefish | - | - | - | - | - | |
| Arctic grayling | - | - | - | - | - | |
| northern pike | - | - | - | - | - | |
| lake chub | 4.0(12) | 15.6(140) | 244.3(733) | 5.5(22) | 47.7(907) | 37.0 |
| emerald shiner | - | - | - | - | - | |
| spottail shiner | - | - | - | - | - | |
| longnose dace | - | 0.2(2) | 50.3(151) | 1.3(5) | 8.3(158) | 6.5 |
| longnose sucker | - | 4.0(36) | 213.7(641) | 12.7(51) | 38.3(728) | 29.7 |
| white sucker | 0.3(1) | 0.6(5) | 133.3(400) | 2.0(8) | 21.8(414) | 16.9 |
| burbot | - | - | - | - | - | |
| brook stickleback | - | - | - | 0.3(1) | 0.1(1) | <0.1 |
| trout-perch | 1.0(3) | 16.6(149) | 24.0(72) | 0.3(1) | 11.8(225) | 9.2 |
| yellow perch | - | - | - | - | - | |
| walleye | - | 0.1(1) | - | - | 0.1(1) | <0.1 |
| slimy sculpin | 1.0(3) | 0.2(2) | 3.7(11) | 0.3(1) | 0.9(17) | 0.7 |
| spoonhead sculpin | - | - | - | - | - | |
| TOTAL | 6.3(19) | 37.2(335) | 669.3(2008) | 22.3(89) | 129.0(2451) | 100.0 |

(Continued)

TABLE 37. Continued.

| | MIDDLE STATION | | | | | |
|---|---|---|---|---|---|---|
| | May 14 | June 16 | Aug. 17 | Sept 28 | Total | % of |
| Effort (Seines): | 6 | 3 | 3 | 3 | 15 | Total |
| lake whitefish | - | - | - | - | - | |
| mountain whitefish | - | - | - | - | - | |
| Arctic grayling | - | - | - | - | - | |
| northern pike | - | - | - | 0.3(1) | 0.1(1) | 0.1 |
| lake chub | 7.7(46) | 2.0(6) | 128.3(385) | 320.3(961) | 93.2(1398) | 90.1 |
| emerald shiner | - | - | - | - | - | |
| spottail shiner | 0.3(2) | - | - | - | 0.1(2) | 0.1 |
| longnose dace | 0.3(2) | - | - | - | 0.1(2) | 0.1 |
| longnose sucker | 0.2(1) | 0.3(1) | 5.0(15) | - | 1.1(17) | 1.1 |
| white sucker | - | - | 1.7(5) | 12.0(36) | 5.5(82) | 5.3 |
| burbot | - | - | - | - | - | |
| brook stickleback | - | - | - | - | - | |
| trout-perch | 1.3(8) | 11.3(34) | 0.7(2) | - | 2.9(44) | 2.8 |
| yellow perch | - | - | - | - | - | |
| walleye | - | - | - | - | - | |
| slimy sculpin | 0.5(3) | 0.3(1) | - | 0.3(1) | 0.3(5) | 0.3 |
| spoonhead sculpin | - | - | - | - | - | |
| TOTAL | 10.3(62) | 14.0(42) | 135.0(405) | 333.0(999) | 103.4(1551) | 100.0 |

(Continued)

TABLE 37. Continued.

| | LOWER STATION | | | | | |
|---|---|---|---|---|---|---|
| | May 10 | June 17 | Aug. 15 | Sept 26 | Total | % of |
| Effort (Seines): | 10 | 11 | 6 | 3 | 30 | Total |
| lake whitefish | - | 0.1(1) | - | - | 0.0(1) | 0.1 |
| mountain whitefish | - | 0.1(1) | - | - | 0.1(1) | 0.1 |
| Arctic grayling | 0.1(1) | - | 0.3(2) | - | 0.1(3) | 0.3 |
| northern pike | 0.1(1) | 0.1(1) | - | - | 0.1(2) | 0.2 |
| lake chub | 7.6(76) | 7.0(77) | 1.3(8) | - | 5.4(161) | 16.2 |
| emerald shiner | 0.1(1) | 0.8(9) | - | - | 0.3(10) | 1.0 |
| spottail shiner | 0.7(7) | - | - | - | 0.4(7) | 0.7 |
| longnose dace | 0.3(3) | - | - | - | 0.1(3) | 0.3 |
| longnose sucker | 1.8(18) | 2.7(30) | 1.5(9) | - | 1.9(57) | 5.7 |
| white sucker | 0.1(1) | - | 0.7(4) | 1.7(5) | 0.3(10) | 1.0 |
| burbot | - | - | 0.3(2) | - | 0.1(2) | 0.2 |
| brook stickleback | - | - | - | - | - | |
| trout-perch | 8.9(89) | 28.8(317) | 38.0(228) | 1.7(5) | 21.3(639) | 64.3 |
| yellow perch | - | - | 10.5(63) | 3.7(11) | 2.5(74) | 7.4 |
| walleye | - | 0.1(1) | 0.5(3) | - | 0.1(4) | 0.4 |
| slimy sculpin | 0.6(6) | 0.7(8) | 0.8(5) | 0.3(1) | 0.7(20) | 2.0 |
| spoonhead sculpin | - | - | 0.2(1) | - | 0.0(1) | 0.1 |
| TOTAL | 20.3(203) | 40.5(445) | 54.2(325) | 7.3(22) | 33.2(995) | 100.0 |

TABLE 38. Summary of catch by species in near-shore habitats sampled August 17-19, 1977. Data are expressed as total numbers of fish in three seine hauls.

| | Upper | | | | | | | Middle | | | | | Lower | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | N | % |
| lake whitefish | | | | | | | | | | | | | | | |
| mountain whitefish | | | | | | | | | | | | | | | |
| Arctic grayling | | | | | | | | | | | | | 2 | 2 | <0.1 |
| goldeye | | | | | | | | | | | | | | | |
| northern pike | | | | | | | | | | | | | | | |
| lake chub | 733 | 106 | 30 | 750 | 66 | 40 | 198 | 385 | | 24 | 46 | 7 | 4 | 2389 | 52.5 |
| emerald shiner | | | | | | | | | | | | | | | |
| spottail shiner | | | | | | | | | | | | | | | |
| flathead chub | | | | | | | | | | | | | | | |
| longnose dace | 151 | 13 | | 10 | 2 | 2 | | | | 5 | | 4 | | 187 | 4.1 |
| longnose sucker | 641 | 6 | 15 | 180 | 10 | 20 | 18 | 15 | | | | 3 | 5 | 913 | 20.1 |
| white sucker | 400 | 35 | 15 | 120 | 46 | 44 | 54 | 5 | | 6 | 17 | 2 | 2 | 746 | 16.4 |
| burbot | | | | | | | | | | | | | 2 | 2 | <0.1 |
| brook stickleback | | 2 | | | | | | | | 2 | | | | 4 | 0.1 |
| trout-perch | 72 | 13 | 6 | | 2 | 2 | 6 | | | | 3 | 1 | 114 | 219 | 4.8 |
| yellow perch | | | | | | | | | | | | | 63 | 63 | 1.4 |
| walleye | | 9 | | | | | | | | | | | 3 | 12 | 0.3 |
| slimy sculpin | 5 | 11 | | | | | | | | | | | | 16 | 0.3 |
| spoonhead sculpin | | | | | | | | | | | | | 1 | 1 | <0.1 |
| Totals | 2002 | 195 | 66 | 1060 | 126 | 108 | 276 | 405 | - | 37 | 66 | 17 | 196 | 4554 | 100.0 |

lakes. The biology of the species has been well documented in the Peace-Athabasca Delta by Battle and Sprules (1960), Kennedy and Sprules (1967), and more recently by Kooyman (1972) and Donald and Kooyman (1977).

In the MacKay River, a total of 33 immature goldeye, ranging in size from 232 to 287 fork length (Figure 22) was collected. There is no evidence that goldeye spawn in the MacKay Rive- and both young-of-the-year and mature fish are absent. Like the Athabasca River, the MacKay River probably serves only as a summer feeding area for immature goldeye. Data on their seasonal abundance at permanent gillnet stations (Figure 23, Table 39) show them present from May to September at the Lower Station, from May to July at the Middle Station, and absent altogether from the Upper Station. By September, goldeye had left the MacKay River, presumably migrating to overwintering areas elsewhere.

Data describing the length-age relationships, sex ratios, and maturity of goldeye are presented in Table 40. Chi-square analysis indicated that females were significantly more abundant than males ($P<0.05$) at age 6 and overall. The length-age relationship of goldeye (aged by scales) from the MacKay was almost identical to that of fish collected from the Athabasca River (McCart *et al.*, 1977) which were aged with otoliths. Growth curves for both the MacKay and Athabasca rivers are similar to those (Figure 24) for populations in Lake Claire, Alberta, and the Saskatchewan Delta, Manitoba. At ages 3 to 6, the lengths of the MacKay and Athabasca River fish were about intermediate between the two latter populations but the growth rate appears to be slower. The samples from the Athabasca and MacKay rivers may, however, be biased.

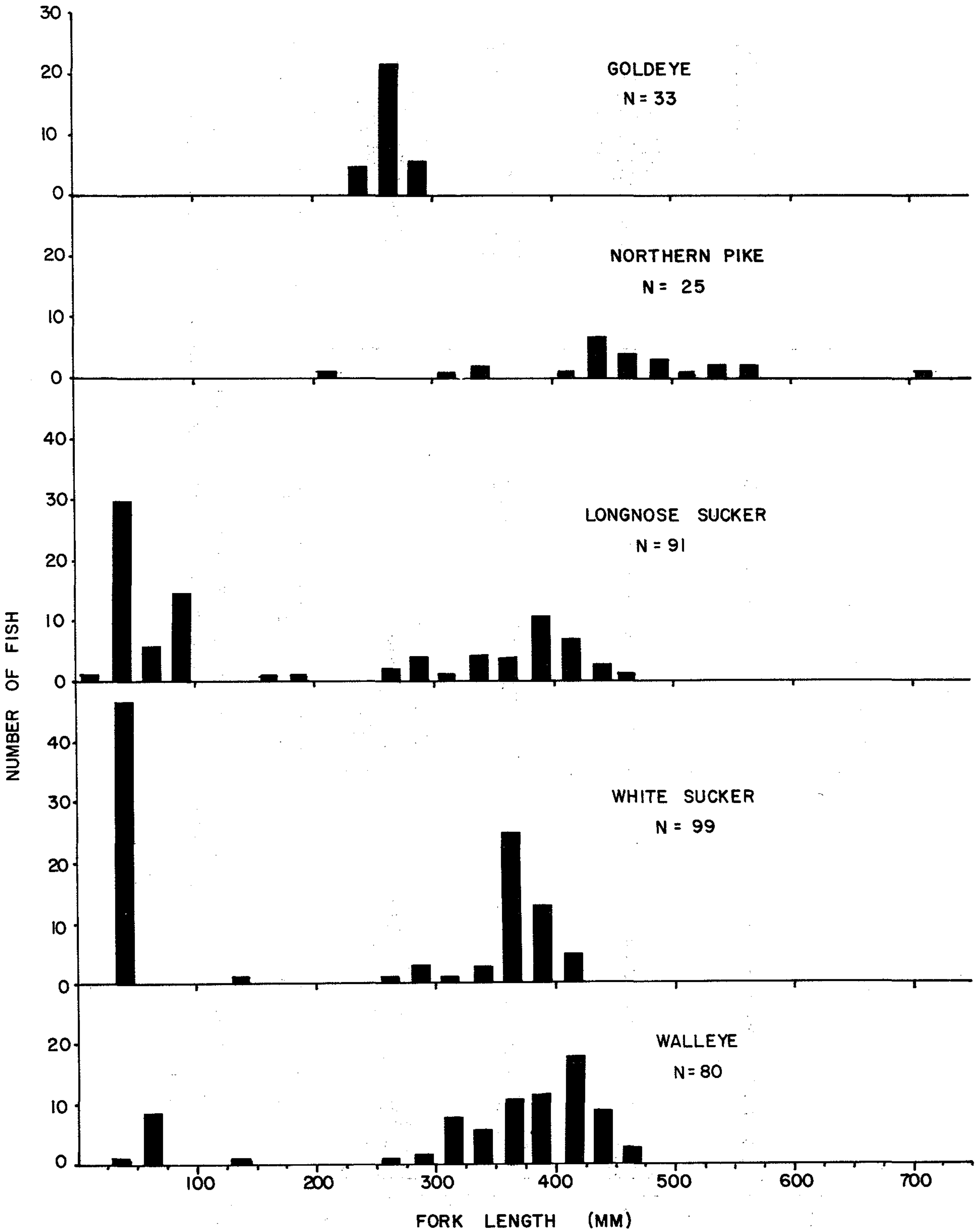



FIGURE 22. Length-frequency of five major species collected from the MacKay River, 1977.

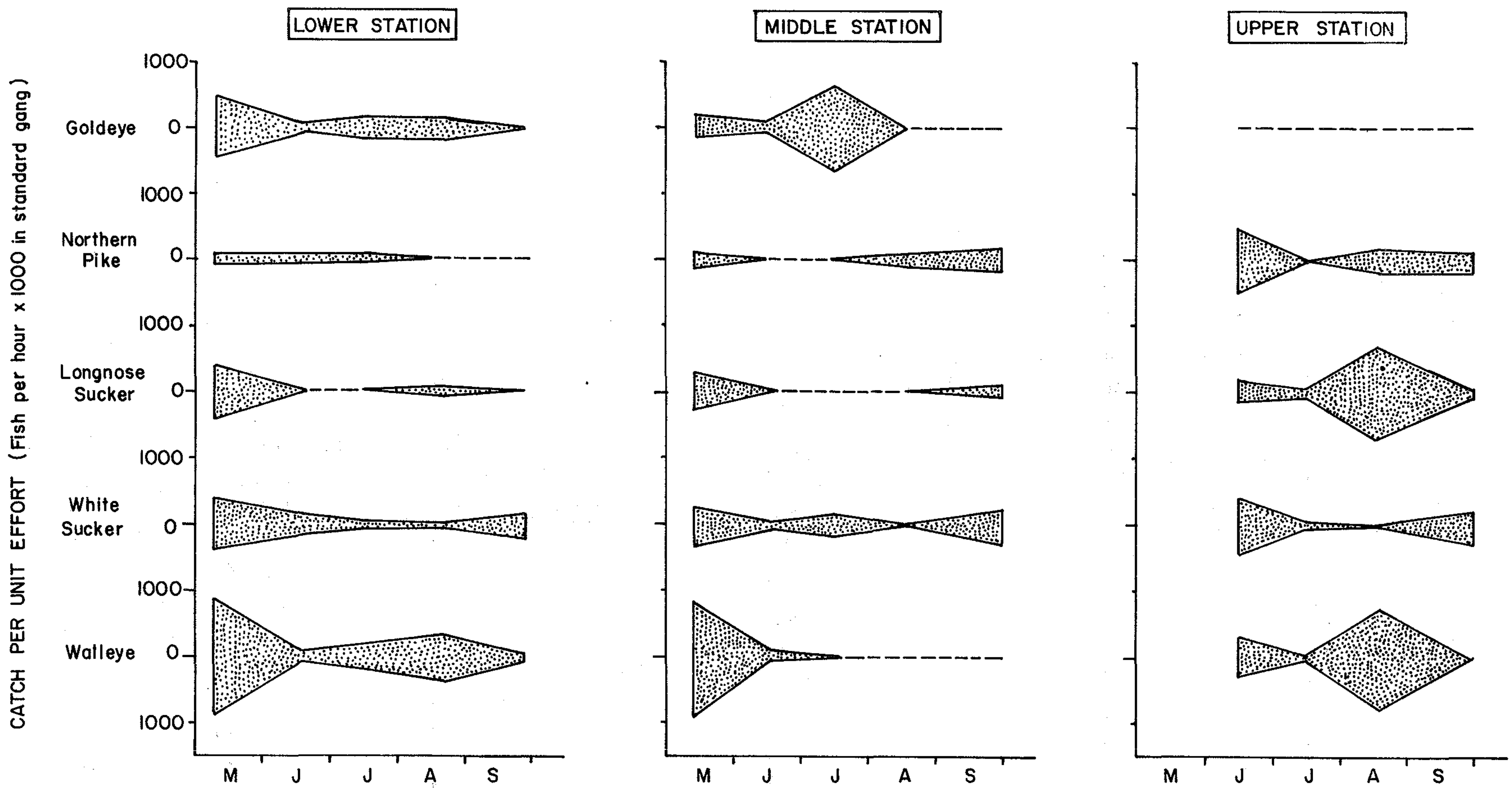



FIGURE 23. Seasonal abundance of five fish species at permanent sampling stations on the MacKay River, 1977. Catch per unit effort is catch per hour per standard gang x 1000.

TABLE 39. Summary of gillnet catches at permanent sampling sites on the MacKay River, 1977. Data are expressed as catch per unit effort (number of fish per hour per standard gang x 1000) with actual numbers of fish captured in brackets.

UPPER STATION

| Effort (hours): | June 15<br>7 | July 15<br>22 | Aug. 17<br>20 | Sept 29<br>23.5 | Total<br>72.5 | % of<br>Total |
|---|---|---|---|---|---|---|
| lake whitefish | - | - | - | - | - | |
| grayling | - | - | - | - | - | |
| goldeye | - | - | - | - | - | |
| northern pike | 429(3) | - | 150(3) | 170(4) | 138(10) | 17.9 |
| flathead chub | - | - | - | - | - | |
| longnose sucker | 143(1) | 91(2) | 700(14) | 85(2) | 262(19) | 33.9 |
| white sucker | 429(3) | 46(1) | - | 213(5) | 124(9) | 16.1 |
| walleye | 286(2) | 46(1) | 750(15) | - | 248(18) | 32.1 |
| TOTAL | 1286(9) | 182(4) | 1600(32) | 468(11) | 772(56) | 100.0 |

MIDDLE STATION

| Effort (hours): | May 14<br>26 | June 16<br>23 | July 15<br>17 | Aug. 18<br>9 | Sept 29<br>23.5 | Total<br>98.5 | % of<br>Total |
|---|---|---|---|---|---|---|---|
| lake whitefish | - | - | - | - | - | - | |
| grayling | 39(1) | - | - | - | - | 10(1) | 1.4 |
| goldeye | 192(5) | 87(2) | 647(11) | - | - | 183(18) | 24.7 |
| northern pike | 115(3) | - | - | 111(1) | 170(4) | 81(8) | 11.0 |
| flathead chub | - | - | - | - | - | - | |
| longnose sucker | 231(6) | - | - | - | 85(2) | 81(8) | 11.0 |
| white sucker | 269(7) | 43(1) | 118(2) | - | 213(5) | 152(15) | 20.5 |
| walleye | 808(21) | 87(2) | - | - | - | 233(23) | 31.5 |
| TOTAL | 1654(43) | 217(5) | 765(13) | 111(1) | 468(11) | 740(73) | 100.1 |

(Continued)

TABLE 39. Continued.

| | LOWER STATION | | | | | | |
|---|---|---|---|---|---|---|---|
| | May 10 | June 17 | July 16 | Aug. 21 | Sept 27 | Total | % of |
| Effort (hours): | 17.5 | 15.5 | 16 | 22 | 26 | 97 | Total |
| lake whitefish | 171(3) | - | - | - | - | 31(3) | 3.9 |
| grayling | - | - | - | - | - | - | |
| goldeye | 457(8) | 65(1) | 125(2) | 182(4) | - | 155(15) | 19.5 |
| northern pike | 57(1) | 65(1) | 63(1) | - | - | 31(3) | 3.9 |
| flathead chub | 171(3) | - | - | - | - | 31(3) | 3.9 |
| longnose sucker | 400(7) | - | - | 46(1) | - | 83(8) | 10.4 |
| white sucker | 400(7) | 129(2) | 63(1) | 46(1) | 192(5) | 165(16) | 20.8 |
| walleye | 857(15) | 65(1) | 188(3) | 364(8) | 77(2) | 299(29) | 37.7 |
| TOTAL | 2514(44) | 323(5) | 437(7) | 636(14) | 269(7) | 794(77) | 100.1 |

TABLE 40. Observed length-age relationships (based on scales), and age-specific sex ratios of goldeye from the MacKay River, 1977.

| 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 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 3 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 4 | 240.0 | 7.2 | 232-246 | 1 | 33.3 | 0.0 | 2 | 66.7 | 0.0 | 0 | 3 |
| 5 | 264.0 | 10.6 | 248-280 | 6 | 46.1 | 0.0 | 7 | 53.9 | 0.0 | 0 | 13 |
| 6 | 268.2 | 9.1 | 253-287 | 3 | 18.8 | 0.0 | 13 | 81.2 | 0.0 | 0 | 16 |
| Total | | | | 10 | 31.2 | | 22 | 68.8 | | 0 | 32 |

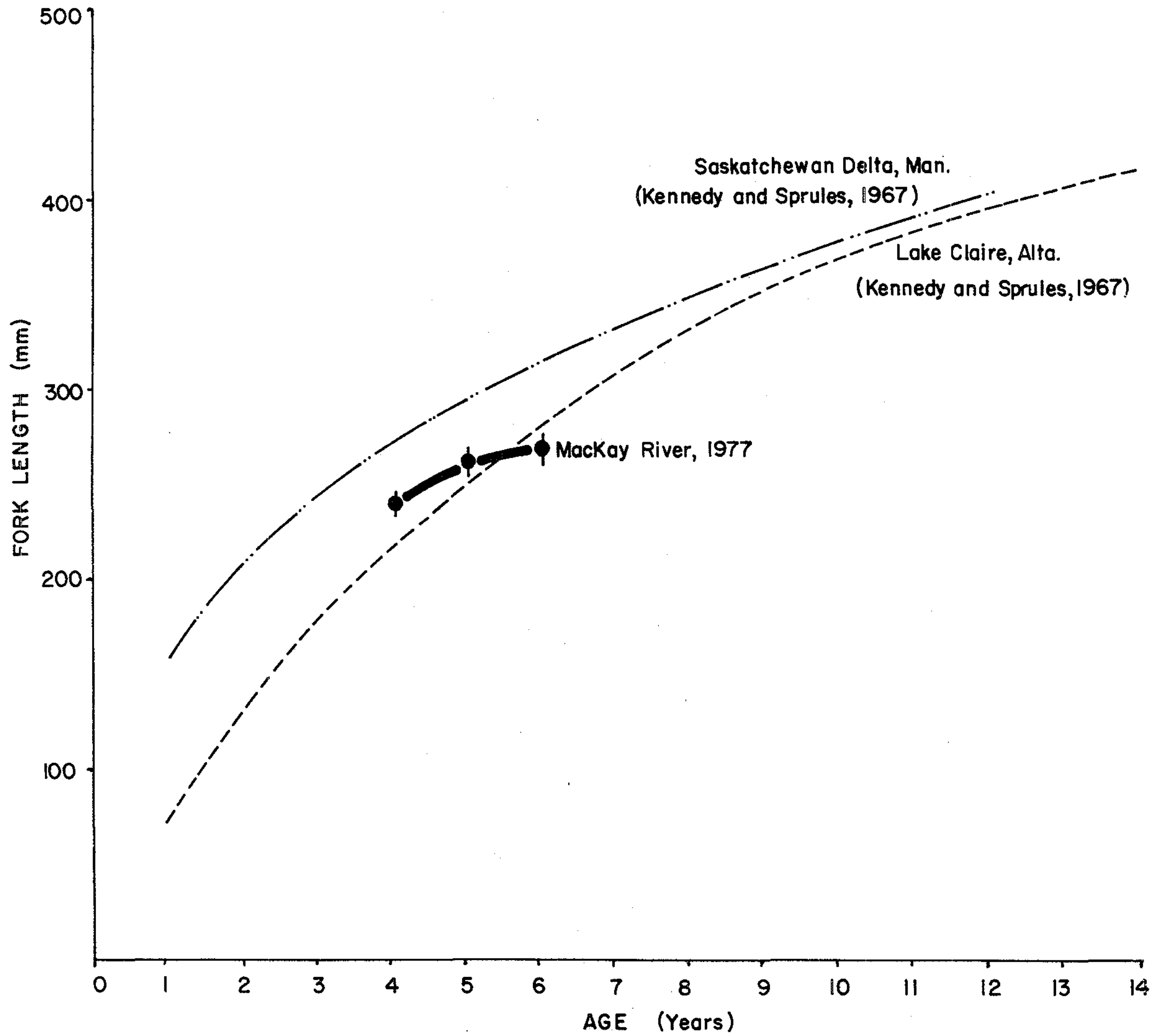



FIGURE 24. Comparison of growth rates of goldeye in the MacKay River and two other locations in Alberta and Manitoba. All ages are based on scales. Points and vertical lines are mean fork lengths ± 1 S.D.

In order to explain the scarcity of 5 year old fish in certain lake populations and conversely their abundance in river populations, Kennedy and Sprules (1967) postulated large summer feeding runs from lakes into rivers by these fish. Such runs have since been documented (Donald and Kooyman, 1977) by tagging studies. If these represent fish just approaching maturity, a biased sample consisting of fast growing young fish and slow growing older fish would result, given that maturity in fish is governed more by size than by age (Bell *et al.*, 1977). The average size at first maturity for fish in Lake Claire was 270 mm fork length compared to 263.8 ± 12.3 (N=32) for goldeye collected in the MacKay River.

The frequency of occurrence of food items in goldeye stomachs is presented in Table 41. Goldeye eat a wide variety of food items ranging from benthic invertebrates to surface insects. Odonata nymphs (41.9%), Trichoptera larvae (19.4%), Coleoptera (41.9%), and Hymenoptera adults (25.8%) were major food items. Vegetable matter (leaves, twigs, needles) was, however, the most frequent item encountered.

Northern Pike

Northern pike were captured throughout the open water season of each permanent station (Figure 23; see also Table 39), but there was no obvious pattern in seasonal abundance, perhaps because of the small sample size (N=21). If any upstream spawning migration does occur in the MacKay River, it was likely already completed by the first sampling period on May 10, 1977. Of three mature pike captured at this time, all were spawned-out males.

TABLE 41. Frequency of occurrence of food items in stomachs of four species of fish sampled from the MacKay River, 1977.

| Food Item | WALL N | WALL % | PIKE N | PIKE % | GOLD N | GOLD % | TRPH N | TRPH % |
|---|---|---|---|---|---|---|---|---|
| Benthos | | | | | | | | |
| Ephemeroptera | | | | | 1 | 3.2 | 34 | 89.5 |
| Odonata | 4 | 13.3 | 1 | 11.1 | 13 | 41.9 | | |
| Plecoptera | 2 | 6.7 | | | 3 | 9.7 | | |
| Trichoptera | | | | | 6 | 19.4 | | |
| Chironomidae | | | | | 1 | 3.2 | 25 | 65.8 |
| Simuliidae | | | | | 1 | 3.2 | | |
| Ceratopogonidae | | | | | | | 3 | 7.9 |
| Tipulidae | 1 | 3.3 | | | | | | |
| Oligochaeta | | | | | | | 1 | 2.6 |
| Surface Insects | | | | | | | | |
| Corixidae | | | | | 2 | 6.5 | | |
| Coleoptera | | | | | 13 | 41.9 | | |
| Diptera | | | | | 2 | 6.5 | 1 | 2.6 |
| Tabanidae | | | | | 2 | 6.5 | | |
| Hymenoptera | | | | | 8 | 25.8 | | |
| Lepidoptera | | | | | 1 | 3.2 | | |
| Unidentified Insect Parts | | | | | 6 | 19.4 | | |
| Arachnida | | | | | 3 | 9.7 | | |
| Fish Remains | 24 | 80.0 | 9 | 100.0 | 1 | 3.2 | 1 | 2.6 |
| Vegetable Matter | | | | | 19 | 61.3 | | |
| Digested Matter | 2 | 6.7 | | | 11 | 35.5 | 11 | 28.9 |
| Stomachs Containing Food | 30 | | 9 | | 31 | | 38 | |
| Stomachs Empty | 23 | | 12 | | 1 | | 9 | |
| Stomachs Analysed | 53 | | 21 | | 32 | | 47 | |

Spawning appears to be limited in the MacKay River. Despite extensive sampling in nearshore habitats from the Upper to Lower Stations (Tables 36, 37, and 38), no young-of-the-year were ever captured.

Northern pike sampled during the study ranged from 210 to 718 mm fork length (Figure 22) with most fish in the 425-575 mm range. Their growth rate is evidently slower than other populations described in Alberta or the Northwest Territories (Figure 25). However, because of the small sample size (N=21), the growth rate should be considered tentative pending additional samples.

Males mature as early as age 4 while all were mature by age 5. All females from age 3 to 10 were mature with the exception of one age 6 female (Table 42). Overall sex ratios did not differ significantly from a 1:1 ratio ($X^2$=0.4; P>0.05).

Twelve of 21 stomachs examined were empty (Table 41). The remaining 9 stomachs all contained fish remains (longnose dace, longnose sucker juveniles and young-of-the-year, sculpins) with an occasional Odonata nymph.

### Longnose Suckers

Several authors have demonstrated a correlation between longnose sucker spawning migrations and increasing water temperatures (Bond and Machniak, 1977; Brown and Graham, 1954; Geen *et al.*, 1966). The critical stream temperature associated with the onset of spawning migrations appears to be 5 C.

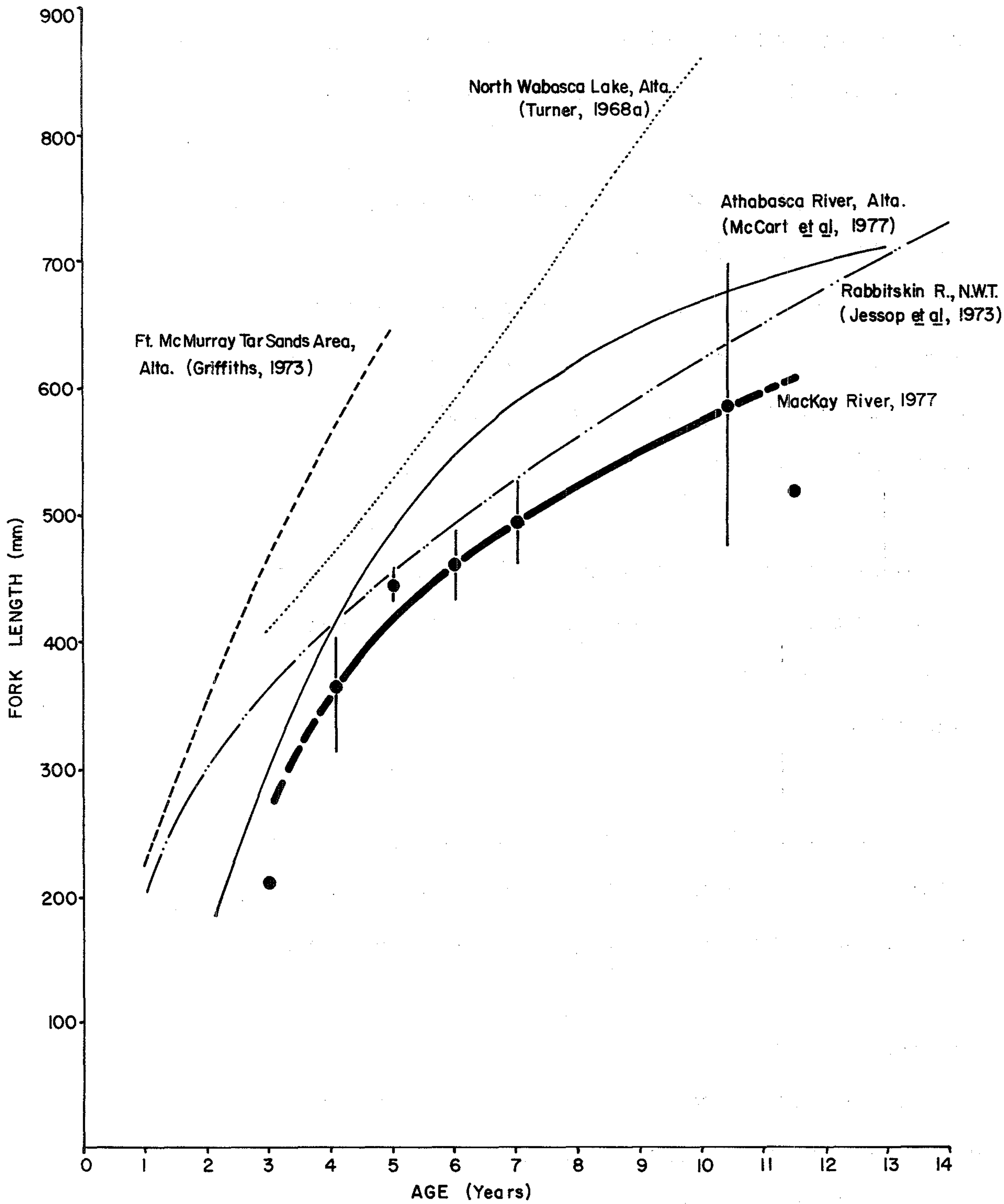



FIGURE 25. Comparison of growth rates of northern pike in the MacKay River and four other populations in Alberta and the Northwest Territories. All samples were aged from scales. Points and vertical lines are mean fork lengths ± 1 S.D.

TABLE 42. Observed length-age relationships (based on scales), age at maturity, and age-specific sex ratios of northern pike from the MacKay River, 1977.

| 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 | 210 | - | - | 0 | - | - | 1 | 100.0 | 100.0 | 0 | 1 |
| 4 | 357.3 | 47.0 | 323-426 | 3 | 75.0 | 66.7 | 1 | 25.0 | 100.0 | 0 | 4 |
| 5 | 446.3 | 13.4 | 434-465 | 2 | 50.0 | 100.0 | 2 | 50.0 | 100.0 | 0 | 4 |
| 6 | 460.0 | 29.1 | 428-496 | 2 | 40.0 | 100.0 | 3 | 60.0 | 66.7 | 0 | 5 |
| 7 | 495.7 | 36.0 | 453-541 | 4 | 100.0 | 100.0 | 0 | - | - | 0 | 4 |
| 8 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 9 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 10 | 588.0 | 112.6 | 520-718 | 0 | - | - | 2 | 100.0 | 100.0 | 0 | 2 |
| 11 | 520 | - | - | 1 | 100.0 | 100.0 | 0 | - | - | 0 | 1 |
| Total | | | | 12 | 57.1 | | 9 | 42.9 | | 0 | 21 |

Longnose suckers were first sampled at the Lower and Middle Stations on May 11 and 14 at which time water temperatures were about 14 C. All longnose suckers were either completely spent or nearly so, suggesting that spawning was already over. Bond and Machniak (1977) describe a similar pattern in the Muskeg River, another tributary of the Athabasca. At 14 C, longnose suckers had ceased moving upstream and began moving downstream. In the MacKay River, the peak in numbers which occurred at the Lower and Middle Stations in May (Figure 23) may have been the result of such a downstream movement. Reasons for the increased catches of longnose suckers at the Upper Station in August are unknown, but may have been due to greater gillnet efficiency during the low water levels at this time.

The exact spawning locations of longnose suckers are unknown. Longnose sucker young-of-the-year were widely distributed throughout the study area but were most abundant at the Upper Station (Tables 37, 38, Figure 26). This, coupled with the fact that longnose sucker fry often migrate downstream from spawning areas shortly after emergence (Geen *et al.*, 1966), suggests that most longnose suckers spawn upstream of the study area.

Data describing growth and age at maturity for longnose suckers are presented in Table 43. Although data are scarce, particularly for females (N=7), longnose suckers in the MacKay River appear to mature at an advanced age. All males 8 years and older were mature while the youngest mature female sampled was age 13. Overall sex ratios did not differ significantly from an expected 1:1 ratio ($X^2$=1.8, P>0.05).

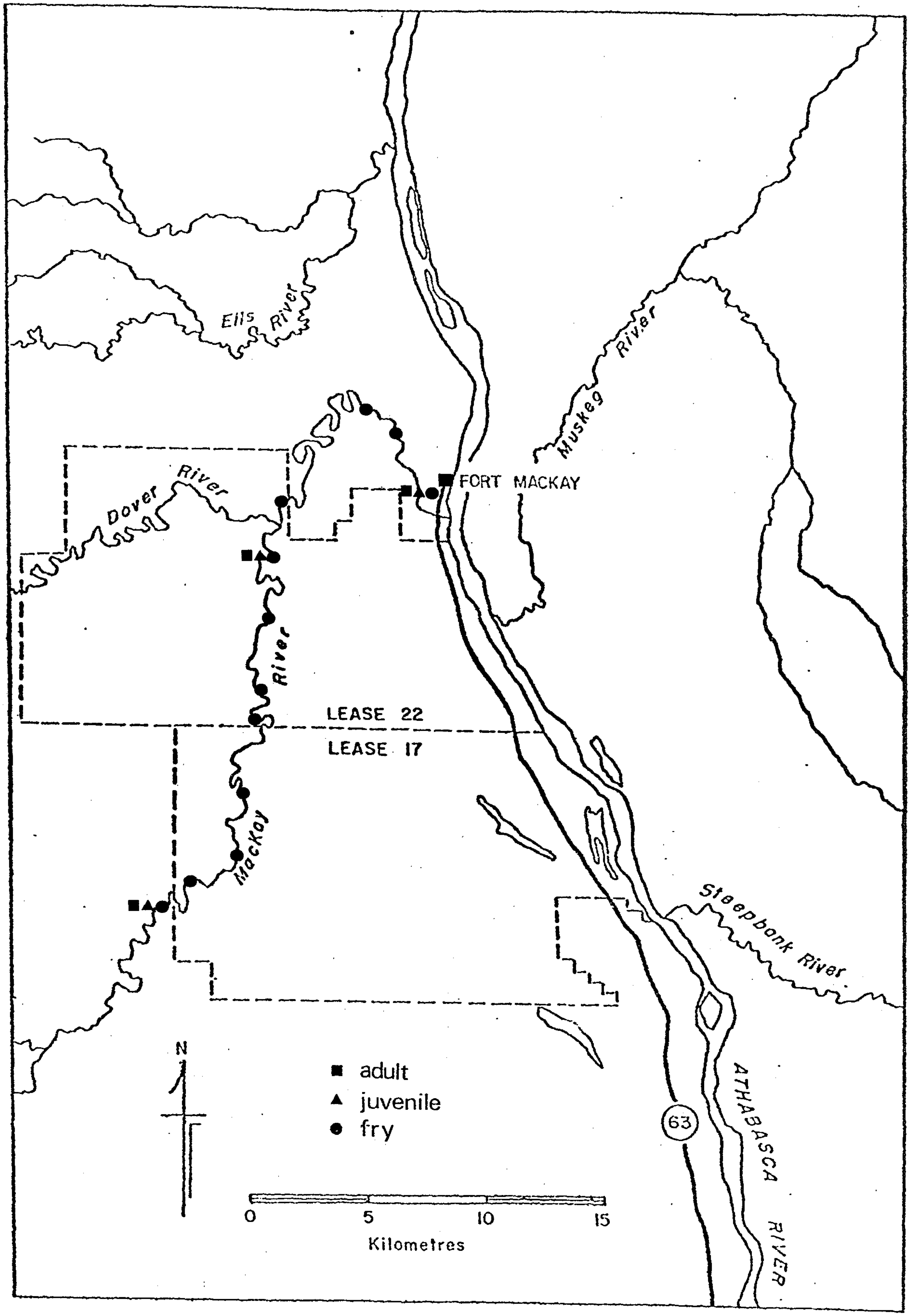



FIGURE 26. Sites where longnose suckers were captured in the study area.

TABLE 43. Observed length-age relationships (based on otoliths), age at maturity, and age-specific sex ratios of longnose suckers from the MacKay River, 1977.

| Age | Fork Length (mm) Mean | S.D. | Range | Males N | % | % Mature | Females N | % | % Mature | Unsexed | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 34.2 | 5.8 | 23-45 | 0 | - | - | 0 | - | - | 17 | 17 |
| 1 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 2 | 86.0 | 12.9 | 56-100 | 0 | - | - | 0 | - | - | 15 | 15 |
| 3 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 4 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 5 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 6 | 174.0 | 5.7 | 170-178 | 1 | 50.0 | 0.0 | 1 | 50.0 | 0.0 | 0 | 2 |
| 7 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 8 | 319.3 | 54.4 | 264-388 | 1 | 33.3 | 100.0 | 2 | 66.7 | 0.0 | 1 | 4 |
| 9 | 321.3 | 26.6 | 292-344 | 2 | 66.7 | 100.0 | 1 | 33.3 | 0.0 | 0 | 3 |
| 10 | 359 | - | - | 1 | 100.0 | 100.0 | 0 | - | - | 0 | 1 |
| 11 | 397.0 | 26.9 | 378-416 | 1 | 50.0 | 100.0 | 1 | 50.0 | 0.0 | 0 | 2 |
| 12 | 374.3 | 15.9 | 356-385 | 3 | 100.0 | 100.0 | 0 | - | - | 0 | 3 |
| 13 | 415.0 | 24.0 | 398-432 | 1 | 50.0 | 100.0 | 1 | 50.0 | 100.0 | 0 | 2 |
| 14 | 406.5 | 14.8 | 396-417 | 2 | 100.0 | 100.0 | 0 | - | - | 0 | 2 |
| 15 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 16 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 17 | 429.5 | 54.4 | 391-468 | 1 | 50.0 | 100.0 | 1 | 50.0 | 100.0 | 0 | 2 |
| Total | | | | 13 | 65.0 | | 7 | 35.0 | | 33 | 53 |

A comparison of the growth rate of MacKay River longnose suckers with those of other populations in Alberta and the Northwest Territories (Figure 27) indicates that longnose suckers in the MacKay are relatively long lived but slower growing than those in the Athabasca River and two populations in the Northwest Territories.

With the exception of an occasional corixid adult or chironomid larvae, the stomach contents of longnose suckers usually contained plant material and other matter too digested for identification.

White Sucker

The biology of white suckers is in many ways similar to that of longnose suckers. The two species are often found together in lakes, rivers, and streams throughout most of Canada and hybridization between the two species has been documented (Hubbs *et al.*, 1943).

White sucker spawning migrations appear to start when daily maximum water temperatures approach 10 C (Geen *et al.*, 1966). By the time the Lower and Middle Stations were sampled (May 10 to 14), water temperatures were 14 to 15 C. This, coupled with the fact that all white suckers sampled at this time were ripe (males only) or spawned-out (males and females), suggests that spawning had already occurred.

At the Lower and Middle Stations, there were two peaks in abundance of white suckers, one in May and one in September. At the Upper Station, there were peaks in June and late September. These peaks may represent

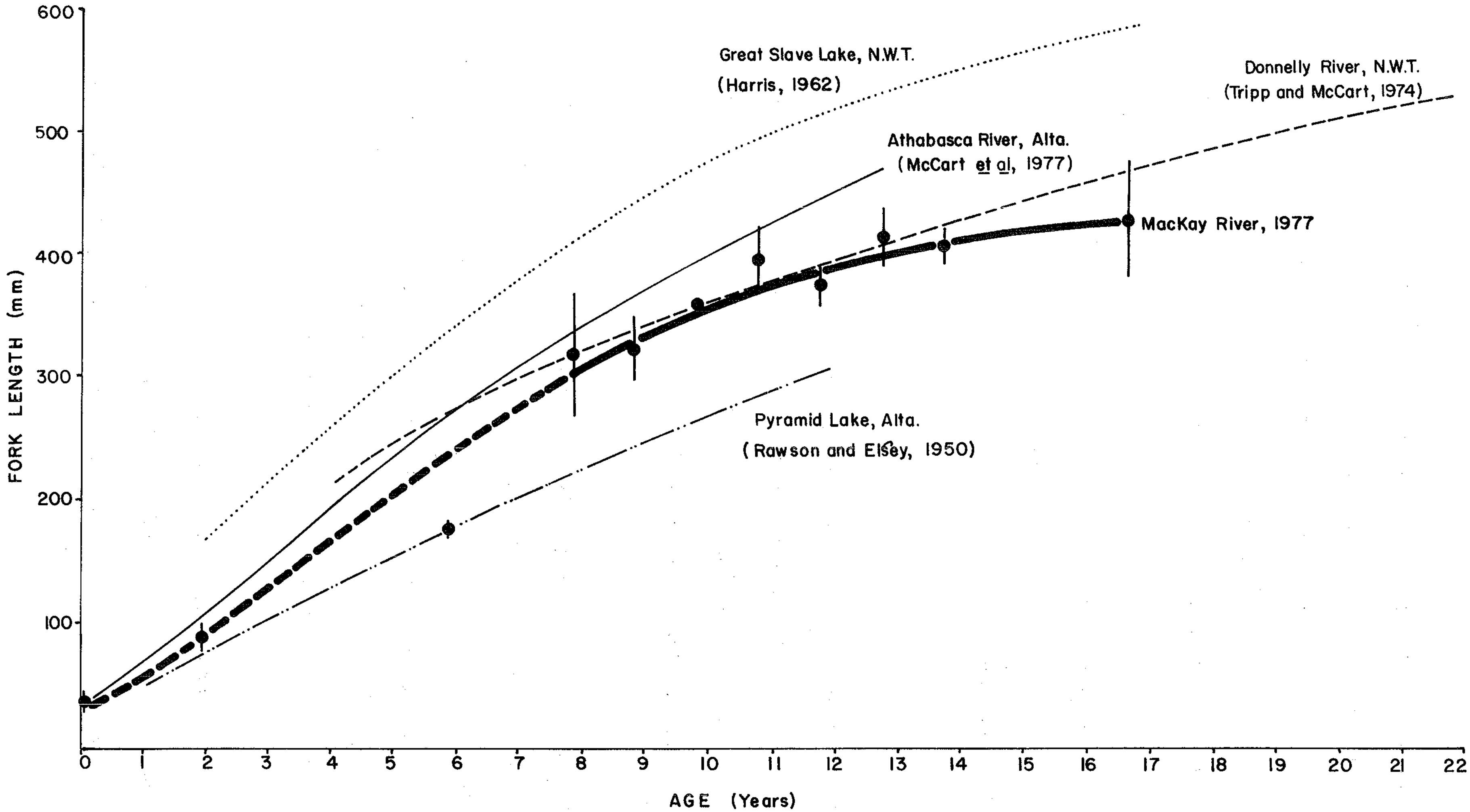



FIGURE 27. Comparison of growth rates of longnose suckers in the MacKay River and four other locations in Alberta and the Northwest Territories. The MacKay River, Athabasca River, and Donnelly River populations were aged by otoliths; the others by scales. Points and vertical lines are mean fork lengths ± 1 S.D.

a post-spawning downstream migration early in the season, and a downstream movement to overwintering areas in the fall.

Young-of-the-year were widely distributed throughout the study area (Figure 28) but like longnose sucker young-of-the-year were concentrated in the upstream part of the study area (Tables 37, 38). Since young-of-the-year often move downstream shortly after emergence (Geen *et al.*, 1966) suggesting that, like those of longnose suckers, the spawning areas of white sucker extend some distance upstream.

White suckers collected in the study area ranged from 26 (young-of-the-year) to 416 mm (Figure 22). All life history stages were sampled although juveniles aged 1 to 7 were scarce. Either juvenile white suckers occupy areas outside of the study area and have a distribution different from that of mature and maturing fish, or the sample was biased because fish approximately 100 to 250 mm fork length are too large to be captured by seine or too small to be captured in gillnets.

Data describing the age-length relationship, age at maturity, and sex ratios of white sucker in the MacKay River are presented in Table 44. All males were mature by age 8 and females by age 12. Data for younger age classes are absent. In the Muskeg River (Bond and Machniak, 1977), males matured as early as 3 years and females at 4 years. A comparison of growth data, however, shows a significantly faster growth rate in the Muskeg River than in the MacKay River (Figure 29).

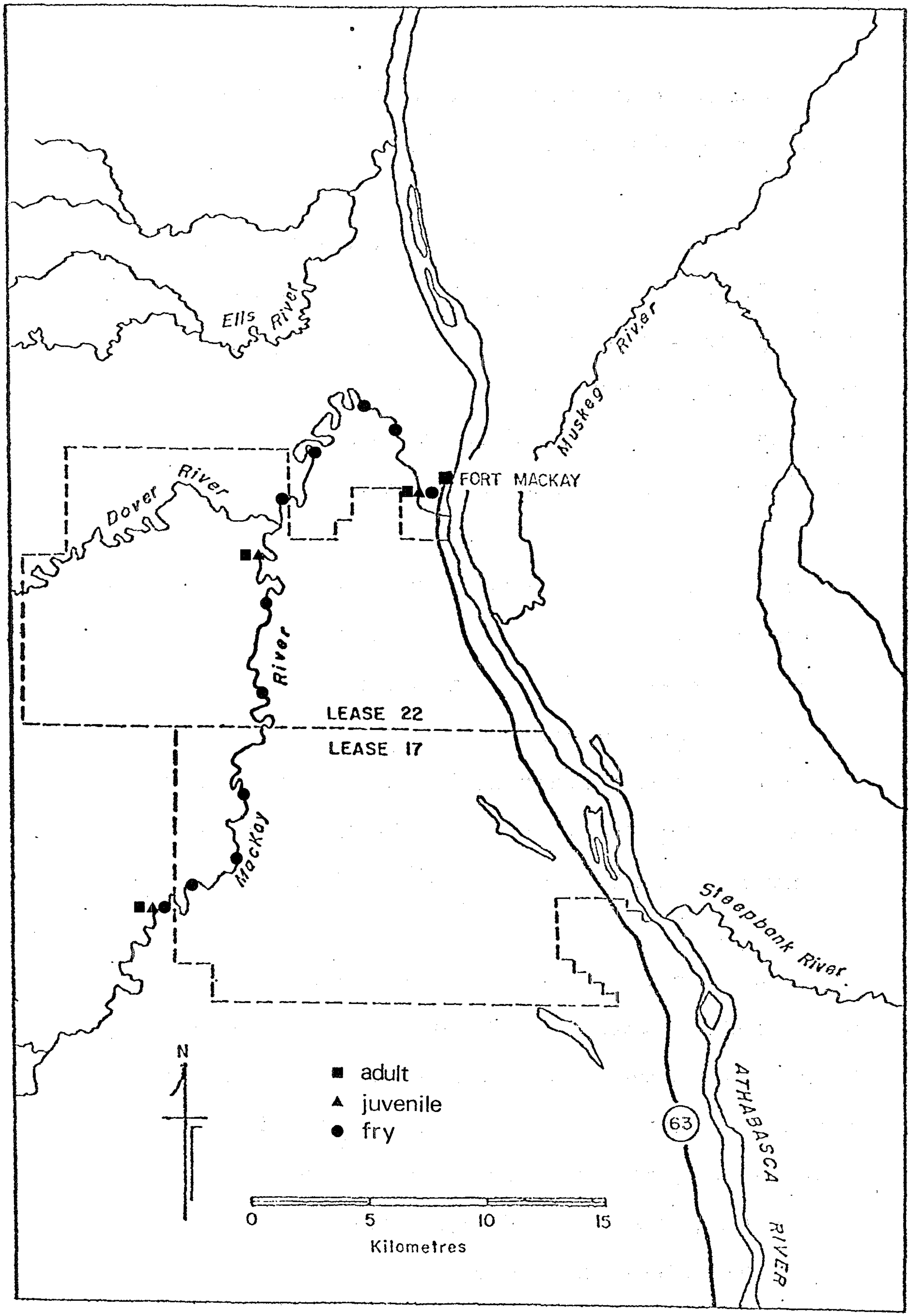



FIGURE 28. Sites where white suckers were captured in the study area.

TABLE 44. Observed length-age relationships (based on otoliths), age at maturity, and age-specific sex ratios of white suckers from the MacKay River, 1977.

| Age | Fork Length (mm) Mean | S.D. | Range | Males N | % | % Mature | Females N | % | % Mature | Unsexed | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 37.0 | 5.1 | 26-48 | 0 | - | - | 0 | - | - | 37 | 37 |
| 1 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 2 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 3 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 4 | 140 | - | - | 0 | - | - | 1 | 100.0 | 0.0 | 0 | 1 |
| 5 | 292 | - | - | 1 | 100.0 | 0.0 | 0 | - | - | 0 | 1 |
| 6 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 7 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 8 | 326.0 | 40.2 | 262-352 | 3 | 50.0 | 100.0 | 3 | 50.0 | 33.3 | 0 | 6 |
| 9 | 344.0 | 33.8 | 286-376 | 3 | 50.0 | 100.0 | 3 | 50.0 | 66.7 | 0 | 6 |
| 10 | 352.3 | 32.1 | 283-379 | 5 | 71.4 | 100.0 | 2 | 38.6 | 100.0 | 0 | 7 |
| 11 | 368.3 | 12.7 | 349-385 | 3 | 42.9 | 100.0 | 4 | 57.1 | 50.0 | 0 | 7 |
| 12 | 373.4 | 11.4 | 356-387 | 3 | 57.1 | 100.0 | 4 | 42.9 | 100.0 | 0 | 7 |
| 13 | 381.5 | 25.4 | 354-412 | 5 | 83.3 | 100.0 | 1 | 16.7 | 100.0 | 0 | 6 |
| 14 | 391.0 | 15.9 | 379-409 | 2 | 66.7 | 100.0 | 1 | 33.3 | 100.0 | 0 | 3 |
| 15 | 416 | - | - | 0 | - | - | 1 | 100.0 | 100.0 | 0 | 1 |
| Total | | | | 25 | 55.6 | | 20 | 44.4 | | 37 | 82 |

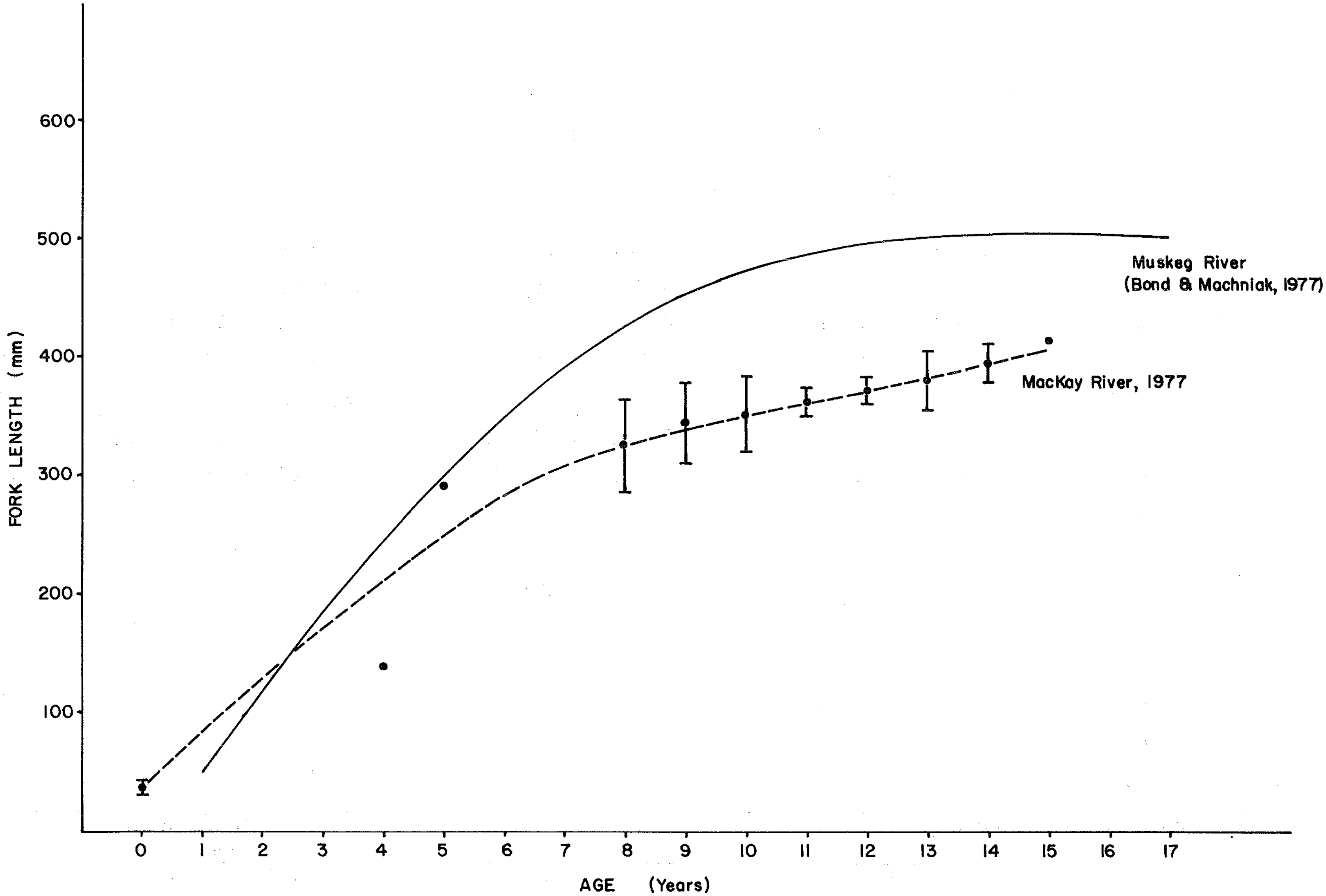



FIGURE 29. Comparison of growth rates for white suckers in the MacKay River and the Muskeg River. All samples were aged by otoliths. Points and vertical lines are mean fork lengths ± 1 S.D.

Sex ratios did not differ significantly from an expected 1:1 ratio at any age or overall ($X^2$=0.56, P>0.05).

The stomach contents of white suckers were examined but found to be unidentifiable.

Trout-Perch

The trout-perch typically inhabits the quiet backwaters of large turbid rivers and shallow, sandy areas in lakes. Trout-perch in the MacKay River were commonly found in such habitats rather than the faster current of riffled areas. They were widely distributed throughout the study area (Figure 30, Table 38) and accounted for 19.5% of all fish seined at permanent sampling stations (Table 36). Maximum abundance, however, was recorded in the slower lower section of the river where they accounted for 64.2% of all fish sampled.

Trout-perch sampled from the study area ranged in length from 11 to 89 mm fork length (Figure 31).

The growth rate of trout-perch from the MacKay River has been compared with those from the Athabasca River, the Mackenzie Delta, and Mackenzie River (Figure 32). With the exception of the latter, all growth rates are based on otolith-derived ages. Growth in the MacKay River is initially similar to that in the Mackenzie Delta but declines with age. Comparison with the Athabasca River trout-perch indicates that, at the same age, mean fork lengths differ by approximately one season's growth. Since

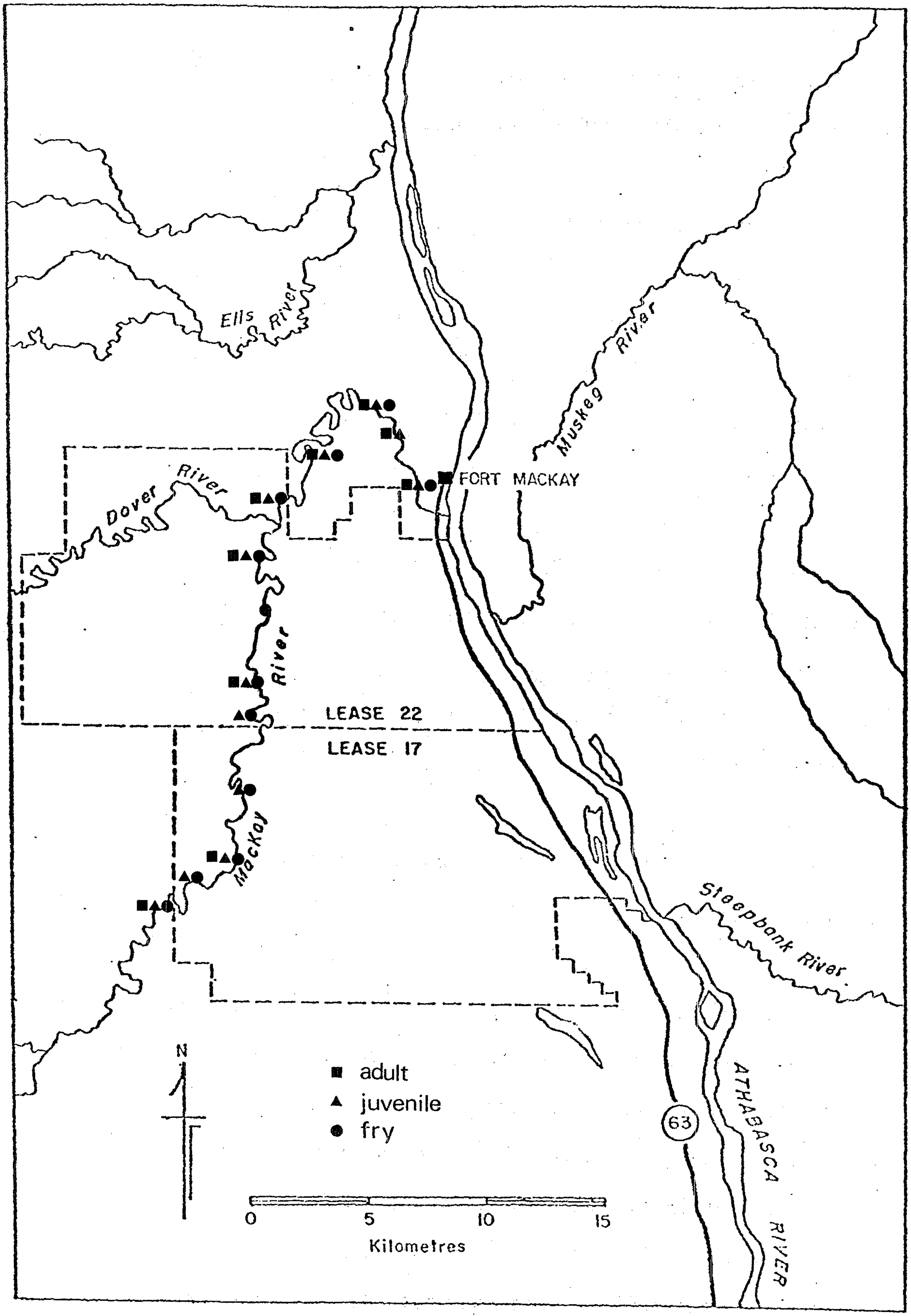



FIGURE 30. Sites where trout-perch were captured in the study area.

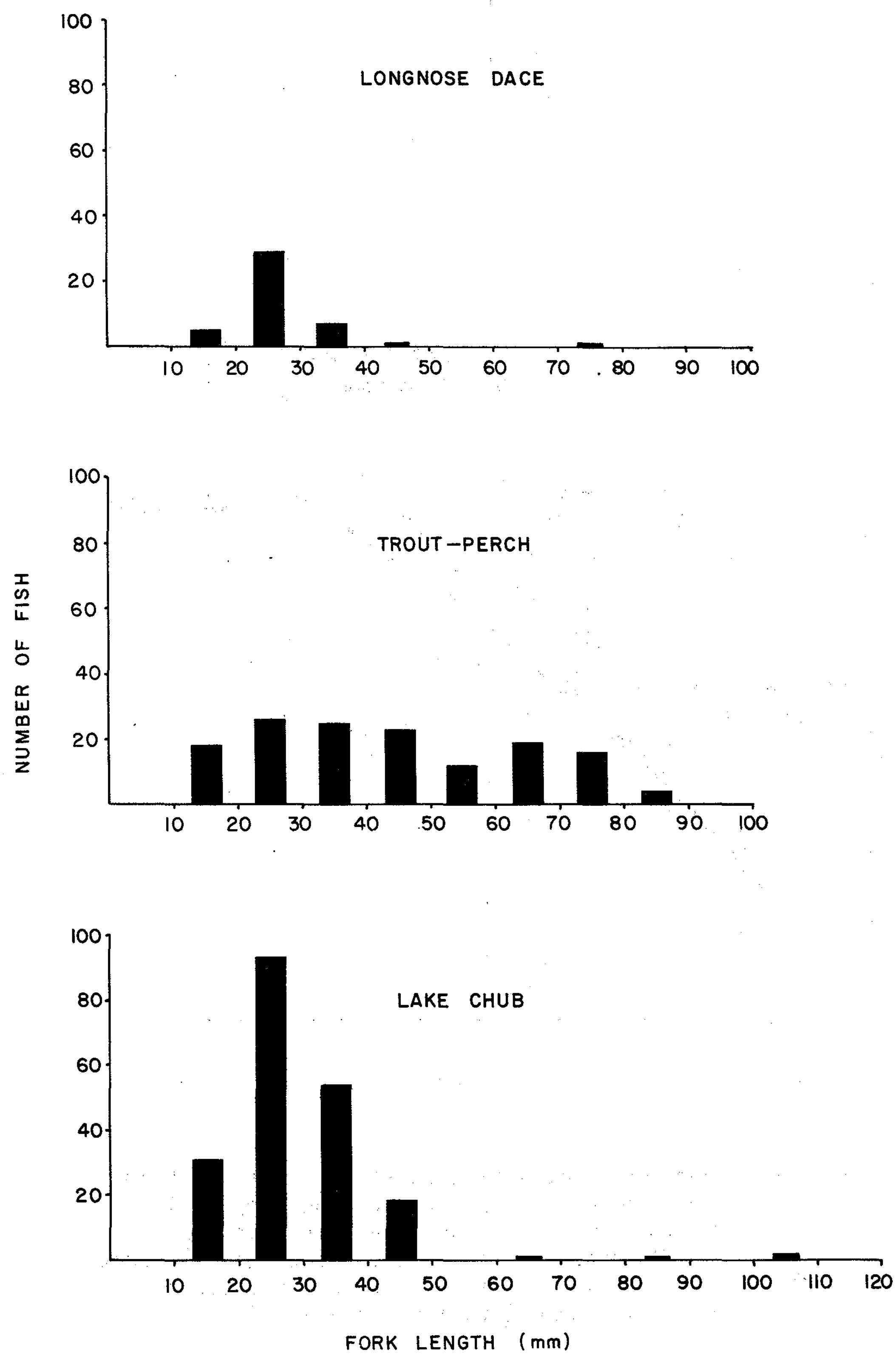



FIGURE 31. Length-frequencies of longnose dace, trout-perch, and lake chub collected in the MacKay River, 1977.

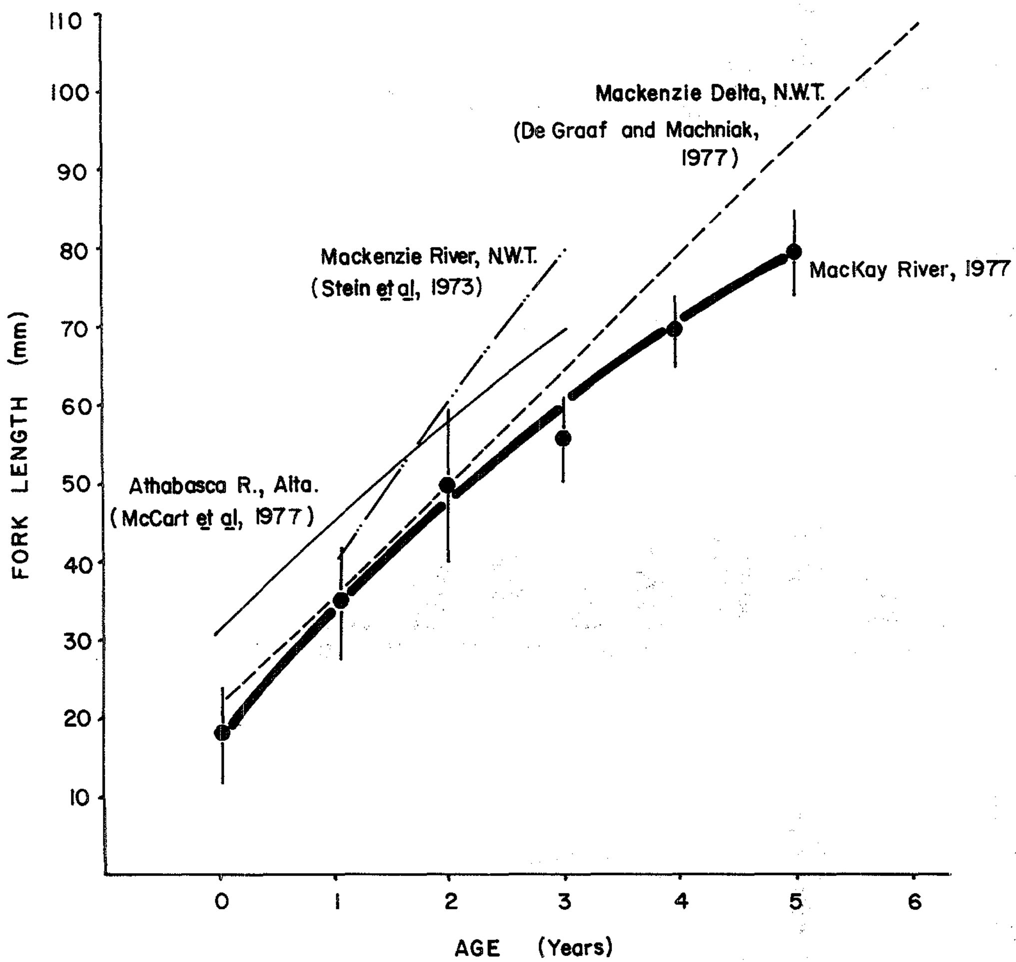



FIGURE 32. Comparison of growth rates of trout-perch in the MacKay River and three other populations in Alberta and the Northwest Territories. The Mackenzie River samples were aged by scales; all others by otoliths. Points and vertical lines are mean fork lengths ± 1 S.D.

all samples from the MacKay River were collected early in the study period before any significant growth had occurred, growth may in fact be identical to growth in the Athabasca River. Maximum recorded age was 6 in the Mackenzie Delta, 5 in the MacKay River, and 3 in the Athabasca River.

Age at first maturity (Table 45) was 2 years for males and 3 years for females. By age 4, all fish were mature. Sex ratios did not differ significantly from an expected 1:1 ratio at any age or overall.

The exact time of trout-perch spawning in the MacKay River is unknown but apparently occurs over an extended period. Large numbers of recently hatched young-of-the-year (11-15 mm) were collected at both the Upper and Lower Stations June 14-17, suggesting that most spawning occurred near the end of May or early June. However, the presence of mature green females with relatively large eggs (1.1-1.6 mm) in mid-June together with the occasional young-of-the-year (<17 mm) captured in mid August together suggest that some spawning may occur well into July.

Mean fecundity for six trout-perch sampled on June 16 and ranging in fork length from 55 to 73 mm was 189 $\pm$ 13.8 (range 172-204).

The stomach contents of 47 trout-perch were examined of which 38 (81%) contained food (Table 41). Ephemeroptera nymphs (89.5%) and chironomid larvae (65.9%) were by far the most common food items consumed. Other items included ceratopogonids, oligochaetes, adult midges, and trout-perch young-of-the-year.

TABLE 45. Observed length-age relationships based on otoliths, age at maturity, and age specific sex ratios of trout-perch from the MacKay River, 1977.

| Age | Fork Length (mm) Mean | S.D. | Range | Males N | % | % Mature | Females N | % | % Mature | Unsexed | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 17.1 | 6.7 | 11-33 | - | - | - | - | - | - | 23 | 23 |
| 1 | 34.1 | 7.0 | 29-38 | - | - | - | - | - | - | 8 | 8 |
| 2 | 49.3 | 10.2 | 44-54 | 5 | 71.4 | 80.0 | 2 | 28.6 | 0.0 | 5 | 12 |
| 3 | 55.9 | 5.7 | 46-64 | 7 | 53.9 | 85.7 | 6 | 46.1 | 83.3 | 1 | 14 |
| 4 | 70.0 | 4.5 | 62-79 | 13 | 54.2 | 100.0 | 11 | 45.8 | 100.0 | 0 | 24 |
| 5 | 79.6 | 5.9 | 72-89 | 1 | 14.2 | 100.0 | 6 | 85.7 | 100.0 | 0 | 7 |
| Totals | | | | 26 | 51.0 | | 25 | 49.0 | | 37 | 88 |

Walleye

The walleye is apparently the most abundant of the larger fish species in the Athabasca River (McCart *et al.*, 1977). It is also the most abundant of the larger fish species captured in the MacKay River, accounting for 34% of the total gillnet catch (Table 36). During the spring upstream migration, they were heavily fished for by residents of Fort MacKay and Fort McMurray as well as by Syncrude personnel living at the plant site. While no creel census was taken, anglers that we talked to in the spring indicated they had no difficulty in filling their daily limits.

Data describing length-age relationships, age at maturity, and age-specific sex ratios of walleye from the MacKay River are presented in Table 46. Age at first maturity for males was 7 years and by 10 years all males were mature. Data on the age at maturity and growth for females are lacking since only four females, all immature, were sampled in the MacKay River. Reasons for the imbalance in the representation of the sexes are not known.

In Figure 33, the growth rate of walleye in the MacKay River, 1977, is compared with those of walleye from four locations in Alberta and Saskatchewan. As indicated, walleye in the MacKay River grow at a much slower rate than walleye populations in either North Wabasca Lake, Lac La Ronge, Kehiwin Lake, or the Athabasca River. On the other hand, walleye in the MacKay River attain greater ages. Maximum scale-based age was 14 years in the MacKay compared to 11 in the Athabasca and 6 in North Wabasca Lake. Differences in growth are not likely due to the preponderance of males in the MacKay since most walleye in the Athabasca River were also males (80%).

TABLE 46. Observed length-age relationships (based on scales), age at maturity, and age-specific sex ratios of walleye from the MacKay River, 1977.

| | Fork Length (mm) | | | Males | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | Mean | S.D. | Range | N | % | % Mature | N | % | % Mature | Unsexed | Total |
| 0 | 54.3 | 10.4 | 28-68 | 0 | - | - | 0 | - | - | 10 | 10 |
| 1 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 2 | - | - | - | 0 | - | - | 0 | - | - | 0 | 0 |
| 3 | 139 | - | - | 0 | - | - | 0 | - | - | 1 | 1 |
| 4 | 260 | - | - | 1 | 100.0 | 0.0 | 0 | - | - | 0 | 1 |
| 5 | 311.0 | 2.8 | 309-313 | 2 | 100.0 | 0.0 | 0 | - | - | 0 | 2 |
| 6 | 309.6 | 10.7 | 301-328 | 2 | 40.0 | 0.0 | 3 | 60.0 | 0.0 | 0 | 5 |
| 7 | 358.3 | 25.1 | 329-385 | 4 | 100.0 | 75.0 | 0 | - | - | 0 | 4 |
| 8 | 373.2 | 27.1 | 345-439 | 8 | 88.9 | 100.0 | 1 | 11.1 | 0.0 | 0 | 9 |
| 9 | 397.3 | 24.4 | 365-431 | 8 | 100.0 | 87.5 | 0 | - | - | 0 | 8 |
| 10 | 411.2 | 14.7 | 385-438 | 11 | 100.0 | 100.0 | 0 | - | - | 1 | 12 |
| 11 | 418.3 | 15.1 | 409-448 | 6 | 100.0 | 100.0 | 0 | - | - | 0 | 6 |
| 12 | 444.0 | 14.1 | 434-454 | 2 | 100.0 | 100.0 | 0 | - | - | 0 | 2 |
| 13 | 450.0 | 1.4 | 449-451 | 2 | 100.0 | 100.0 | 0 | - | - | 0 | 2 |
| 14 | 440 | - | - | 1 | 100.0 | 100.0 | 0 | - | - | 0 | 1 |
| Total | | | | 47 | 92.1 | | 4 | 7.9 | | 12 | 63 |

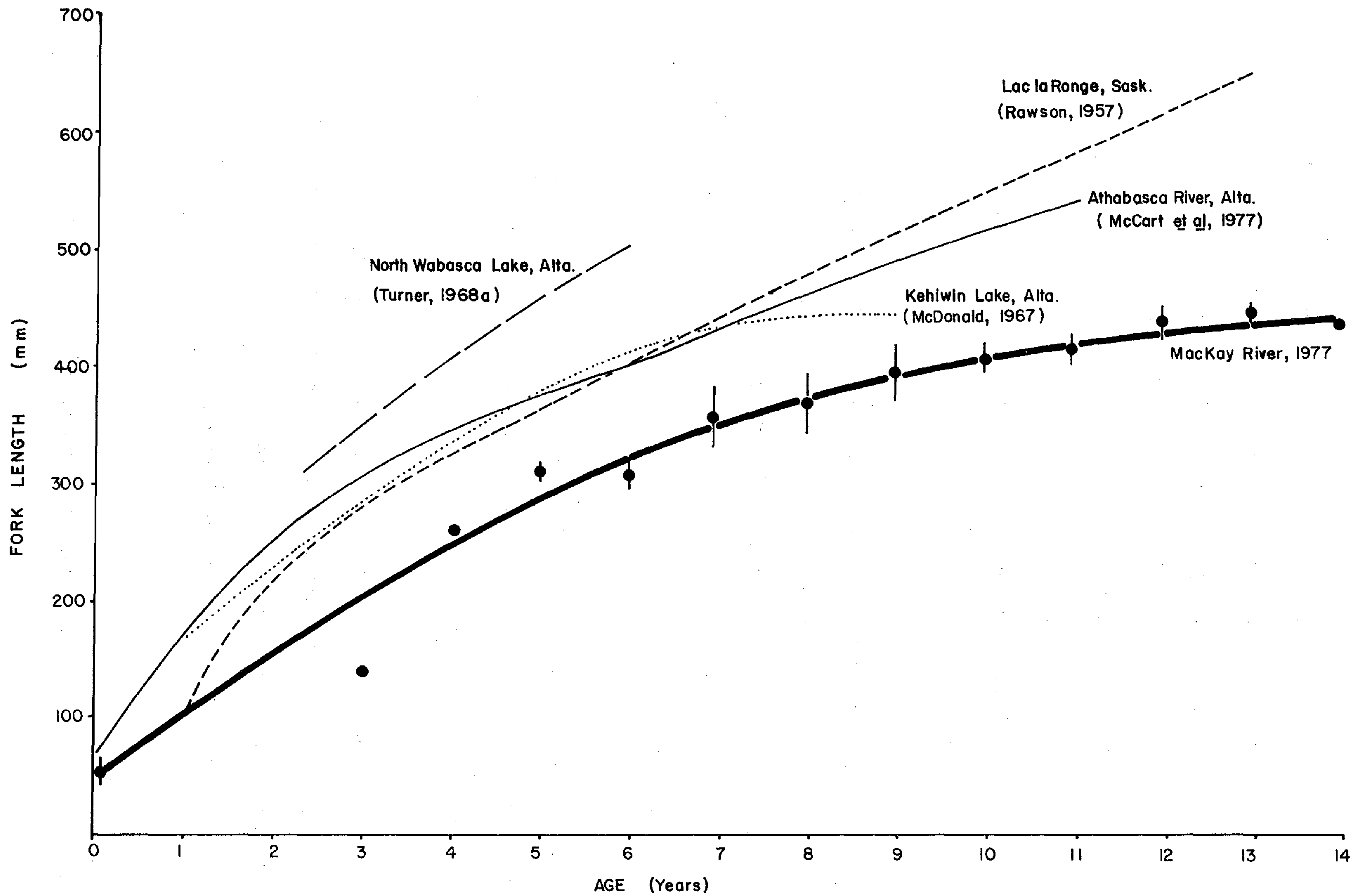



FIGURE 33. Comparison of growth rates of walleye collected in the MacKay River, Alberta, and four other locations in Alberta and Saskatchewan. Points and vertical lines are mean fork lengths ± 1 S.D.

Walleye spawn in the spring shortly after spring break-up and usually at water temperatures ranging from 6 to 9 C (Scott and Crossman, 1973). Preferred spawning areas are over rocky substrates in white water below dams or impassable falls. In the study area, rapids are much more frequent near the Upper Station. This area would thus appear more suitable for spawning purposes. However, only 14 young-of-the-year walleye (Figure 34) were captured throughout the study area, suggesting that spawning is limited. Possibly more spawning occurs in areas farther upstream.

The seasonal abundance of walleye at the Middle and Lower Stations was greatest in May (Figure 23) and is possibly associated with a spawning migration. In view of the scarcity of females described above and the high temperatures (14 to 15 C), it is likely, however, that spawning, if any, was already finished.

No walleye were captured in late September at the Upper and Middle Stations suggesting that walleye had by this time moved downstream to overwintering areas elsewhere.

Of 53 walleye stomachs examined, 23 (43.4%) were empty (Table 41). Of those containing food, fish remains, including flathead chub and sculpins, were the most common food items (80.0%). Odonata nymphs (13.3%), plecoptera nymphs (6.7%), and tipulid larvae (3.3%) were also eaten.

### Other Species

Other species are those for which no life history information is presented,

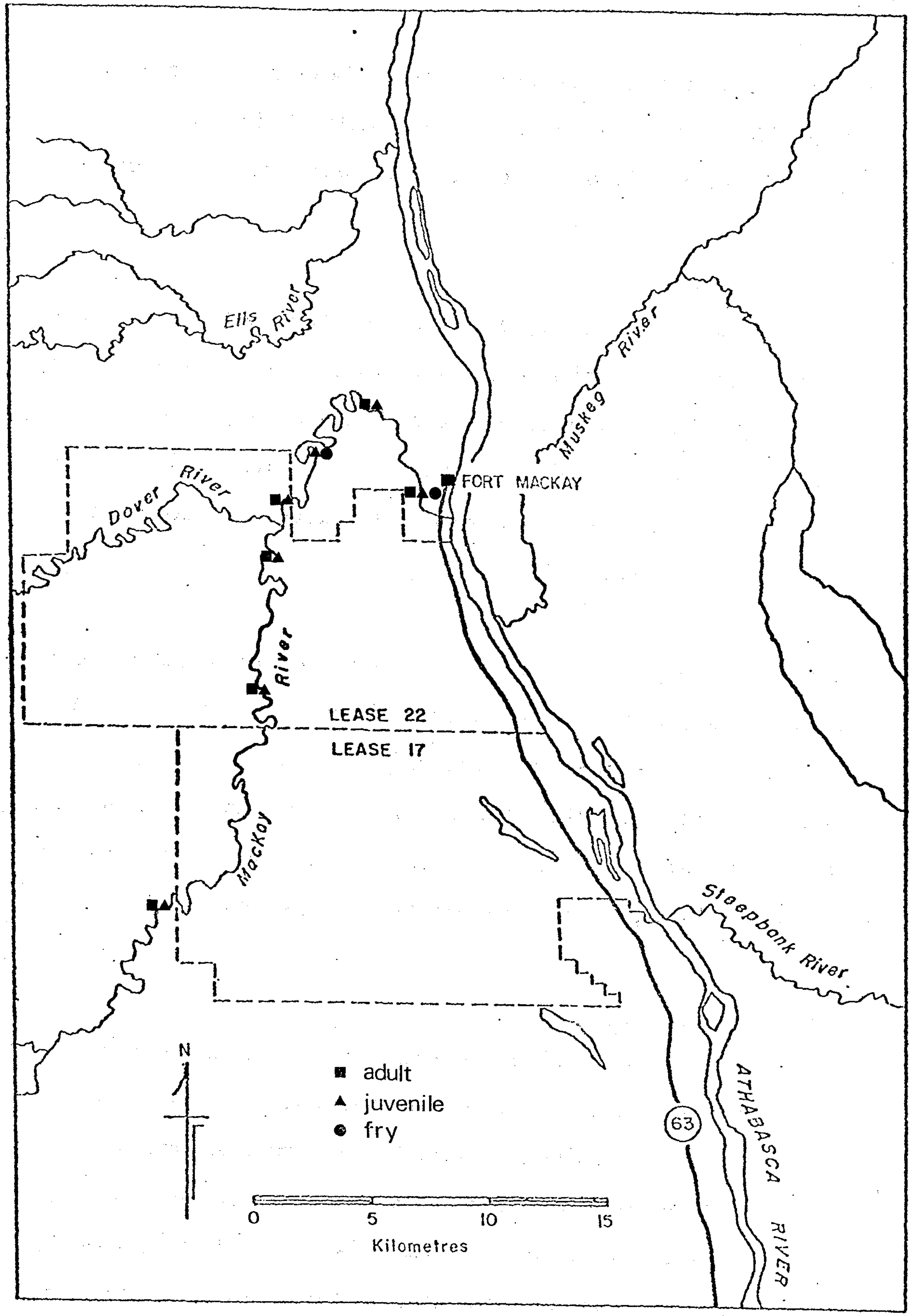



FIGURE 34. Sites where walleye were captured in the study area.

primarily because numbers were insufficient. These include lake whitefish, Arctic grayling, lake chub, emerald shiner, spottail shiner, flathead chub, longnose dace, burbot, brook stickleback, yellow perch, slimy sculpin, and spoonhead sculpin.

Length-frequencies for longnose dace and lake chub are presented in Figure 31. With the exception of a single mature female (76 mm fork length) all other longnose dace were immature juveniles and young-of-the-year. Similarly, the majority of lake chubs were also juveniles and young-of-the-year. The distribution of lake chub and longnose dace are shown in Figures 35 and 36, respectively.

Length-frequencies of the remaining species are presented in Table 47. Of these, lake whitefish, flathead chub, and burbot were rarely sampled and, as previously discussed, are more properly identified with the Athabasca River than with the MacKay. Yellow perch also seem to be largely limited to the Athabasca River but they apparently spawn at the mouth of the MacKay River though they do not venture far upstream.

Fish Overwintering

At least four species of fish use the MacKay River as an overwintering area: Arctic grayling, northern pike, longnose sucker, and white sucker (Table 48). Of these, the grayling was rarely sampled during the open water season but the others were either abundant or common. Grayling may occur during the summer in areas upstream of the study area or in tributaries to the MacKay River (e.g., the Dunkirk and Dover) and move downstream to overwinter

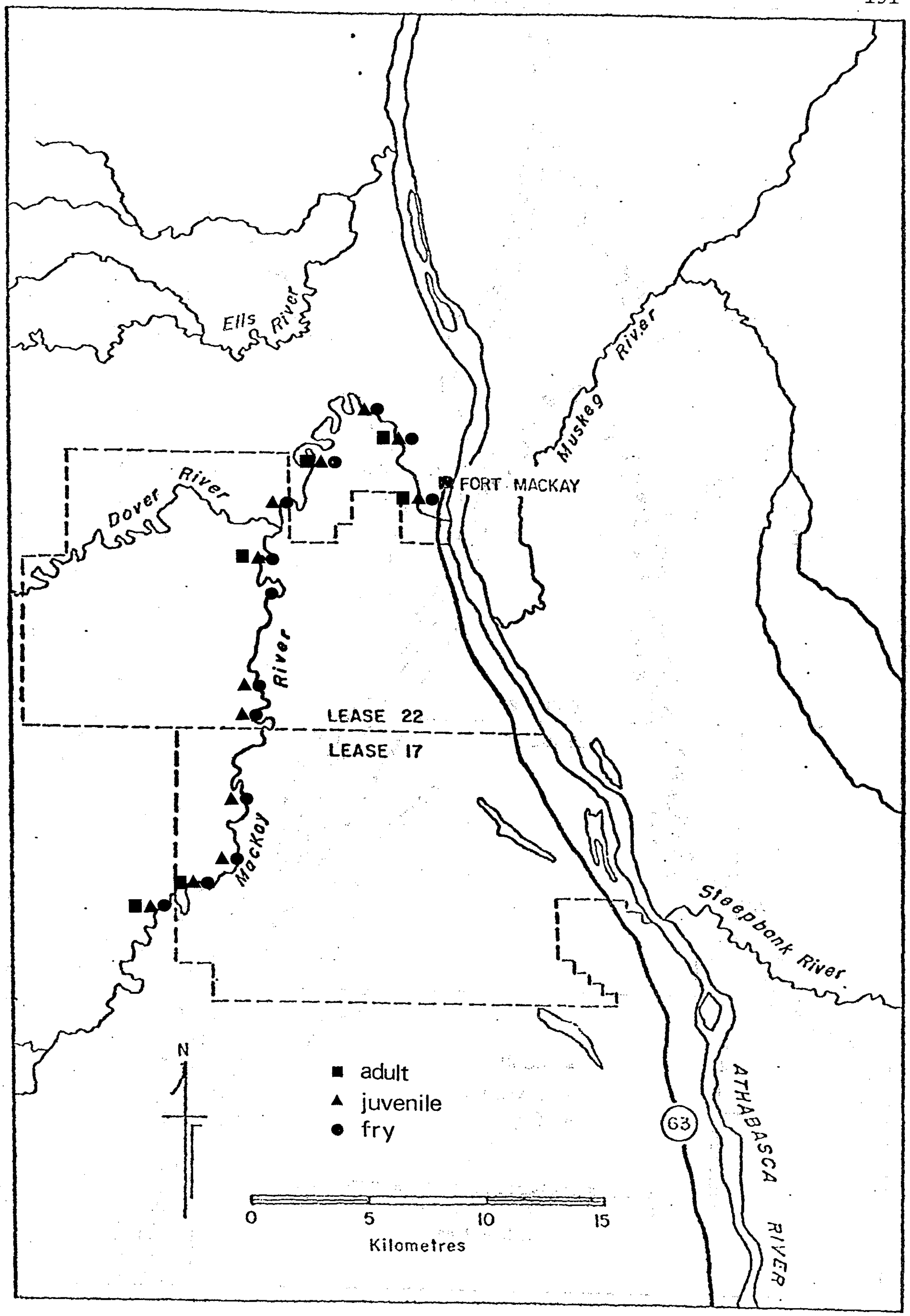



FIGURE 35. Sites where lake chub were captured in the study area.

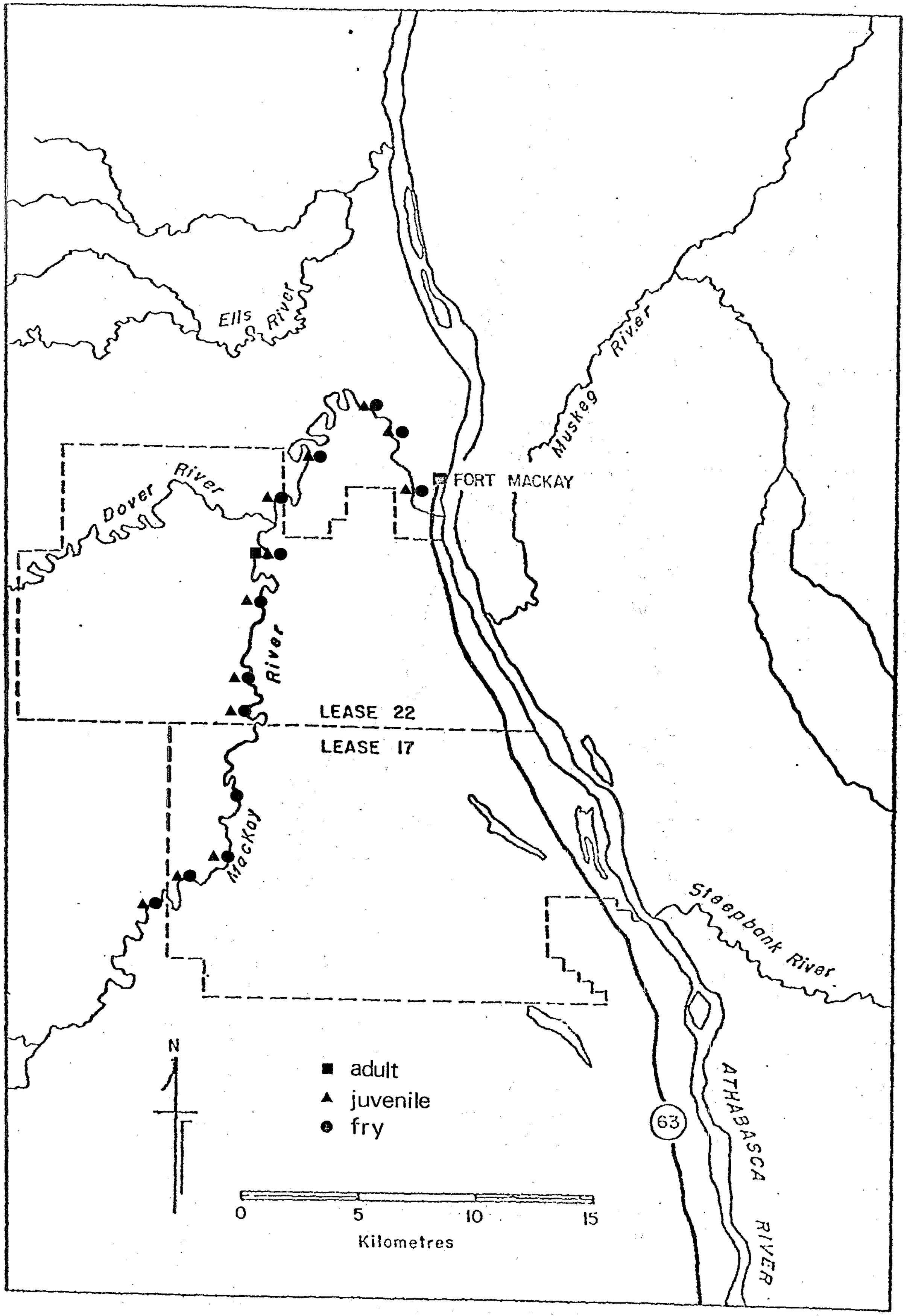



FIGURE 36. Sites where longnose dace were captured in the study area.

TABLE 47. Length-frequency of other species collected from the MacKay River, 1977. Four letter codes are listed in Table 35.

| Size Class (mm) | Species MTWT | EMSH | SPSH | BRST | YWPH | SLSC | SPSC |
|---|---|---|---|---|---|---|---|
| 10-19 | | | | | | 3 | |
| 20-29 | | | | | | | |
| 30-39 | 1 | | | 1 | 3 | | |
| 40-49 | | | 1 | 1 | 23 | | 1 |
| 50-59 | | | 1 | 2 | 9 | 4 | |
| 60-69 | | | 2 | | | 2 | |
| 70-79 | | 5 | | | | 2 | |
| 80-89 | | 2 | | | | | |
| 90-99 | | 1 | | | | | |
| Totals: | 1 | 8 | 4 | 4 | 35 | 11 | 1 |

| | Species LKWT | GRAY | FLCB | BURB |
|---|---|---|---|---|
| 0-49 | | | | |
| 50-74 | | | | |
| 75-99 | | | | |
| 100-124 | | | | |
| 125-149 | | | | 2 |
| 150-174 | | | | |
| 175-199 | | 1 | | |
| 200-224 | | | | |
| 225-249 | | | | |
| 250-274 | | | | |
| 275-299 | | | 2 | |
| 300-324 | | | 1 | |
| 325-349 | 1 | 2 | | |
| 350-374 | 1 | 3 | | |
| 375-399 | 1 | | | |
| Totals: | 3 | 6 | 3 | 2 |

TABLE 48. Summary of gillnet catches at the Lower and Middle Stations on the MacKay River, December, 1977 and January, 1978.

| Station | Lower | Lower | Middle |
|---|---|---|---|
| Sampling Period | Dec. 8-11 | Jan. 12-15 | Jan. 13-15 |
| Effort (hours/ mesh size) | 72/6.4 cm | 72/6.4 cm | 44.5/8.9 cm |
| Arctic grayling | 4 | | |
| northern pike | 3 | 1 | |
| longnose sucker | 1 | | |
| white sucker | | | 1 |

in the study area. Alternatively, they may enter the mouth of the MacKay after leaving streams known to support grayling (e.g., the Ells, Muskeg, and Steepbank).

Sculpins (probably *C. cognatus)* and longnose sucker fry were found in the stomachs of pike taken during the winter suggesting that these species also overwinter in the MacKay River.

The Sport Fishery

Recreational use of the MacKay River is confined to angling near its mouth. Angling is most intense on weekends shortly after spring break-up, coinciding with the upstream migration of the walleye. Walleye are by far the preferred species but northern pike are also angled. Goldeye, although abundant, are not highly regarded and are usually released when caught. They become more important as a sport fish in the summer when catches of walleye and pike are low.

Angling in the MacKay River drops off with declining walleye catches in June and July. By August and September, very few people fish in the MacKay River.

Because of the large walleye run present in the MacKay River and its accessibility, it is one of the preferred rivers in the area for fishing. In view of the additional development of tar sands proposed for this area, demands on the sport fishery of the MacKay River can be expected to increase significantly in the future.

There is no domestic fishery on the MacKay River itself. However, residents of Fort MacKay are permitted to gillnet the Athabasca River near the mouth of the MacKay and undoubtedly capture fish that would otherwise move into the MacKay.

Fisheries Assessment

In the absence of sufficient data, an accurate assessment of the MacKay River to the overall fisheries of the region is difficult. However, in view of the fact that the MacKay River is the largest watershed in the western region of the Athabasca Oil Sands area, its contribution to the fisheries of the region has to be considered high.

The MacKay River is a major summer feeding area for goldeye, northern pike, and walleye and supports a relatively important sports fishery. As development proceeds, demands on it are certain to increase at a faster rate than for less accessible rivers, i.e., those further north or on the east bank of the Athabasca River.

The major importance of the MacKay River to the fisheries of the region is probably as a spawning, rearing, and summer feeding area for fish species commonly regarded as forage species. These include lake chub, longnose sucker, white sucker, and trout-perch. They are probably the most abundant forage species in the region for more desirable fish species such as walleye and northern pike.

# LITERATURE CITED

Alberta Environment. 1977. Alberta surface water quality objectives. Alberta Environment, Water Quality Branch, Standards and Approvals Division.

Allen, R.K., and G.F. Edmunds, Jr. 1961a. A revision of the genus *Ephemerella* (Ephemeroptera: Ephemerellidae). II. 3. The subgenus *Caudatalla*. Ann. Entomol. Soc. Amer. 54:603-612.

Allen, R.K., and G.F. Edmunds, Jr. 1961b. A revision of the genus *Ephemerella* (Ephemeroptera: Ephemerellidae). III. The subgenus *Attenuatella*. J. Kansas Entomol. Soc. 34:161-173.

Allen, R.K., and G.F. Edmunds, Jr. 1965. A revision of the genus *Ephemerella* (Ephemeroptera: Ephemerellidae). VIII. The subgenus *Ephemerella* in North America. Misc. Publ. Entomol. Soc. Amer. 4:244-282.

American Public Health Association. 1971. Standard methods for the examination of water and wastewater. 13th Ed. APHA, New York.

Barber, W.E., and N.R. Kevern. 1973. Ecological factors influencing macroinvertebrate standing crop distribution. Hydrobiol. 43:53-75.

Barton, D.R., and R.R. Wallace. 1977. Ecological studies on the benthic invertebrates of rivers in the AOSERP Program study area, northeast Alberta, Canada. Alberta Oil Sands Environmental Research Program. Project AF 2.0.

Battle, H.I., and W.M. Sprules. 1960. A description of the semi-buoyant eggs and early development stages of the goldeye, *Hiodon alosoides* (Rafinesque). J. Fish. Res. Board Can. 17(2):245-265.

Bell, G., P. Handford, and C. Dietz. 1977. Dynamics of an exploited population of lake whitefish *(Coregonus clupeaformis)*. J. Fish. Res. Board Can. 34(7):942-953.

Blum, J.L. 1956. The ecology of river algae. Bot. Rev. 22(5):291-341.

Blum, J.L. 1957. An ecological study of the algae of the Saline River, Michigan. Hydrobiol. 9:361-408.

Bond, W.A., and K. Machniak. 1977. Interim report on an intensive study of the fish fauna of the Muskeg River watershed of Northeastern Alberta. AOSERP. Aquatic Fauna Technical Research Committee. Project AF 4.5.1. 137 pp.

Bourrelly, P. 1968. Les algues d'eau douce. II. Les algues jaunes et brunes. Editions N. Boubée et Cie. Paris. 438 pp.

Brown, C.J.D., and R.J. Graham. 1954. Observations on the longnose sucker in Yellowstone Lake. Trans. Amer. Fish. Soc. 83:38-46.

Cairns, J., G.R. Lanza, and B.C. Parker. 1972. Pollution related structural and functional changes in aquatic communities with emphasis on freshwater algae and protozoa. Proc. Acad. Nat. Sci. Phila. 124: 79-127.

Cleve-Euler, A. 1951-1955. Die Diatomeen von Schweden und Finnland. Kgl, Sveska Vetenskapsakad. Hand. NS 2-5.

Clifford, H.F. 1969. Limnological features of a northern brown-water stream, with special reference to the life histories of the aquatic insects. Amer. Midl. Nat. 82:578-597.

Clifford, H.F., M.R. Robertson, and K.A. Zelt. 1973. Life cycle patterns of mayflies (Ephemeroptera) from some streams of Alberta, Canada. Proc. First Int. Conf. Ephemeroptera. E.J. Brill, Leiden, Netherlands. 312 pp.

Cordone, A.J., and D.W. Kelley. 1961. The influence of inorganic sediment on the aquatic life of streams. Calif. Fish and Game 47:189-228.

Davis, R.W., J. Culp, R.B. Green, M. O'Connell, G. Scott, and C. Zimmermann. 1977. River classification study of the South Saskatchewan River basin. Report to Alberta Environment. 625 pp.

de Graaf, D., and K. Machniak. 1977. Fisheries investigations of the Mackenzie Delta in the vicinity of the cross delta alternative pipeline route. IN: P.J. McCart (ed.), Studies to determine the impact of gas pipeline development on aquatic ecosystems. Arctic Gas Biological Report Series 39(1). 150 pp.

Den Beste, J., P.T.P. Tsui, and R. Green. 1977a. Biological assessment of the sewage effluents in the Connaught Creek-Beaver River drainage, Glacier National Parks, B.C. Aquatic Environments Limited. Report to E.P.S. and Parks Canada. 219 pp.

Den Beste, J., P.T.P. Tsui, and R. Green. 1977b. Biological assessment of the effects of sewage effluents in the Kicking Horse River (Yoho National Park). Aquatic Environments Limited. Report to E.P.S. and Parks Canada. 220 pp.

Desikachary, T.V. 1959. Cyanophyta. Indian Council of Agricultural Research. New Delhi. 686 pp.

Donald, D.B., and A.H. Kooyman. 1977. Migration and population dynamics of the Peace-Athabasca Delta goldeye population. Canadian Wildllife Service. Occasional Paper No. 31. 19 pp.

Erth, M., S. Juris, and J. Tomajka. 1972. Preliminary data about seasonal changes and vertical stratification of periphyton from the middle reach of the River Danube. Arch. Hydrobiol. (Suppl.). 44:34-48.

Evans, D., and J.G. Stockner. 1972. Attached algae on artificial and natural substrates in Lake Winnipeg, Manitoba. J. Fish. Res. Board Can. 29:31-44.

Gaufin, A.R. 1959. Production of bottom fauna in the Provo River, Utah. Iowa St. Coll. J. Sci. 33:395-419.

Geen, G.H., T.G. Northcote, G.F. Hartman, and C.C. Lindsey. 1966. Life histories of two species of catostomid fishes in Sixteen Mile Lake, British Columbia, with special reference to inlet stream spawning. J. Fish. Res. Board Can. 23(11):1761-1788.

Griffiths, W.E. 1973. Preliminary fisheries survey of the Fort McMurray tar sands area. Fish and Wildlife Division, Alberta Dept. of Lands and Forests. 622 pp.

Hansmann, E.W. 1969. The effects of logging on periphyton communities of coastal streams. Ph.D. Thesis. Oregon State University. 120 pp.

Harris, R.H.D. 1962. Growth and reproduction of the longnose sucker, *Catostomus catostomus* (Forster), in Great Slave Lake. J. Fish. Res. Board Can. 19(1):113-126.

Hartland-Rowe, R. 1964. Factors influencing the life-histories of some stream insects in Alberta. Verh. int. Verein. Theor. angew. Limnol. xv:917-925.

Hillard, D.K. 1966. Studies on Chrysophyceae from some ponds and lakes in Alaska. V. Hydrobiol. 28(3-4):553-576.

Hillard, D.K. 1967. Studies on Chrysophyceae from some ponds and lakes in Alaska. VII. Nova Hedwigia XIV, 1:39-60.

Hubbs, C.L., L.C. Hubbs, and R.E. Johnson. 1943. Hybridization in nature between species of catostomid fishes. Contr. Lab. Vertebrate Biol., Univ. Michigan 22:1-76.

Hynes, H.B.N. 1970. The ecology of running waters. Univ. of Toronto Press. 555 pp.

Jenson, S.L. 1966. The mayflies of Idaho. M.S. Thesis. Univ. of Utah, Salt Lake City.

Kennedy, W.A., and W.M. Sprules. 1967. Goldeye in Canada. Fish. Res. Board Can. Bull. 161. 45 pp.

Kooyman, A.H. 1972. Status of goldeye, *Hiodon alosoides*, populations in the Peace-Athabasca Delta. Peace-Athabasca Delta Project: Ecological Investigations. Vol. 2.

Lagler, K.F. 1956. Freshwater fishery biology. Second Edition. Wm. C. Brown Co., Dubuque, Iowa. 421 pp.

Langer, O.E., and M.D. Nassichuk. 1975. Selected biological studies of the Thompson River System. Fish. and Mar. Serv., Tech. Rep. No. POC/T-75-22. 186 pp.

Lloyd, M., and R.J. Ghelardi. 1964. A table for calculating the "equitability" component of species diversity. J. Anim. Ecol. 33:217-225.

Lloyd, M., J.H. Zar, and J.R. Karr. 1968. On the calculation of information--theoretical measures of diversity. Amer. Mid. Nat. 79:257-272.

Macan, T.T. 1957. The life-histories and migrations of the Ephemeroptera in a stony stream. Trans. Soc. Brit. Ent. 12:129-156.

MacArthur, R.H. 1957. On the relative abundance of bird species. Proc. Nat. Acad. Sci., Washington, D.C. 43:293-295.

Margalet, R. 1974. Sampling techniques and methods for estimating quantity and quality of biomass. 2:12 Counting. IN: R.A. Vollenweider (ed.), A manual on methods for measuring primary production in aquatic environments. I.B.P. Handbook 12. Blackwell Scientific Publications, Oxford. 225 pp.

McCart, P., P. Craig, and H. Bain. 1972. Report on fisheries investigations in the Sagavanirktok River and neighboring drainages. Report to Alyeska Pipeline Service Company, Bellevue, Washington. 170 pp.

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

McDonald, D. 1967. Kehiwin Lake. Province of Alberta, Dept. of Lands and Forests. 47 pp.

McKeague, J.A. (Ed.). 1976. Manual of soil sampling and methods of analysis. Prep. by Subcommittee of Can. Soil Survey Committee on Methods of Analysis. Soil Res. Institute.

Needham, J.G., J.R. Traver, and Y. Hsu. 1935. The biology of mayflies. Comstock Publishing Co., Ithaca. 759 pp.

Nordeng, H. 1961. On the biology of char *(Salvelinus alpinus,* L.) in Salangen, North Norway. Nytt. Magasin for Zoologi 10:67-123.

Northcote, T.G., G.L. Enns, and M.H. Anderson. 1975. Periphytic and planktonic algae of the lower Fraser River in relation to water quality conditions. Westwater Research Center, Univ. British Columbia. Tech. Rep. No. 8. 61 pp.

Patrick, R. 1973. Use of algae, especially diatoms, in the assessment of water quality. ASTM STP 528:76-95.

Patrick, R., and C.W. Reimer. 1966. The diatoms of the United States. Monograph 13, Acad. Nat. Sci. Phila. I:1-688.

Patrick, R., and C.W. Reimer. 1975. The diatoms of the United States. Monograph 13, Acad. Nat. Sci. Phila. II:1-213.

Pennak, R.W. 1953. Freshwater invertebrates of the United States. Ronald Press Co., N.Y. 769 pp.

Percival, E., and H. Whitehead. 1929. A quantitative study of some types of streambed. J. Ecol. 17:282-314.

Prescott, G.W. 1962. Algae of the western Great Lakes Area, revised edition. Wm. C. Brown Co. Publishers. 977 pp.

Rawson, D.S., and J.E. Elsey. 1950. Reduction in the longnose sucker population of Pyramid Lake, Alberta, in an attempt to improve angling. Trans. Amer. Fish. Soc. 78(1948):13-31.

Rawson, D.S. 1957. The life history and ecology of the yellow walleye, *Stizostedion vitreum*, in Lac La Ronge, Saskatchewan. Trans. Amer. Fish. Soc. 86(1956):15-37.

Roeder, D.R., G.H. Crum, D.M. Rosenberg, N.B. Snow. 1975. Effects of Norman Wells crude oil on periphyton in selected lakes and rivers in the N.W.T. Fish. and Mar. Serv., Tech. Rep. No. 552. 1975. 31 pp.

Robertson, M.R. 1967. Certain limnological characteristics of the La Biche and Wandering rivers. M.Sc. Thesis, Univ. of Alberta. Edmonton. 74 pp.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. J. Fish. Res. Board Can. Bull. 184. 966 pp.

Saether, O.A. 1969. Some Nearctic Podonominae, Diamesinae, and Orthocladiinae (Diptera:Chironomidae). Fish. Res. Board Can. Bull. 170. 154 pp.

Saether, O.A. 1975. Nearctic and Palaearctic *Heterotrissocladius* (Diptera:Chironomidae). Bull. Fish. Res. Board Can. 193. 67 pp.

Saether, O.A. 1976. Revision of *Hydrobaenus, Trissocladius, Zalutschia, Paratrissolcadius*, and some related genera (Diptera:Chironomidae). Bull. Fish. Res. Board Can. 195. 287 pp.

Saether, O.A. 1977. Taxonomic studies on Chironomidae: *Nanocladius, Pseudochironomus*, and the *Harnischia* complex. Bull. Fish. Res. Board Can. 196. 143 pp.

Shannon, C.E., and W. Weaver. 1949. The mathematical theory of communication. Univ. of Illinois Press, Urbana. 117 pp.

Skuja, H.L. 1948. Taxonomie des Phytoplanktons einiger Seen in Uppland, Schweden, Symb. Bot. Upsal. 9. 399 pp.

Skuja, H.L. 1964. Grundzuge der Algenflora und Algen Vegetation des Fjeldgegenden un Abisko I. Nova Acta Regiae Soc. Sci. Upsal. Ser. IV. 18. 465 pp.

Smith, G.M. 1950. The fresh-water algae of the United States. McGraw-Hill Book Co., Inc., New York. 719 pp.

Sprules, W.M. 1947. An ecological investigation of stream insects in Algonquin Park, Ontario. Univ. Toronto Stud. Biol. Ser. 56:1-81.

Squires, L.E., S.R. Rushforth, and C.J. Endsley. 1973. An ecological survey of the algae of Huntington Canyon, Utah. Brigham Young Univ. Sci. Bull. Biol. Ser. 18(2). 87 pp.

Sreevinasa, M.R., and H.C. Duthie. 1973. Diatom flora of the Grand River, Ontario, Canada. Hydrobiol. 42:161-224.

Stein, J.N., C.S. Jessop, T.R. Porter, and K.T.J. Chang-Kue. 1973. Fish resources of the Mackenzie River Valley. Fisheries Service, Dept. of the Environment, Environmental Social Program, Northern Pipelines. Interim Report II. 260 pp.

Stockner, J.G., and F.A.J. Armstrong. 1971. Periphyton of the Experimental Lake Area, Northwestern Ontario. J. Fish. Res. Board Can. 28(2):215-229.

Strickland, J.D.H., and T.R. Parsons. 1968. A practical handbook of seawater analysis. Fish. Res. Board Can. Bull. No. 167. 311 pp.

Tiffany, L.H., and M.E. Britton. 1952. The algae of Illinois. The University of Chicago Press, Chicago. 407 pp.

Tilden, J. 1910. The Myxophyceae of North America. Minnesota Algae. Vol. 1. Minneapolis. 328 pp.

Tripp, D.B., and P.J. McCart. 1974. Life histories of grayling *(Thymallus arcticus)* and longnose suckers *(Catostomus catostomus)* in the Donnelly River system, N.W.T. IN: P.J. McCart (ed.), Life histories of anadromous and freshwater fish in the western Arctic. Arctic Gas Biological Report Series 20(1). 91 pp.

Turner, W.R. 1968. Preliminary biological survey of Wabasca Lakes Area, 1967. Province of Alberta, Dept. of Lands and Forests. 70 pp.

Ulfstrand, S. 1968. Benthic animal communities in Lapland streams. Oikos Supp. 10. 120 pp.

Usinger, R.L. 1963. Aquatic insects of California. Univ. of Calif. Press. Berkeley and Los Angeles. 507 pp.

Utermöhl, H. 1958. Zur Vervollkommnung der quantitativen Phytoplankton methodik. Mitt. Internat. Verein. Limnol. 9:1-38.

Ward, H.B., and G.C. Whipple. 1959. Freshwater biology. Second Edition. W.T. Edmundson (ed.). John Wiley and Sons, Inc., N.Y. 1248 pp.

Weber, C.L. (ed.). 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. U.S. E.P.A. EPA-670/4-73-001.

Wilhm, J.L. 1970. Range of diversity index in benthic macroinvertebrate populations. J. Wat. Poll. Cont. Fed. 42:R221-R224.

Zelt, K.A. 1970. The mayfly (Ephemeroptera) and stonefly (Plecoptera) fauna of a foothills stream in Alberta with special reference to sampling procedures. Alberta Fish and Wildlife Division. Report 6.

Zoto, G., D.O. Dillon, and E.H. Schlichting. 1973. A rapid method for clearing diatoms for taxonomic and ecological studies. Phycol. 12(1/2):69-70.