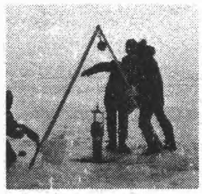
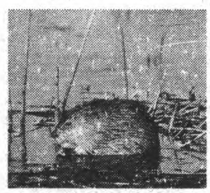
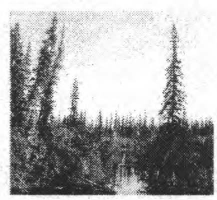
Canada Alberta Northwest Territories

Northern River Basins Study



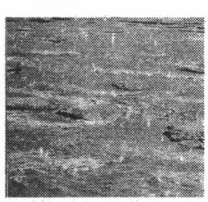



NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 107

INDICATORS OF ECOSYSTEM INTEGRITY: PEACE-ATHABASCA DELTA



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NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 107

INDICATORS OF ECOSYSTEM INTEGRITY: PEACE-ATHABASCA DELTA

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

NORTHERN RIVER BASINS STUDY
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Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

(Dr. Fred J. Wrona, Science Director) — 13 May 96 (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No

(Dr. P. A. Larkin, Ph.D., Chair) — May 24/96 (Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

(Lucille Partington, Co-chair) — 29 May / 96 (Date)

(Robert McLeod, Co-chair) — May 21/96 (Date)

INDICATORS OF ECOSYSTEM INTEGRITY: PEACE-ATHABASCA DELTA

STUDY PERSPECTIVE

> ***Related Study Questions***
>
> *14) What long term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems?*

Indicators of aquatic ecosystem integrity were identified for the Peace-Athabasca Delta to provide the Northern Rivers Basin Study with information on ecological parameters that could be measured during future monitoring programs in the Peace, Athabasca, and Slave river basins. The indicators identified in this report should be measured as part of a long-term monitoring program with an objective to periodically assess the ecological integrity of aquatic ecosystems within the Peace-Athabasca Delta. The ecological integrity of the Delta is threatened by industrial and municipal effluents, climate change, hydroelectric operations and development, atmospheric pollutants, and renewable resource use both within and beyond the Delta.

The indicators were developed from historic information and a 1994 survey of water quality, zooplankton, and benthic invertebrates of Mamawi Lake. Indicator selection was biased toward ecological parameters that are currently being monitored with the addition of others that could be monitored over the long-term at low cost. The recommended indicators include three physical/chemical variables (meterological, water quality, water level) and four structural indicators (clam-shrimp, fish community structure, goldeye, and walleye). Articulation of the indicators (ecological integrity) was biased toward the intent and purpose of the Canada National Parks Act. Eighty percent of the Delta is within Wood Buffalo National Park. In the future, other indicators, particularly those of a functional nature, should be added to this list as additional resources for monitoring are identified and when new information on ecological processes in the Delta become known.

At present, meterological, water quality, water level, and walleye catch data are collected each year by Environment Canada, Alberta Environmental Protection, and Heritage Canada. These specific monitoring and data acquisition programs should be maintained in the future. In agreement with the recommendations in this report, Heritage Canada and/or other federal agencies should initiate a long-term monitoring program to assess the status of clam-shrimp and goldeye populations in the Delta and the fish community structure of the Mamawi-Claire lakes system. These two lakes are the largest lakes within the Peace-Athabasca Delta. Periodically, a full assessment of the ecological integrity of the aquatic environments of the Peace-Athabasca Delta should be completed using the indicators identified in this report and other information that is required.

REPORT SUMMARY

Indicators of aquatic ecosystem integrity were identified for the Peace-Athabasca Delta of northeastern Alberta. Eighty percent of the Peace-Athabasca Delta is within Wood Buffalo National Park. About 10% of the Delta includes Chipewyan Indian Reserve 201 with the remaining land under provincial (Alberta) jurisdiction. The Indicators were developed from historical data and from a 1994 limnological survey of Mamawi and Claire lakes. The principal criteria for selecting Indicators were: relevance to the public, cost of collecting data, and linkages within the food web which includes the people of the Fort Chipewyan area. Articulation of the Indicators was biased toward the intent and purpose of the Canadian National Parks Act. Three physical/chemical and four structural Indicators were identified. Functional Indicators were not proposed, although they need to be identified in the future. The seven Indicators are:

Physical/Chemical Indicators

1. Climate,
2. Water quality (lower Peace and Athabasca rivers),
3. Lake Claire water level,

Structural Indicators

4. Clam-shrimp abundance (Mamawi Lake),
5. Fish community structure (Mamawi and Claire lakes),
6. Goldeye abundance (Mamawi and Claire lakes),
7. Walleye commercial harvest (western Lake Athabasca).

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1.0 INTRODUCTION

The Northern River Basins Study was initiated to determine impacts of industrial developments on the Peace, Athabasca, and Slave rivers, and to develop methods to assess the cumulative impacts of future industrial developments on these basins. The Northern River Basins Study Board developed 16 questions that determined the scope of the scientific program and specifically, question 14 identified the need to implement long-term monitoring of key components of aquatic ecosystems:

"What long-term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems. These programs must ensure that all stakeholders have the opportunity for input."

The purpose of this report is to identify potential ecological indicators that could be used in future monitoring programs assessing the health and integrity of the aquatic environment of the Peace-Athabasca Delta. Our focus is primarily the large persistent delta lakes and channels. We do not consider the terrestrial component of the Peace-Athabasca Delta or the wetland and perched basin habitats, although all are ecologically linked in the delta ecosystem.

1.1 DEFINITIONS

In the context of the Peace-Athabasca Delta we define ecosystem, ecological integrity, and ecosystem indicator as follows:

"An *ecosystem* is an interacting dynamic and complex system of living and non-living components linked by the cycling of materials and the flow of energy."

"*Ecological integrity* is the maintenance of the structures and function of the Peace-Athabasca Delta ecosystem unimpaired by anthropogenic stresses with indigenous plant and animal species persisting at historic population levels and with sustained harvest (but not exploitation) of renewable resources by people." People are both indigenous to and an important ecological link in the Delta ecosystem.

"*Ecosystem indicators* are aspects or components of an ecosystem that are monitored (measured) to assess ecological integrity."

1.2 PEACE-ATHABASCA DELTA

The Peace-Athabasca Delta is one of the largest freshwater deltas in the world (Peace-Athabasca Delta Project 1973). The Athabasca River delta is steadily expanding into Lake Athabasca (Fig. 1); the Peace River delta is much less active, only recharging perched basins and permanent connected lakes during high water and spring flood events. The Peace-Athabasca Delta has four major permanent lakes (Mamawi, Claire, Baril, and Richardson) all with a maximum depth of 3 m or less. The near shore zone and bays of these lakes are characterized by thick growths of submergent and

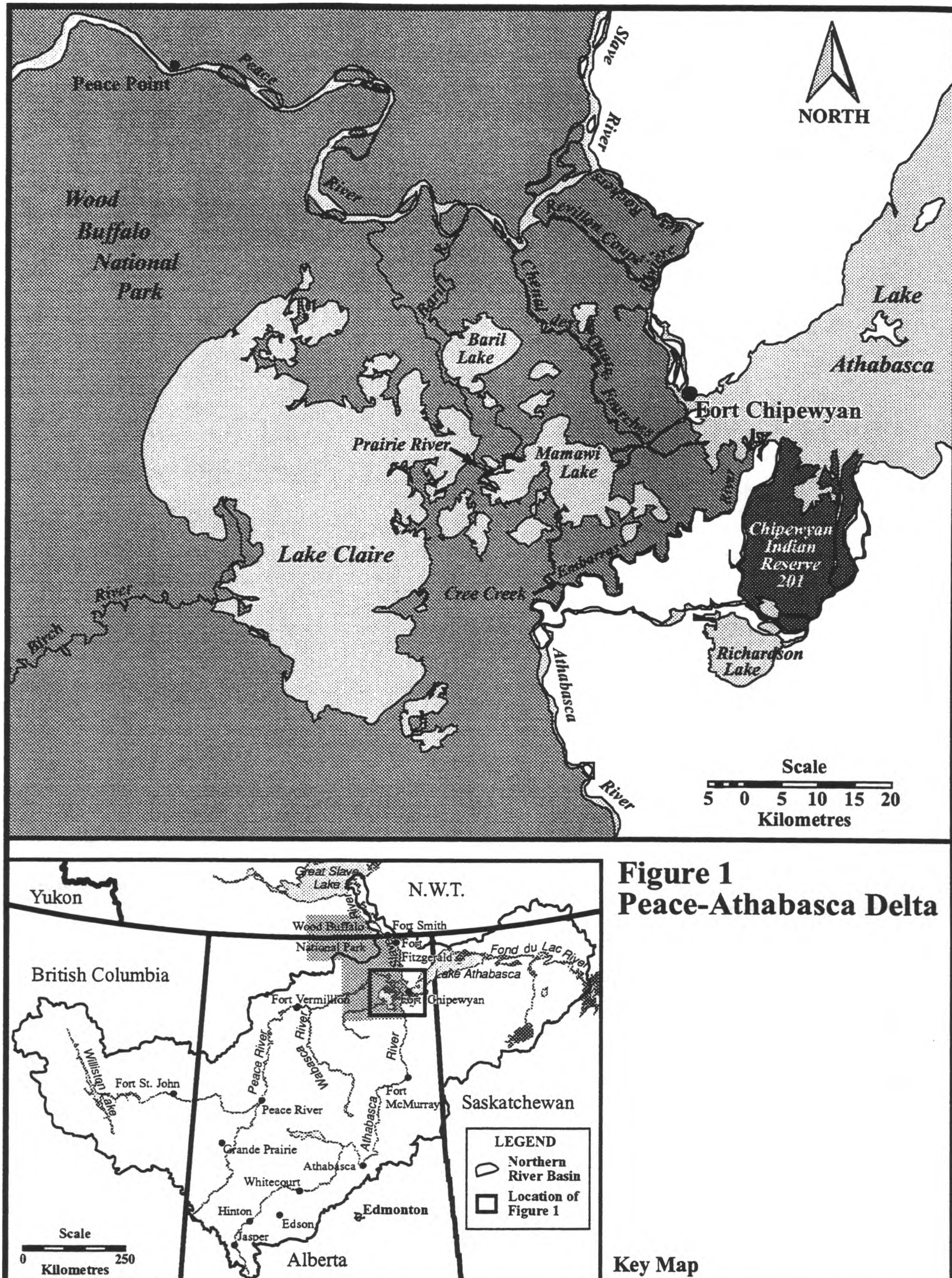


Figure 1
Peace-Athabasca Delta

emergent vegetation. Freeze-up occurs in late October and ice cover lasts for a minimum of 6 months. Ice thickness is more than 1 m, and all delta lakes are devoid of oxygen and fish by late winter.

Eighty percent of the Peace-Athabasca Delta is within Wood Buffalo National Park. About 10% of the Delta is within the Chipewyan Indian Reserve 201 with the remaining land under provincial (Alberta) jurisdiction. The lower 250 km of the Peace River is also within the Park. The centre of the Athabasca, Embarras, Riviere des Rochers, and Slave rivers is the eastern boundary of Wood Buffalo National Park. The Peace-Athabasca Delta is an important regional source of fish, and supports a productive commercial, domestic, and sport fishery. A puzzling characteristic of the Delta is that in permanent channels and lakes east of Mamawi Lake, walleye are the dominant species, while goldeye are the dominant species in Mamawi amd Claire lakes and their associated channels and lakes. The western portion of Lake Athabasca, including the actively expanding portion of the Athabasca delta, supports a commercial fishery with an annual quota for walleye of 45,400 kg. Important spawning habitat for this walleye population includes Richardson Lake, and bays and channels at the outer edge of the Athabasca River delta. Mamawi and Claire lakes are critical spawning and feeding habitat for a population of goldeye that winters in the lower Peace River and migrates into the Delta in spring. The domestic gill-net fishery for walleye, lake whitefish, northern pike, and goldeye occurs throughout the Delta at traditional sites (Flett et al. 1996). Sport fishing for walleye and northern pike occurs primarily in the Athabasca River delta.

2.0 ECOLOGICAL INDICATORS

We propose that identification, selection, and use of ecological indicators is a social, economic, and scientific exercise which "operates" under the following general model (Table 1).

Table 1. Development and use of ecosystem indicators.

	RESPONSIBILITY	EXAMPLES
Objective	Social/economic	Maintain ecological integrity of...
Indicator	Social/scientific	Maintain moose population at $1/km^2$
Measurement	Scientific/technical	Count moose (M), or moose pellets (P), M = a + b(P)
Remediation Adjustment	Senior Management/ Technical	Increase harvest Prescribed burn to increase browse

2.1 ECOSYSTEM OBJECTIVE

We propose that the Objective for the Peace-Athabasca delta ecosystem is:

> *To maintain the ecological integrity of the Peace-Athabasca Delta for future generations.*

The social/economic input to the development of this Objective is through review and approval of this document by the Northern River Basins Study Board. The Board has representation from the public, industry, First Nations, and municipal, provincial, and federal governments. In addition, social input and guidance is obtained through the intent and purpose of the National Parks Act which is, of course, a product of the elected representatives of the people.

2.2 SELECTION OF ECOLOGICAL INDICATORS

A suite of indicators are necessary to assess the effects of potential stresses to an ecosystem, and to assess the key functional linkages between abiotic and biotic components of the ecosystem. Several indicators are more likely to be sensitive to ecosystem dysfunction than a single indicator which may only be responding to natural processes. The significant stresses to the Peace-Athabasca Delta in the future are likely to be: contaminants from municipal and industrial effluents within the Peace and Athabasca river basins, persistent contaminants originating from atmospheric deposition, overexploitation of natural renewable resources, and climate change.

Criteria for selecting indicators have been outlined by Johnson et al. (1993), Stribling (1994), Banff-Bow Valley Study (1995), and Cash et al. (1996). The selection of ecological indicators should consider, but not be restricted to, the following criteria:

1. relevance to the public,
2. cost of measurement,
3. linkages to other components of the ecosystem such as an important link within a known food web,
4. sensitivity to stresses such as contaminants, changes in hydrologic regime, exotic species introductions, climate change, or overexploitation,
5. life-cycles for biological indicators should be completed entirely within the ecosystem. For example, resident fish species would provide a better ecological indicator than a species of migratory bird that stages in the Peace-Athabasca Delta but breeds in the arctic and migrates to South America for the winter,
6. for biological indicators, life-cycles and trophic positions should be known,
7. for abiotic indicators, historic information such as flow, depth, and temperature should be available or deemed important to understand.

3.0 ECOSYSTEM ISSUES AND INDICATORS : PEACE ATHABASCA DELTA

The ecosystem indicators presented in this report were developed from historical information on the aquatic chemical and biological characteristics of the Peace-Athabasca Delta, the climate of the region, and data collected during a 1994 survey of the Mamawi-Claire lakes system. The 1994 survey included an assessment of water quality, zooplankton, and the benthic invertebrates of Mamawi Lake (Appendices B to E), and an assessment of fish community composition and abundance of goldeye in both Mamawi Lake and Lake Claire combined.

Seven key indicators are proposed for the aquatic environment on the basis that the "integrity" of the Delta ecosystem would be altered if any one where to be impacted by anthropogenic stresses. Remedial action would then be required by governments and the public to restore the ecological integrity of the Peace-Athabasca Delta. Three physical/chemical and four structural indicators of ecosystem integrity are identified. Functional indicators were not proposed, although there are functional linkages between and among the indicators. The seven Indicators are:

Physical/Chemical Indicators

1. Climate,
2. Water quality,
3. Lake Claire water levels,

Structural Indicators

4. Clam-shrimp abundance,
5. Fish community structure (Mamawi and Claire lakes),
6. Goldeye abundance, and
7. Walleye commercial harvest.

Ecosystem science is not sufficiently advanced to predict with certainty which aquatic species of the peace-Athabasca Delta will respond, or how they will respond, to the variety of potential disturbances and contaminants that might originate from within and beyond the basins. Therefore, the management of the Delta ecosystem should be dynamic and flexible, and not tied specifically to the set of indicators proposed herein. In the future, new and better indicators should be added to the above list. Finally, ecosystems and delta ecosystems in particular are evolving physically and biologically in time and space. Indicators need to be developed that record and account for the natural evolution of the Delta. These indicators must be able to differentiate between anthropogenic stress and natural evolution.

3.1 ECOSYSTEM ISSUE 1 - CLIMATE

The climate of the Fort Chipewyan and surrounding area is not affected by global or region atmospheric pollutants.

3.1.2 Indicator

The climate of Fort Chipewyan and surrounding area follows recognized annual and longer-term patterns and their variability. This variability is not measurably affected by regional or global input of human generated substances such as green-house gases (carbon dioxide, water vapour, methane) or industrial smoke.

3.1.3 Indicator Measures

Mean daily temperature, hourly wind speed and direction, precipitation, and daily number of hours of bright sunshine are measured at Fort Chipewyan (Station 3072658).

3.1.4 Background

A variety of weather parameters have been recorded at Fort Chipewyan beginning in 1883. However, these observations are not continuous and they have been taken at different locations in the Fort Chipewyan area. The record of continuous temperature and precipitation observations extends from 1963 to the present. Table 2 shows the mean monthly temperatures for Fort Chipewyan for the period 1883 to 1992. The present weather observing program needs to be expanded to include 24-hour wind speed and direction, and duration of bright sunshine. Any statistically measured change in climate at Fort Chipewyan would constitute a compromise of ecological integrity of the Peace-Athabasca Delta.

Table 2. Mean monthly temperature at Fort Chipewyan, Alberta - Station Number 3072657

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1883	M	M	M	M	M	M	M	M	M	N	-15.8	-23.5
1884	-24.1N	-24.2	-15.7	-4.7	6.4	12.3	16.0N	13.5N	7.5	-3.1	-10.4	-8.5
1885	-28.8	-21.6N	-14.0N	-1.7	5.6N	14.7	15.8N	14.3N	8.2	-0.4	-4.3	-17.1
1886	-32.6	-26.4	-17.3	-2.9	3.9	16.2	16.6	13.4	4.6N	1.3	-11.8	-21.0
1887	-30.4	-26.7	-18.8N	-3.7N	6.2	M	M	M	M	N	-12.2	-25.5
1888	M	M	-20.0	-8.6	3.9	8.6N	N	12.3	10.9	3.1	-10.1	-14.0N
1889	-17.2	-19.3	-8.4	0.8	6.6	12.9	N	16.0N	6.1	1.8	-7.6	-22.8
1890	-26.9	-27.0	-16.8	-8.1	2.4	10.2	15.3	13.6	6.9	2.3	-8.2	-17.9
1891	-22.3	-27.0	-16.3	0.4	3.5	N	16.8	N	M	M	M	M
1892	M	M	M	M	M	M	M	M	M	M	M	M
1893	N	-22.2N	N	-8.9N	N	N	17.8N	15.4	8.0	-0.8N	N	-27.7N
1894	-29.7	-21.1	-14.8	-4.6	6.8	N	17.4N	16.6N	N	1.7N	-12.6	N
1895	-26.2N	-20.4	M	M	N	14.4N	N	12.7	6.6N	-0.3N	-13.4	-19.3
1896	-29.1	-19.2	-15.7	-5.5	6.0	12.7	16.2	14.2	N	N	-15.1	-16.1
1897	-26.4N	-22.1N	-17.7	-1.8	6.5N	13.4	15.8N	15.7	N	-2.1N	-14.3	-17.3
1898	-19.3	-23.3	-14.1	1.6	10.6N	N	16.3N	14.7	N	-3.5	-15.9	-17.1
1899	-25.1N	-28.1	-21.2N	-5.6	N	N	M	M	M	N	-5.3	-18.1
1900	-24.5	-26.1	-15.4	4.3N	11.1N	14.7	15.9	14.5	N	2.1	-12.6	-15.3N
1901	-23.2	-19.3	-11.4	-1.0	8.4	12.1	15.8	15.3	8.6	3.6	-13.6	-16.9
1902	-20.0	-17.4	-15.7	-4.1	7.0	9.6	17.1	14.6	6.7	3.0	-13.8	-19.8
1903	-22.5	-17.8	-14.5	-4.5	4.0	13.5	17.0	15.4	6.2	0.4	-8.7	-17.3
1904	-24.4	-29.0	-16.1	2.7	6.8	12.8	15.4	13.6	5.5	2.8	-4.5	-19.6
1905	-22.9	-18.0	-9.6	0.8	10.3	M	M	M	M	M	M	M
1906	M	-24.3	-14.2	1.7	6.5N	15.1	N	11.7	N	N	-11.1	-25.5
1907	-31.4	-24.6	-17.6	-12.1	-2.5	8.9N	11.2N	10.1N	3.0	0.1	-11.0	N
1908	N	-20.5	-24.6	-7.8	6.5N	13.2	16.3	14.3	9.7	2.4	N	-19.9
1909	N	N	N	-9.8	N	15.1	17.3	13.4	9.5N	0.9N	N	-17.8N
1910	N	-22.7	-9.2	-0.5	5.3	14.2	17.0	12.6	7.2	2.2N	-11.0	-18.8
1911	-34.0	-19.0	-11.8	-5.4	7.7	13.5	15.5	12.3	7.1	N	-11.5	-13.8N
1912	N	-19.5N	N	-1.8	N	15.5	N	M	M	M	M	M
1913	M	M	M	M	M	M	M	M	M	M	M	M
1914	M	M	M	M	M	M	16.6N	15.2	M	4.2	-7.9	-22.3
1915	-20.7N	-15.3	N	6.6	9.0N	10.8	15.7	18.1	6.5	0.5	-10.3	-15.0N
1916	-29.0N	N	-16.5N	0.5	6.9	13.7N	16.0N	M	9.4	0.8	-7.7	-23.6
1917	-29.1	-25.4	-12.7	-3.2	6.9	11.5	17.3	13.9	10.0	-0.8	-2.1	-29.5
1918	-26.3	-25.4	-15.9	-3.1	2.6	10.8	14.1	14.0	8.9N	-0.1	-8.8	-15.8
1919	-17.8	-22.3	-19.6	2.1	5.9	12.5	14.6	16.5	11.0	-5.6	-14.2	-19.7
1920	-23.9	-12.6	-14.3	-5.9	6.5	11.3	18.4	15.6	8.8	1.8	-6.9	-19.6
1921	-22.1	-18.1	-19.2	0.0	7.5	15.4	16.6	13.1	8.2	3.2	-13.8	-16.0
1922	-20.6	-24.1	-16.2	-2.8	7.7	12.6	16.8	15.4	8.2	0.9	-7.8	-23.3
1923	-24.5	-22.0	-20.3	-5.3	3.8	15.1	15.9	12.5	10.0	4.7	-6.8	-21.3
1924	-26.4	-15.7	-9.6	-7.4	6.6	11.8	16.5	13.8	8.4	3.2	-11.0	-23.2
1925	-28.0	-26.3	-15.5	1.0	7.1N	12.6	18.2	N	6.9	-2.8	-12.2	-16.0
1926	-19.2	-16.3	-10.9	-1.5	8.2	N	17.7	14.2	6.4	-0.9	-11.3	-18.2
1927	-21.0	-20.6	-9.9	-2.3	6.7	13.1	18.1	N	9.0	3.2	-17.1	-24.6
1928	-16.9	-12.8	-9.7	-7.8	7.1	14.5	18.2	12.8	9.4	2.2	-4.8	-12.0
1929	-27.6	-22.2	-14.8	-3.9	5.8	11.7	16.6	15.9	7.8	6.0	-8.0	-21.1
1930	-23.4	-16.9	-9.2	2.4	6.1	14.1	18.1	16.5	7.9	-0.4	-10.0	-11.1
1931	-18.3	-9.8	-15.8	-0.7	M	12.7	17.3	17.4	10.4	4.1	-7.9	-16.3
1932	-22.6	-23.6	-20.8	-0.1	9.2	14.0	18.9	18.5	8.5	-1.2	-15.7	-20.8
1933	-28.6	-27.0	-14.3	-3.8	8.7	13.6	16.4	16.3	8.1	-1.6	-13.6	-32.0
1934	-22.8	-16.3	-15.6	-0.3	8.3	13.1	15.3	12.7	5.1	0.7	-9.6	-20.0
1935	-29.1	-12.1	-17.7	-6.1	9.1	13.5	17.9	13.6	8.3	-0.9	-15.1	-16.4
1936	-30.3	-32.0	-12.8	-6.2	8.6	13.1	19.3	16.2	7.4	-1.4	-5.1	-19.9
1937	-27.5	-22.1	-11.0	2.4	10.4	15.2	18.7	N	M	M	M	M
1938	N	-23.3	-10.9	-3.3	7.7	15.1	17.6	13.5	13.4	4.1	-9.6	-15.2
1939	-21.2	-30.0	-16.8	-1.3	8.1	12.6	17.1	16.2	7.1	-2.3	-6.1	-10.9

M = no data for this month, N = incomplete or based on partial data

Table 2. continued

1940	-19.7	-18.3	-11.3	0.7	8.1N	M	13.4	13.8N	11.9N	M	M	M
1941	M	M	M	M	M	M	M	M	M	M	M	M
1942	M	M	M	M	M	M	M	M	M	M	M	M
1943	M	M	M	M	M	M	M	M	M	M	M	M
1944	M	M	M	M	M	M	M	M	M	M	M	M
1945	M	M	M	M	M	M	M	M	M	M	M	M
1946	M	M	M	M	M	M	M	M	M	M	M	M
1947	M	M	M	M	M	M	M	M	M	M	M	M
1948	M	M	M	M	M	M	M	M	M	M	M	M
1949	M	M	M	M	M	M	M	M	M	M	M	M
1950	M	M	M	M	M	M	M	M	M	M	M	M
1951	M	M	M	M	M	M	M	M	M	M	M	M
1952	M	M	M	M	M	M	M	M	M	M	M	M
1953	M	M	M	M	M	M	M	M	M	M	M	M
1954	M	M	M	M	M	M	M	M	M	M	M	M
1955	M	M	M	M	M	M	M	M	M	M	M	M
1956	M	M	M	M	M	M	M	M	M	M	M	M
1957	M	M	M	M	M	M	M	M	M	M	M	M
1958	M	M	M	M	M	M	M	M	M	M	M	M
1959	M	M	M	M	M	M	M	M	M	M	M	M
1960	M	M	M	M	M	M	M	M	M	M	M	M
1961	M	M	M	M	M	M	M	M	M	M	M	M
1962	M	M	M	M	M	M	M	M	M	3.3N	-9.0	-18.3
1963	-27.6	-20.6	-14.7	-0.7	6.7	15.6	18.6	17.1	10.3	6.4	-11.5	-18.2
1964	-21.1	-14.2	-20.9	-2.7	7.8	14.9	18.4	15.2	7.7	3.7	-9.0	-23.3
1965	-26.0	-27.5	-13.9	0.4	7.9	13.2	17.5	15.0	4.4	2.9	-12.3	-16.6
1966	-31.3	-19.2	-10.9	-5.0	8.4	14.1	16.3	15.4	10.8	0.2	-17.9	-16.8
1967	-23.2	-22.0	-18.8	-4.7	5.8	12.6	16.6	16.4	12.1	2.1	M	M
1968	-26.4	-18.0	-8.4	-1.6	6.8	12.7	13.8	12.7	7.7	1.9	-8.8	-23.4
1969	-32.2	-17.5	-12.7	1.7	6.0	10.6	15.9	15.5	7.7	-1.2	-10.6	-11.9
1970	-24.9	-20.7	-14.0	0.0	7.7	15.8	16.5	15.0	7.5	0.8	-12.7	-23.1
1971	-28.6	-18.6	-13.3	0.9	10.6	15.2	15.8	16.4	8.5	2.5	-11.2	-24.9
1972	-29.2	-26.2	-11.4	-4.7	9.6	15.3	15.1	15.8	3.4	-1.7	-10.5	-23.5
1973	-19.8	-21.1	-8.1	0.2	12.7	14.9	17.3	15.0	9.0	2.2	-15.0	-22.2
1974	-29.4	-20.6	-18.4	-0.8	7.1	14.1	16.0	12.9	5.3	0.1	-6.2	-13.1
1975	-27.0	-20.9	-14.8	-0.2	8.1	14.7	18.1	13.8	9.7	1.3	-13.1	-20.8
1976	-22.8	-22.0	-15.1	4.6	10.2	14.2	16.8	16.3	10.2	-0.3	-8.6	-23.0
1977	-23.0	-10.5	-9.3	1.9	10.4	14.0	14.6	10.8	9.6	2.9	-11.0	-24.9
1978	-23.0	-16.3	-12.7	-1.4	7.3	13.2	14.2	13.1	8.5	2.8	-12.0	-22.6
1979	-23.1	-30.7	-14.8	-4.9	5.9	13.5	18.2	13.2	9.4	N	N	-13.9
1980	-23.0N	-16.2	-12.5	6.6	9.7	16.2	17.2	15.0	7.3	3.9	-7.4	M
1981	M	-16.3	-7.9	-3.8	9.9	13.5	17.2	18.7	10.1	-0.7	-5.5	-19.5
1982	-34.5	-22.4	-16.0	-3.2	7.1	13.4	16.7	12.2	9.4	2.6	-16.3	-20.5
1983	-21.6	-20.6	-11.7	-0.5	3.7	13.4	17.3	16.5	7.2	1.9	-5.4	-24.7
1984	-22.9	-13.1	-10.3	3.8	7.8	14.1	17.7	17.4	6.9	-0.3	-14.7	-26.3
1985	-19.0	-25.6	-9.0	0.2	9.4	13.8	15.0	13.2	6.6	-0.9	-18.2	-17.5
1986	-18.5	-19.3	-10.1	-1.5	9.7	12.8	15.7	14.6	8.7	1.6	-16.1	-12.5
1987	-14.3	-12.7	-12.4	2.4	9.8	15.0	16.7	12.4	11.4	2.0	-6.5	-13.1
1988	-23.4	-21.3	-9.4	-1.4	6.0	15.3	16.3	15.7	9.2	1.2	-11.6	-18.5
1989	-22.3	-18.0	-18.4	-2.7	7.9	14.3	18.1	16.8	8.2	1.4	-16.4	-22.3
1990	-23.0	-23.6	-8.5	-1.0	8.4	14.9	17.2	14.9	9.2	-1.8	-17.4	-25.3
1991	-22.7	-16.2	-13.2	1.4	10.7	15.0	17.2	18.5	8.4	-4.1	-13.0	-19.0
1992	-18.4	-18.3	-8.4	-0.2	8.0	13.6	15.9	14.1	5.8	1.2	-5.2	-20.9N
1993	M	M	M	M	M	M	M	M	M	M	M	M
Historical Monthly mean	-15.0	-14.4	-9.4	-1.3	4.5	8.7	10.2	9.3	4.9	0.6	-7.5	-12.5

M = no data for this month, N = incomplete or based on partial data

3.2 ECOSYSTEM ISSUE 2 - WATER QUALITY

Water quality is maintained to support indigenous flora and fauna, and consumptive uses by people. Surface water from lakes and rivers in the Delta is used for drinking water.

3.2.1 Indicator

Quality of water flowing into the Peace-Athabasca Delta from the Peace and Athabasca rivers is free of contaminants and toxic substances, and levels of nutrients, major ions, and metals are within natural ranges and limits. In not more than one in ten samples, total dissolved phosphorus should not exceed 0.4 mg/L, dissolved sulphate (SO_4) 39 mg/L, and dissolved oxygen not less than 8.0 mg/L. Total dissolved solids (TDS) should not exceed 148 and 272 mg/L for the Athabasca and Peace rivers, respectively, also in not more than 1 in 10 samples.

3.2.2 Indicator Measures

Water quality is assessed each month on the Athabasca River above Embarras Portage (Station Number 00AL07DD0001) and on the Peace River at Peace Point (Station Number 00AL07KC0001).

3.2.3 Background

Water quality has been monitored for the Athabasca River above Embarras Portage and for the Peace River at Peace Point from August 1989 to the present. Water quality data summaries for these sites are presented in Tables 3 and 4, respectively. The 10th (oxygen) or 90th percentiles (sulphate, total dissolved solids, and total dissolved phosphorus) from the data summaries were used as the parameter specific Indicators identified above. The concentration of specific parameters that are identified in this Ecosystem Indicator can be altered by municipal and industrial (pulp mill) effluents or land-use practices (agriculture and forestry). The water quality Indicators were selected to assess impact, in the future, of municipal and industrial effluents on the Delta. Seasonal specific water quality Indicators should be developed in the future. Repeated and consistent statistically demonstrated increases in the specific and other water quality parameters (decrease for oxygen) would constitute a compromise of ecosystem integrity. Low levels of contaminants from pulp mills are present in fish from both the lower Peace and Athabasca rivers (Pastershank and Muir 1995, Muir and Pastershank 1996) suggesting that this Ecosystem Indicator (2) is currently being compromised.

Table 3. Water Quality of the Athabasca River above Embarras Portage (00AL07DD0001) (August 1989 to September 1995)

Parameter	#	Minimum	Maximum	Mean	Std dev	10th Percentile	Median	90th Percentile
TDS**	54.	114.	305.	193.8	59.5	129.	177.	272.
Colour-T	58.	7.5	105.	35.22	22.69	10.	25.	65.
Cond.	54.	213.	550.	352.5	105.3	229.	328.5	497.
Temp(F)	58.	0.	23.5	8.28	7.78	0.	8.	20.
Turb.	58.	2.8	452.	59.51	103.86	3.9	14.05	200.
Li-tot	15.	0.0107	0.0245	0.01664	0.00483	0.0115	0.0156	0.0228
Be-tot	15.	L0.05	0.32	*0.079	*0.089	L0.05	L0.05	*0.22
B-diss	53.	L0.01	0.232	*0.047	*0.053	*0.013	*0.028	*0.139
TOC**	56.	5.15	29.5	10.743	5.755	6.29	8.49	20.9
DOC	57.	4.11	16.3	8.35	2.948	5.16	7.1	12.6
HCO3**	54.	97.9	199.	146.7	31.44	109.	136.	188.
Free CO2**	53.	0.05	115.06	5.816	17.401	0.44	1.45	8.99
POC	56.	0.202	16.9	2.4063	3.5856	0.244	0.9125	6.8
NO3+NO2	57.	L0.002	0.292	*0.0763	*0.079	L0.01	*0.052	*0.201
NH3-tot	57.	L0.005	0.63	*0.0547	*0.0869	L0.005	*0.026	*0.109
NH3(un-ion)**	50.	0.	0.	0.	0.	0.	0.	0.
TN**	56.	0.148	1.7	0.4755	0.3317	0.214	0.3625	1.
DN	57.	0.058	0.632	0.2789	0.1376	0.109	0.277	0.491
PN	56.	0.019	1.34	0.1976	0.2747	0.026	0.1005	0.503
DO	51.	7.2	15.37	10.15	1.89	8.	10.47	12.73
OH**	53.	0.	0.	0.	0.	0.	0.	0.
F-diss	54.	0.08	0.15	0.113	0.018	0.09	0.11	0.14
Alk-tot	54.	80.3	163.1	120.36	25.81	89.1	111.5	154.
Alk-p	54.	0.	0.	0.	0.	0.	0.	0.
pH	54.	7.17	8.17	7.762	0.206	7.46	7.775	7.99
NFR	58.	1.5	774.	106.58	187.16	2.4	27.2	346.
FNFR	58.	L1.	716.	*97.9	*173.6	*1.6	*24.9	*316.
Hard-tot**	54.	88.7	182.	131.64	28.26	97.3	121.5	168.
Hard-nonCO3	54.	1.3	27.	11.28	5.22	4.9	11.	17.
Na-diss	54.	6.29	45.1	21.363	11.506	9.35	17.7	36.2
%Na**	54.	11.7	38.6	24.14	6.77	16.	23.65	32.7
Mg-diss	54.	6.56	14.	9.86	2.335	7.01	9.37	12.8
Al-tot	17.	0.037	4.67	1.0085	1.3562	0.041	0.488	3.54
SiO2	54.	L0.2	9.8	*6.35	*2.5	*3.51	*5.92	*9.44
P-tot diss	8.	0.011	0.02	0.0149	0.0029		0.0145	
P-tot	58.	0.014	0.6	0.1009	0.1291	0.025	0.0425	0.32
P-diss	49.	0.004	0.031	0.0144	0.006	0.006	0.014	0.024
P-part**	57.	0.005	0.589	0.0878	0.1303	0.009	0.033	0.305
SO4-diss	54.	7.1	50.9	26.08	9.69	14.4	25.3	38.9
Cl-diss	54.	3.3	53.7	20.23	13.36	5.9	16.7	37.
K-diss	54.	0.66	2.54	1.221	0.354	0.8	1.22	1.6
Ca-diss	54.	24.7	49.8	36.45	7.57	27.4	33.5	46.2
V-tot	56.	L0.0005	0.0136	*0.00201	*0.00271	L0.0005	*0.0009	*0.0061
Cr-tot	17.	0.0002	0.0062	0.00151	0.00182	0.0002	0.0006	0.0051
Mn-tot	15.	0.0222	0.316	0.08135	0.08084	0.0253	0.0447	0.177
Mn-ext	38.	0.024	0.523	0.0805	0.1002	0.028	0.043	0.183
Fe-tot	15.	0.369	10.5	2.1012	2.7713	0.41	0.735	5.84
Fe-ext	38.	0.394	11.5	1.416	2.3396	0.411	0.5745	3.54
Co-tot	56.	*0.0001	0.0069	*0.001	*0.00137	L0.0005	*0.00028	*0.0024
Ni-tot	56.	0.0009	0.0274	0.00407	0.00531	0.0011	0.0018	0.0101
Cu-tot	56.	0.0006	0.0188	0.00308	0.00363	0.0009	0.00145	0.0057
Zn-tot	56.	0.0007	0.0459	0.00787	0.00869	0.0021	0.00425	0.0169
As-diss	55.	0.0001	0.0007	0.00031	0.00012	0.0002	0.0003	0.0005
Se-diss	55.	L0.0001	0.0003	*0.00016	*0.00007	*0.0001	*0.0002	*0.0002
Sr-tot	15.	0.161	0.33	0.2418	0.0517	0.167	0.227	0.312
Mo-tot	15.	L0.0001	0.0014	*0.00073	*0.00034	*0.0002	*0.0007	*0.0011
Cd-tot	56.	L0.0001	0.001	*0.00015	*0.00016	L0.0001	*0.0001	*0.0003
Ba-tot	56.	L0.08	0.2	*0.075	*0.039	L0.08	*0.065	*0.128
Pb-tot	56.	L0.0002	0.0077	*0.00141	*0.0018	L0.0002	*0.00075	*0.0039

*** In all calculations, values of *less than detection limit* have been interpreted as *detection limit/2*.**

**** Calculated parameter**

Table 4. Water Quality of the Peace River at Peace Point (00AL07KC0001) (August 1989 to August 1995)

Parameter	#	Minimum	Maximum	Mean	Std dev	10th Percentile	Median	90th Percentile
TDS**	57.	115.	158.	131.1	10.8	118.	131.	148.
Colour-T	59.	L5.	130.	*30.3	*29.4	*5.	*25.	*90.
Cond.	57.	209.	295.	239.6	18.1	217.	238.	266.
Temp(F)	60.	0.	23.	7.4	8.	0.	2.2	19.
Turb.	59.	3.5	1350.	142.35	245.74	5.7	29.	490.
Li-tot	19.	0.0032	0.0245	0.00892	0.00629	0.0033	0.0066	0.0196
Be-tot	19.	L0.05	0.54	*0.135	*0.158	L0.05	L0.05	*0.41
B-diss	56.	*0.004	4.	*0.094	*0.5327	L0.01	*0.01	*0.101
TOC**	59.	3.14	35.7	9.201	7.288	3.49	6.57	23.1
DOC	59.	2.87	14.3	6.045	3.178	3.17	5.16	12.4
HCO3**	57.	101.	138.	117.7	8.6	107.	116.	129.
Free CO2**	57.	0.12	10.81	2.369	2.371	0.66	1.53	6.27
POC	59.	0.123	25.6	3.1557	4.9141	0.183	0.903	10.5
NO3+NO2	59.	L0.002	0.394	*0.0685	*0.0743	L0.01	*0.056	*0.145
NH3-tot	60.	L0.005	0.695	*0.0289	*0.0888	*0.005	*0.0125	*0.04
NH3(un-ion)**	54.	0.	0.01	0.	0.001	0.	0.	0.
TN**	59.	0.12	2.33	0.487	0.479	0.157	0.227	1.46
DN	59.	0.075	0.75	0.1942	0.123	0.1	0.156	0.44
PN	59.	L0.01	2.1	*0.293	*0.423	*0.02	*0.092	*1.03
DO	54.	7.6	17.7	11.21	2.18	8.21	11.72	13.37
OH**	57.	0.	0.	0.	0.	0.	0.	0.
F-diss	57.	0.04	0.25	0.077	0.031	0.05	0.07	0.11
Alk-tot	57.	83.2	113.	96.61	6.93	87.9	95.4	106.
Alk-p	57.	0.	0.	0.	0.	0.	0.	0.
pH	57.	7.2	8.07	7.79	0.18	7.58	7.82	8.01
NFR	59.	2.	1556.	160.7	278.3	4.4	40.4	576.
FNFR	58.	L1.	1432.	*149.9	*259.7	*3.8	*33.6	*540.
Hard-tot**	57.	98.8	131.	113.02	7.55	103.	112.	126.
Hard-nonCO3	57.	6.7	31.1	16.42	5.62	10.	16.	24.4
Na-diss	57.	2.77	7.91	4.47	1.197	3.02	4.35	6.27
%Na**	57.	5.3	13.	7.76	1.65	5.9	7.5	10.1
Mg-diss	57.	6.34	8.84	7.465	0.631	6.72	7.41	8.51
Al-tot	20.	0.09	7.89	1.749	2.148	0.099	0.548	4.66
SiO2	57.	0.54	4.81	3.907	0.669	3.09	3.95	4.56
P-tot diss	7.	0.004	0.013	0.0076	0.0037		0.006	
P-tot	61.	0.007	1.23	0.1421	0.218	0.012	0.045	0.456
P-diss	52.	L0.002	0.039	*0.0107	*0.0094	*0.002	*0.0085	*0.025
P-part**	58.	0.001	1.22	0.1387	0.2193	0.008	0.0385	0.481
SO4-diss	57.	13.9	34.7	20.82	5.63	15.2	19.	30.4
Cl-diss	57.	1.4	15.7	2.48	1.86	1.7	2.1	3.2
K-diss	57.	0.47	13.8	1.026	1.777	0.51	0.63	1.3
Ca-diss	57.	26.7	38.3	32.95	2.18	30.5	32.9	36.2
V-tot	58.	L0.0005	0.0218	*0.00332	*0.0048	L0.0005	*0.0011	*0.0104
Cr-tot	20.	L0.0002	0.0127	*0.00275	*0.00331	*0.0003	*0.0009	*0.0069
Mn-tot	19.	0.0068	0.307	0.06943	0.08871	0.0073	0.0283	0.249
Mn-ext	38.	0.004	0.587	0.0677	0.114	0.006	0.032	0.243
Fe-tot	19.	0.23	20.4	3.935	5.468	0.257	0.903	13.7
Fe-ext	38.	0.121	19.1	2.0033	3.6693	0.157	0.8275	3.61
Co-tot	58.	*0.0001	0.0112	*0.00154	*0.0021	*0.0002	*0.00065	*0.0042
Ni-tot	58.	L0.0005	0.0354	*0.00527	*0.00632	*0.0009	*0.00295	*0.014
Cu-tot	58.	0.0011	0.0318	0.00511	0.00594	0.0012	0.00255	0.0143
Zn-tot	58.	0.0009	0.1006	0.01535	0.01987	0.002	0.0063	0.0443
As-diss	55.	L0.0001	0.0012	*0.00034	*0.00021	*0.0002	*0.0003	*0.0006
Se-diss	55.	L0.0001	0.0007	*0.00032	*0.00011	*0.0002	*0.0003	*0.0004
Sr-tot	19.	0.122	0.201	0.1428	0.0184	0.124	0.143	0.163
Mo-tot	19.	L0.0001	0.0015	*0.00074	*0.00033	L0.0001	*0.0007	*0.0012
Cd-tot	58.	L0.0001	0.0027	*0.0003	*0.00044	L0.0001	*0.00015	*0.0008
Ba-tot	58.	L0.08	0.369	*0.097	*0.073	L0.08	*0.078	*0.2
Pb-tot	58.	L0.0002	0.0136	*0.00259	*0.00314	*0.0003	*0.0014	*0.0065

*** In all calculations, values of *less than detection limit* have been interpreted as *detection limit/2***

**** Calculated parameter**

3.3 ECOSYSTEM ISSUE 3 - WATER LEVEL

Water levels are maintained in the Peace-Athabasca Delta to provide habitat for aquatic life and to support region boat and barge transportation.

3.3.1 Indicator

Water levels for Lake Claire, the largest lake in the Peace-Athabasca Delta, follow annual and long-term natural patterns and elevations unaffected by flow regulation on the Peace or other rivers; or natural levels are maintained by structures.

3.3.2 Indicator Measure

Water level is measured each day for Lake Claire at the Prairie River outlet to Mamawi Lake throughout the year (Station Number 07KF002).

3.3.3. Background

Water levels and/or discharge has been measured at four sites (Peace Point on the Peace River, Lake Athabasca, the Athabasca River below Fort McMurray, and the Slave River at Fitzgerald) from the 1960s to the present. Seven other hydrometric stations were established within the Peace-Athabasca Delta in the early 1970s and have been in operation since that time. Hydrometric data have also been collected at regular intervals at the Mamawi Creek channel into Mamawi Lake beginning in 1982 when this channel first developed (Peace-Athabasca Delta Implementation Committee 1987). The hydrometric site at the outlet of Lake Claire has been in operation since 1970. Water levels in Lake Claire are directly related to complex relationships among water levels (stage) and discharge from the Peace River, Lake Athabasca, the Birch River, and the Athabasca River including the Mamawi Creek link. These relationships are well understood (Peace-Athabasca Delta Project Group 1973, Peace-Athabasca Delta Implementation Committee 1987). Water levels at Lake Claire differ from those in Mamawi Lake by no more than 30 cm.

From 1970 to 1994, water level for Lake Claire has ranged from 208.04 to 210.51 m above sea level. The mean monthly minimum water level occurs in early winter (208.88 m asl in January) and the mean monthly maximum water level in August (209.36 m asl, Fig. 2). These long-term and annual changes in water level are remarkable given that the mean maximum depth for Mamawi Lake and Lake Claire is about 1.5 and 3 m, respectively.

At present, water levels in the Delta are altered by regulation of the Peace River in British Columbia at the W.A.C. Bennett Dam, but these altered levels have been partly restored to the natural condition by weirs on Riviere des Rochers and Revillon Coupe (Aitken and Sapach 1994). Water levels in Lake Claire are similar to the natural regime from September to May, but lower than the natural regime by about 0.2m from June to August (Fig. 3). Water levels in Mamawi Lake are higher than natural conditions from September to May by up to 0.3 m, and are lower from June to August. The Bennett Dam has also reduced the probability of flooding in spring from ice-jam formation in the lower Peace and Slave rivers. Thus, the requirements of Ecosystem Indicator 3 are not currently being met, ecosystem integrity is being compromised, and additional water regulation or manipulation is required.

Annual variation in water level for Lake Claire would probably affect distribution and abundance of submergent and emergent aquatic plants along the near shore zone and within bays of the lakes. Annual variation in water levels might also determine abundance of some freshwater invertebrate species which are in turn important foods of fish such as goldeye (Kennedy and Sprules 1967, Donald and Kooyman 1977). For example, Daphnia magna, a freshwater crustacean that is usually associated with shallow ephemeral ponds, was present in Mamawi and Claire lakes in summer 1971 when water levels were low (Gallup et al. 1973, Donald and Kooyman 1977) and large portions of the lake bottom were dry. However, D. magna was not found in 1972 or 1994 when water levels were higher. Mean June water level in 1971, 1972, and 1994 was 208.77, 209.83, and 209.40 m asl, respectively. Empirical relationships need to be developed between annual variations in the seasonal water levels for Lake Claire and the abundance of aquatic biota.

Figure 2. Mean daily water level for Lake Claire (1960 to 1989).
The thick dark line is determined from hydrometic data collected within the Delta and nearby rivers, the thin line is simulated natural water levels without regulation by the W.A.C. Bennett Dam and weirs on the Riviere des Rockers and Revillon Coupe. The Dam was operational in 1968, the weirs in 1976.

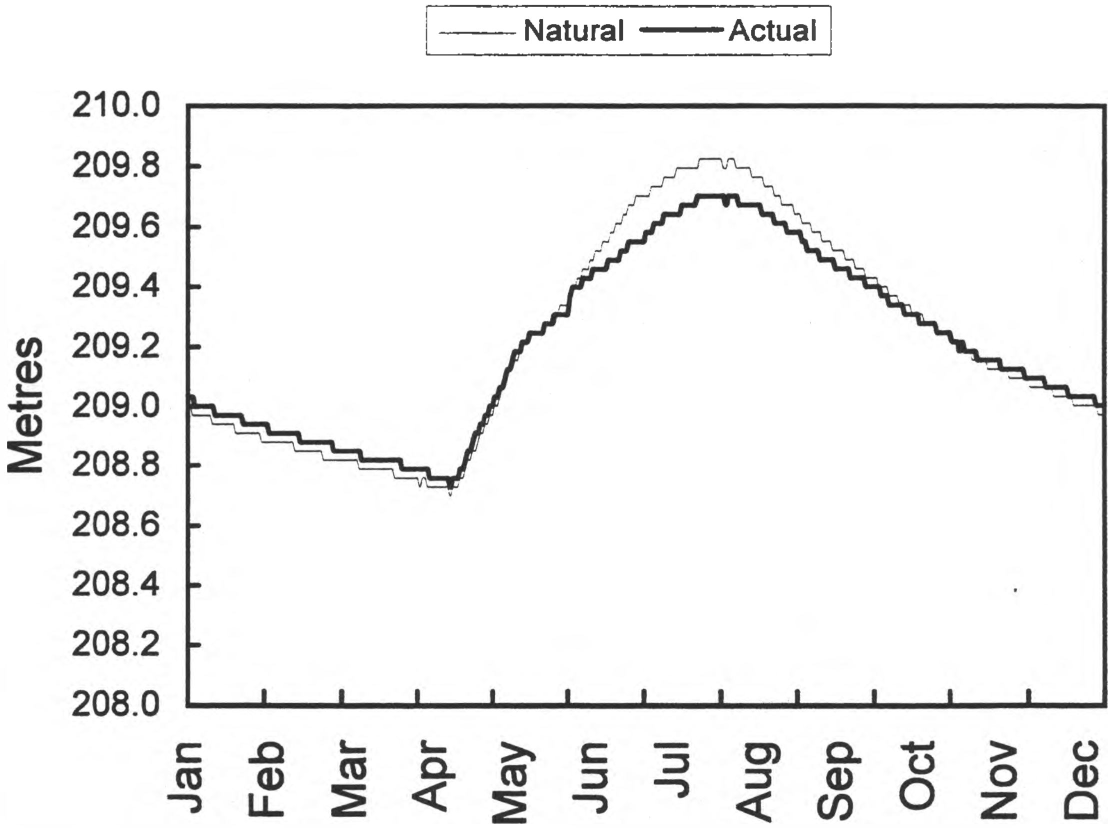
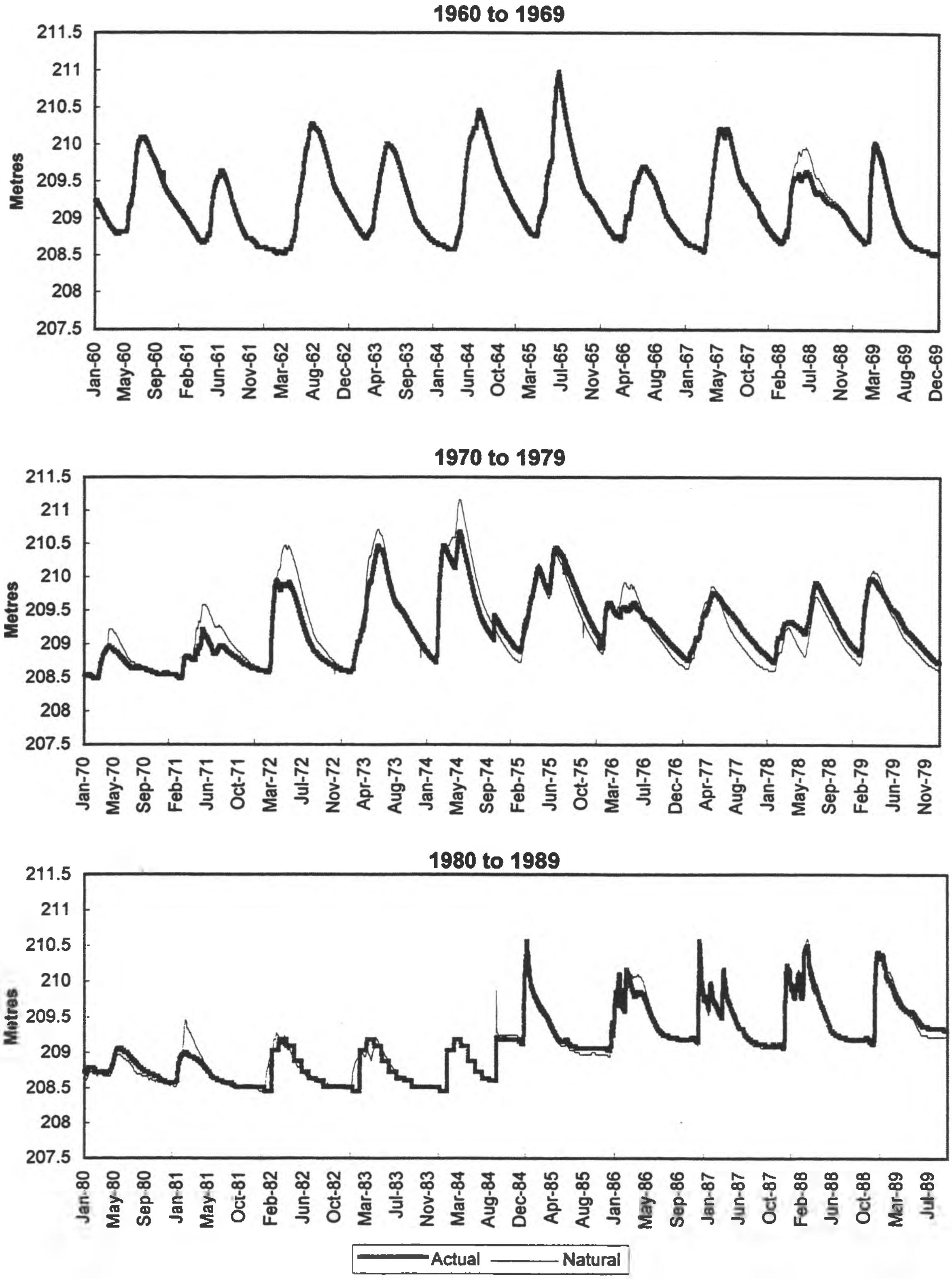


Figure 3. Annual mean daily water level for Lake Claire (1960 to 1989).
The thick dark line is determined from hydrometric data collected from the Delta and nearby rivers, the thin line is simulated natural water levels without regulation by the W.A.C. Bennett Dam and weirs on the Riviere des Rochers and Revillon Coupe. The Dam was operational in 1968, the weirs in 1976.



3.4 ECOSYSTEM ISSUE 4 - BENTHIC INVERTEBRATE COMMUNITY

The abundance and diversity of aquatic benthic invertebrates is maintained in the Peace-Athabasca Delta. Benthic invertebrates are important foods of fish, and through the food chain, invertebrates can be an important source of the contaminant burden of fish.

3.4.1 Indicator

The freshwater clam-shrimp Caenestheriella belfragei maintains a viable population within Mamawi Lake.

3.4.2 Indicator Measure

Population density estimates of the clam-shrimp Caenestheriella belfragei are determined at 50 sites on Mamawi Lake with a bottom-closing net (Lasenby and Sherman 1991, net mesh size 1 mm x 1 mm) at the end of June each year.

3.4.3 Background

The clam-shrimp C. belfragei (Conchostraca) is a large freshwater crustacean with average adult shell size 7.5 mm long, 6 mm wide, and 3.8 mm thick (Edmondson 1959). The geographic range for this species is primarily the central United States north to South Dakota (Donald 1989). In Canada, this species only occurs in the Peace-Athabasca Delta, extending the geographic range of this species north by 1000 km. It is an important food of goldeye, and when abundant is on average 28% of their diet during summer, July to September (Donald and Kooyman 1977). In 1994, the mean density of C. belfragei was $16/m^2$ for the northern half of Mamawi Lake (SD = 14.3, N = 24), but this species was rare or absent from the southern half (N = 23, Fig. 4, Table 5). This difference may indicate that this species is affected by subtle changes in water quality. Water quality in the southern portion of Mamawi Lake is influenced by the Mamawi Creek inlet which has water from the Athabasca River (Table 3). Water quality in the northern half of Mamawi Lake is influenced primarily by inflow from Prairie River which has water from Lake Claire and its principal inlet the Birch River (Figure 1). Water from the southern and northern parts of Mamawi Lake does not seem to mix over a wide area (Appendix B).

A long-term record of the abundance of C. belfragei in Mamawi Lake, and information on the life history of this species (environmental requirements, longevity, fecundity, growth) needs to be obtained before a more precise Indicator can be developed. However, C. belfragei is an ideal benthic invertebrate indicator because it is randomly distributed (mean ≤ standard deviation), and it is large (cost effective to collect and count).

Development of the eggs of some crustacean species are stimulated by low oxygen concentrations during winter. Perhaps development and hatching of the eggs of C. belfragei is inhibited by high winter oxygen concentrations that would be present in Mamawi Lake near the Mamawi Creek inlet (See Table 3). Five of the eight common taxa identified for Mamawi Lake show significant differences in abundance between the northern and southern parts of Mamawi Lake (Table 5).

Other invertebrate species were considered but rejected as suitable indicators of ecosystem integrity. Invertebrate species were rejected if they were relatively rare in the grab samples, were costly to sample and count (small species), had a clumped or patchy distribution (zooplankton), or were known to be an unimportant link in food webs (Sphaeriidae). In general, the benthic fauna of Mamawi Lake is unusually sparse with a low diversity of species (see Appendices F and H).

The benthic fauna of lakes is typically dominated by Chironomidae, Pelecypoda, and Amphipoda with densities often from a few to several thousand per square metre (Brinkhurst 1974). For Mamawi Lake, chironomid density was $222/m^2$, pelecopod density $469/m^2$, and amphipods were essentially absent (June 18-26, 1994, sieve mesh aperture $0.6\ mm^2$). The reduced macroinvertebrate fauna of Mamawi Lake is probably due to the shallow depth of this lake (maximum depth 1.5 m) which results in winter anoxia over large areas and deep freezing into the lake sediments (Reeder and Fee 1973). Furthermore, the large mesh used to sieve lake sediment from the grab samples would not retain small chironomid instars, and would under estimate abundance of this invertebrate group relative to other studies.

Table 5. Abundance of the common macroinvertebrate benthic species in the northern (N = 24) and southern portion (N = 23) of Mamawi Lake, June 1994.

Taxon	Number/m^2					
	North		South			
	Mean	SD	Mean	SD	t	p
Oligochaeta						
Stylodrilus	117	145.0	395	613.9	2.16	< 0.05
Gastropoda						
Valvata tricarinata	0	0.0	37	49.1	3.74	< 0.001
Probythinella lacustris	16	47.2	21	51.7	0.31	> 0.05
Pelecypoda						
Pisidium	457	503.7	458	524.8	0.01	> 0.05
Crustacea						
Caenestheriella belfragei	16	14.3	0	0.0	3.12	< 0.01
Chironomidae						
Procladius	43	89.8	36	51.2	0.35	> 0.05
Cryptochironomus	5	14.6	60	70.8	3.69	< 0.001
Cryptotendipes	2	8.8	93	173.5	2.53	< 0.05

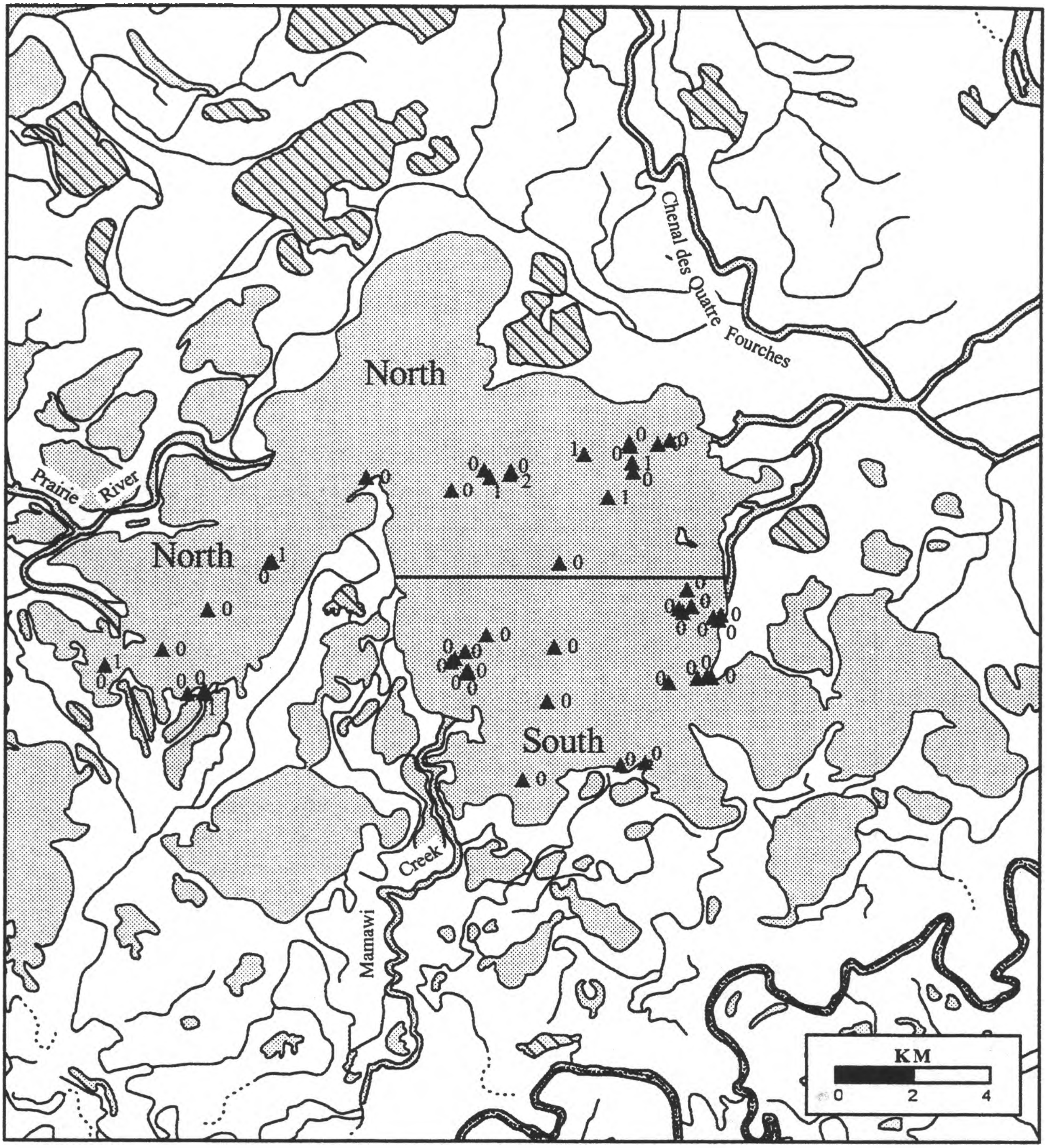


Figure 4. Distribution and number per sample of Caenestheriella belfragei in Mamawi Lake (June, 1994).

3.5 ECOSYSTEM ISSUE 5 - FISH COMMUNITY STRUCTURE

The fish community of the Peace-Athabasca Delta is maintained. Residence of the Peace-Athabasca Delta participate in a productive regional commercial, domestic, and sport fishery. Walleye, lake whitefish, pike, and goldeye are the preferred species in these fisheries.

3.5.1 Indicator

The fish community in Mamawi - Claire lakes of the Peace-Athabasca Delta during early summer is dominated by goldeye; the other fish species in order of decreasing relative abundance are: northern pike > flathead chub ≈ lake whitefish > walleye > longnose suckers > white suckers > burbot.

3.5.2 Indicator Measure

The fish community composition of Mamawi - Claire lakes is assessed every three years at 10 sites (Fig. 5) with multi-filament nylon gill-nets 1.8 m deep. Each net has six panels of equal length consisting of 3.8, 5.1, 6.4, 7.6, 8.9, and 10.1 cm mesh net (stretch measure).

3.5.3 Background

The first surveys of the fish community of Mamawi and Claire lakes were conducted in the late 1940s in anticipation of the development of a commercial fishery on Lake Claire (Table 6). Thereafter, the species composition of the fish community in these lakes was determined in the 1950s, 1970s, and 1990s. Although the gear (mesh size) and reporting method (number or weight) have not been consistent over this historical period, the catch data indicate that the composition of the fish community of the Mamawi - Claire lakes system has generally remained stable over the historical period (1947 to 1994). In summer, goldeye are the dominant species, northern pike are subdominant, and other species are relatively rare. The absence of lake chub in the catches from the 1940s and 1954 is probably the result of the large mesh size of gill-nets used during these years. The maximum length and weight for lake chub in the Delta is 37 cm and 510 g, and consequently this fish species is mostly caught in 6.4 cm mesh-net (Kristensen 1980).

A three year interval between fish community assessment in the Mamawi-Claire lakes system is recommended because of the concern for unnecessary mortality of fish in a National Park, and because a response of this Ecosystem Indicator to any stress would probably take much more than one year. More frequent assessment (annual) could be implemented should a significant change in the community structure be documented or anticipated (for example colonization of the Delta by an exotic fish species).

The regional domestic fishery harvests lake whitefish, walleye, and goldeye for human consumption. Thus, this Indicator (5) is an ecological link between the aquatic ecosystem and the residents of Fort Chipewyan. Any long-term change in the relative abundance of the fish species identified in Indicator 5 would constitute an unacceptable change in the ecological integrity of the Mamawi-Claire lakes ecosystem.

Table 6. Percent composition of the fish community of Mamawi-Claire lakes, 1947 to 1994.

Year	1947	1949	1954	1976	1977	1992	1994
Source	Sprules (1950)		Schultz (1955)	Kristensen and Summers (1978)	Kristensen (1981)	Environment Canada	NRBS
Gill-net mesh size (cm)	10.1	9.5	8.9, 9.5, 10.1	3.8, 6.4, 8.9	3.8, 6.4, 8.9	3.8, 5.1, 6.4, 7.6, 8.9, 10.1	
Fish species							
Goldeye	56%	61%	92%	79%	67%	60%	71%
Northern Pike	20%	21%	4%	15%	19%	19%	11%
Flathead chub	0	0	0	0	2%	8%	6%
Lake whitefish	7%	7%	0	2%	8%	5%	8%
Walleye	8%	3%	2%	2%	2%	5%	3%
Longnose sucker				2%	2%		1%
(combined)	10%	8%	2%			3%	
White sucker				+	+		<1%
Burbot	0	0	0	0	+	+	0
Total catch	204[1]	108,954[1]	563	4158	1154	725	744

[1] - weight in kilograms

3.6 ECOSYSTEM ISSUE 6 - GOLDEYE ABUNDANCE

The goldeye population of the Peace-Athabasca Delta is maintained. Goldeye are an important part of the catch of the regional domestic fishery.

3.6.1 Indicator

The mean catch-per-unit-effort (CPUE) of goldeye during late June in the Mamawi-Claire lakes is not significantly less than 10 goldeye per hour for a 100 m survey gill-net (SD = 6).

3.6.1 Indicator Measure

Goldeye abundance is determined with gill-nets every 3 years in late June from 10 established sites near the shore of Mamawi Lake and Lake Claire (Fig. 5). Gill-nets are 1.8 m deep, and have 6 panels, 10 m each, of 3.8, 5.1, 6.4, 7.6, 8.9, and 10.1 cm mesh net.

3.6.2 Background

Goldeye abundance was determined in June with survey gill-nets at established sites in Mamawi and Claire lakes in 1973, 1987, 1992, and 1994 (Table 7). During those years, mean catch-per-unit-effort (CPUE) ranged from 9.9 to 16.9 and no significant difference in abundance was detected for those years (ANOVA, $F = 0.880$, $df = 3$ and 28, $p = 0.46$).

The standard deviation of the catches for the four years ranged from 58% to 87% of the mean. Using the former value to calculate a standard deviation, we determined that a mean CPUE of about 5.5 (calculated SD = 3.19, N = 10 sites) would be required before a significant decline in the population could be demonstrated ($t = 2.1$, $p < 0.05$, $df = 18$). However, a statistically demonstrated decline in goldeye abundance would constitute a compromise of the ecological integrity of the Mamawi-Claire lakes ecosystem.

Ecosystem Indicator 6 (goldeye) is closely linked to Indicator 1 (climate). Year-class strength for goldeye from the Mamawi-Claire lakes system is highly variable with strong year-classes occurring 1.2 times per decade on average, and other year-classes fail completely (for example the 1985 year-class, Fig. 6). If conditions for development of strong year-classes were significantly altered, the population size of goldeye would be reduced. Recruitment for goldeye is related to two density independent factors, temperature and wind intensity during the early life stages of this species. Year-class strength (recruitment) for goldeye is related to the number of warm days with mean daily air temperature > 15°C from May 1 to July 31 (Fig. 7, $r = 0.57$, $N = 25$, $p < 0.01$, $\log Y = 0.067X - 1.865$ where Y = year-class strength index and X = days with mean daily air temperature > 15°C). This three month period includes the spawning migration, spawning, egg development and hatching, and growth to a 1.9 g fingerling. In addition to the requisite of warm temperatures, strong and abundant year-classes develop when wind intensity, the number of hours with wind speed ≥ 20 km/h, is reduced from May 22 to June 20 (Fig. 8). This 30 day period spans the time when the semi-buoyant eggs and newly hatched larvae of goldeye are present in the delta lakes. Wind intensity during spring was less when dominant year-classes developed compared with weak year-classes (ANOVA, $F = 3.728$, df = 2 and 22, $p = 0.04$; Tukey test of multiple pairwise comparisons, dominant versus weak $p = 0.03$, dominant versus abundant $p = 0.15$, abundant versus weak $p = 0.84$).

It is hypothesized that warm weather in late spring and early summer increases food production, promotes growth and development of young goldeye, and thereby enhances their survival. In the shallow delta lakes, strong winds may cause mortality by dispersing the semi-buoyant eggs and larval goldeye to off-shore and other unfavourable habitats far from the near-shoreline locations where young goldeye are usually found (Donald and Kooyman 1977), and adults probably spawn. The first foods eaten by goldeye fry are small crustaceans (Donald and Kooyman 1977). Wind-driven turbulence might also cause high mortality of larval goldeye by disrupting their feeding during those critical days when their nutritional source changes from the yolk to small crustaceans.

Table 7. Catch-per-unit-effort (CPUE) for goldeye from Mamawi and Claire lakes in June, 1973 to 1994, determined from gill-nets with mesh size ranging from 3.8 to 10.2 cm.

Year	Mean CPUE	Standard deviation	Number of sites
1973	16.9	14.7	8
1987	11.6	7.7	5
1992	11.9	7.0	9
1994	9.9	5.7	10

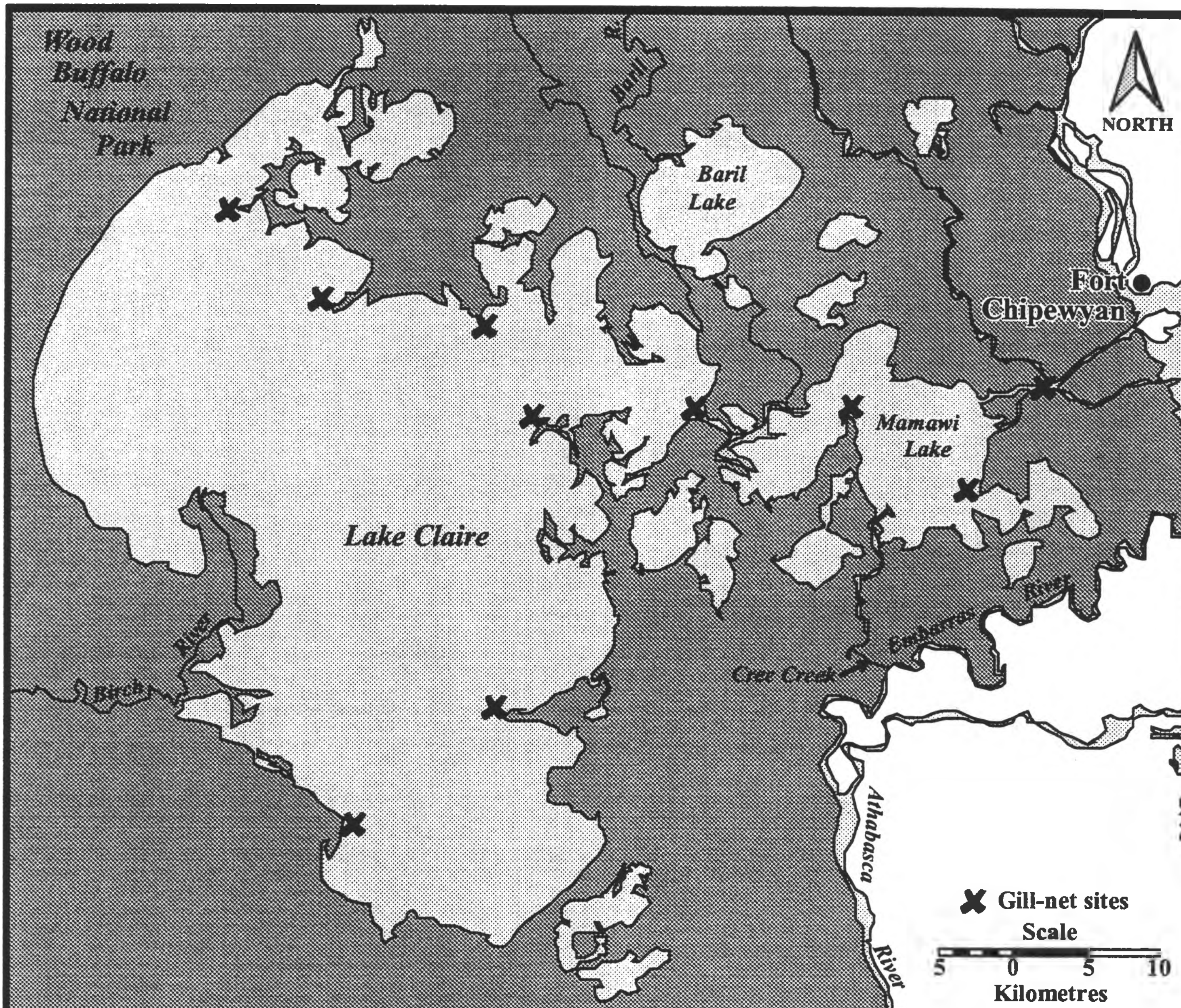


Figure 5
Gill-net sites on Mamawi and Claire Lakes for determining the fish community composition and the abundance of goldeye.

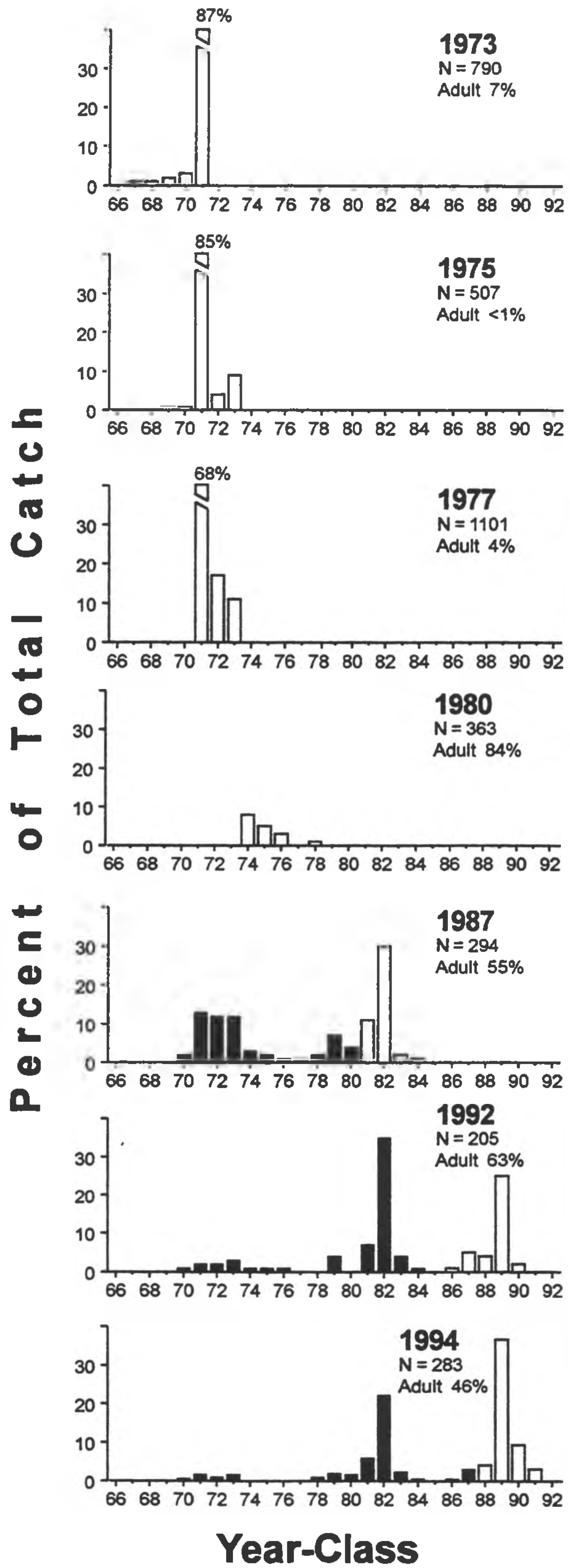


Figure 6. Year-class strength of goldeye determined from catches using survey gill-nets, 38mm to 102mm mesh. Age of immature goldeye, those fish from age 1 to 6, were determined from scales (open); age of adult goldeye, those age 7 and older, were determined from opercula (closed). Data from 1975, 1977, and 1980 are from Kristensen and Summers (1978), and Kristensen (1981 and 1983 unpublished). Year-class frequency for adults in catches from 1973 to 1980 are not shown because scales were used to determine age of adults, and these are unreliable (Donald et al. 1992).

Figure 7. Relationship between year-class strength for goldeye and summer air temperature (number of days with mean daily temperature > 15°C from May 1 to July 31). Year-class strength was measured when a year-class was most abundant in the catches, usually from age 2 to 6. Strong year-classes (■) were > 25% of the catch, abundant year-classes (▲) from 5 to 25%, and weak year-classes (x) were < 5% of the catch.

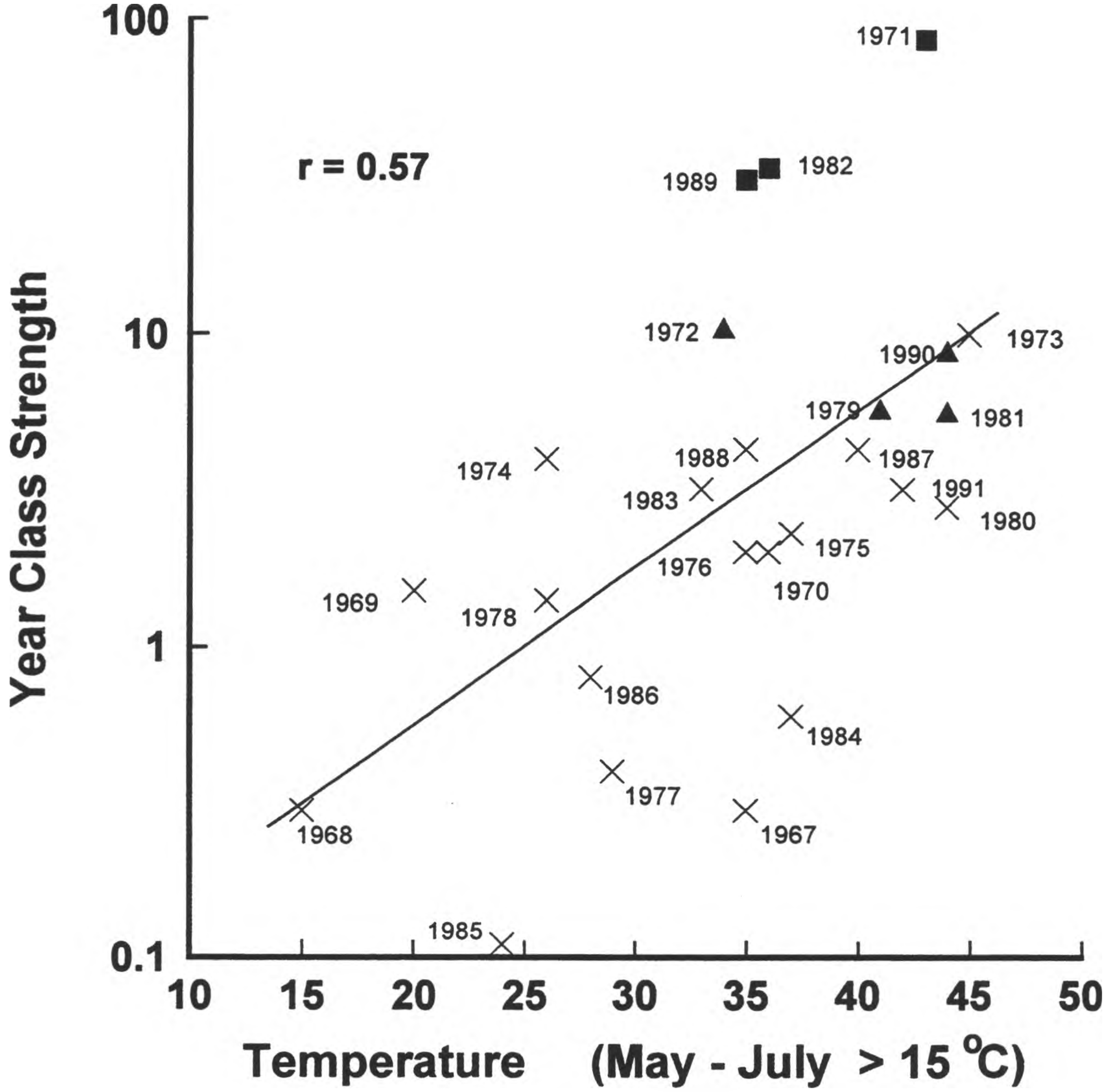
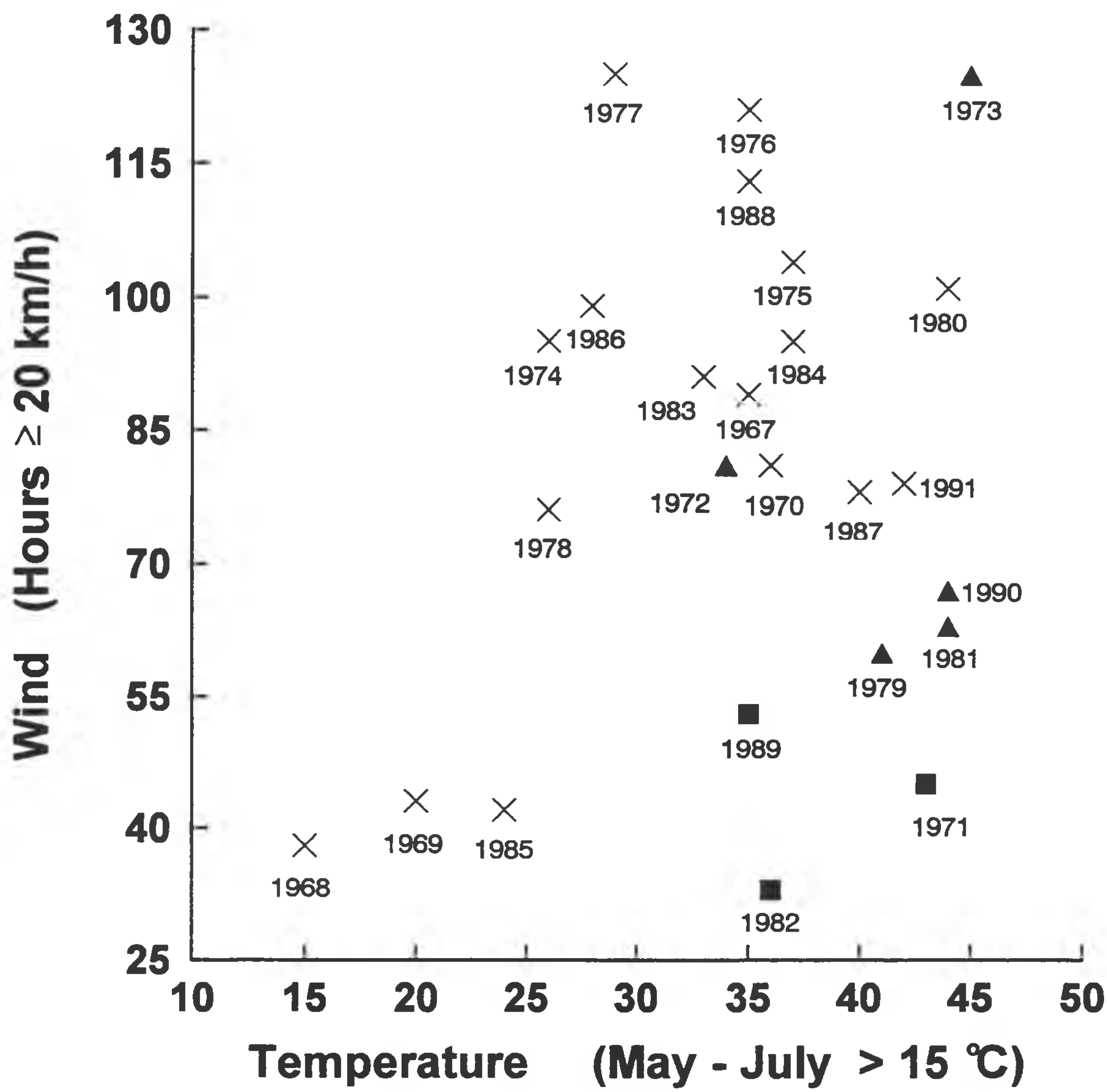


Figure 8. Scatter diagram showing weather conditions associated with strong (■), abundant (▲), and weak (x) year-classes. Temperature is the number of days with mean daily air temperature > 15°C from May 1 to July 31. Wind is the total number of hours with strong wind, ≥ 20 km/h, from May 22 to June 20 summed for the period 0800 to 2300 h.



3.7 ECOSYSTEM ISSUE 7 - WALLEYE COMMERCIAL HARVEST

Walleye populations in the Peace-Athabasca Delta are maintained. Walleye are the most important fish species in the commercial fishery and are an important part of the domestic and sport fish catch. Walleye are an economic and nutritional asset to the residence of the Fort Chipewyan area.

3.7.1 Indicator

The annual commercial harvest of walleye from the Alberta portion of Lake Athabasca is 45,400 kg in at least 7 of 10 years, and contaminant levels will: A) not significantly affect the mortality, growth, and fecundity of the walleye, and B) not affect their "table" quality for human consumption.

3.7.2 Indicator Measure

The commercial harvest of walleye and other fish species for the Alberta portion of Lake Athabasca is recorded each year, and levels for toxic substances such as mercury, dioxins, furans, and pesticides are determined in fish muscle tissue at regular intervals.

3.7.3 Background

The annual commercial harvest of fish from the Alberta portion of Lake Athabasca from 1943 to the present is shown in Table 7. Walleye are the most important fish species in this gill-net fishery, providing the greatest economic return to the licensed fishermen. Northern pike and lake whitefish have also been harvested for commercial sale in most years, but their commercial value is typically much less than walleye. Other species such as burbot and goldeye are also retained for sale in some years. All fish species are caught each year, but unless a suitable price is offered by a marketing agency, some fish species are culled at the catch site and are not included in the annual catch statistics.

The commercial quota for walleye for the Alberta portion of Lake Athabasca is 45,400 kg/year. From 1963 to 1995, the quota was obtained in 7 of 10 years on average. The quota for walleye may not be obtained in some years because of a low price for walleye (effort by commercial fishermen is less), poor weather during the commercial fishing season (May/June), or low numbers of walleye of commercial size.

Walleye as an Ecosystem Indicator provides a direct ecological link from ambient water quality (potentially affected by industrial effluents), to fish health (contaminant levels, taste, odour), to the residence of Fort Chipewyan (nutrition, economic well-being). Moreover, recruitment for walleye from lakes in eastern Canada (Koonce et al. 1977), and perhaps in the Delta, is related to optimal temperature regimes during their early life history stages (link to Indicator 1, climate). Any significant reduction in the long-term commercial catch, or contaminant induced changes in walleye mortality, growth, fecundity, or "table" quality, would compromise the ecological integrity of the Peace-Athabasca Delta.

Table 8. Annual commercial fishery harvest (kg) from the Alberta portion of Lake Athabasca (data from Alberta Fish and Wildlife Division).

Year	Lake whitefish	Lake trout	Walleye	Northern pike	Burbot	Sucker	Goldeye	Total
1943	9,356		82,248	3,701				95,304
1944			72,599					72,599
1945	23,655	57,290	44,166					125,110
1948	42,498	42,177	6,037					90,621
1954	8,602	31,085	3,612					43,299
1955	7,277	32,675	5,057					45,008
1957		43,744	4,446					48,190
1958		113,491	25,111					138,602
1959		78,803	60,256					139,059
1960	9,568	76,212	55,316				2,350	143,446
1961	7,728	483	48,531	19,652			456	80,883
1962			100,107	40,533			6,141	146,781
1963			53,195	36,324			3,102	92,620
1964	722		97,401	77,867			628	176,618
1965			58,435	70,631			177	129,243
1966	1,361		61,492	77,461			748	141,062
1967			60,727	47,539			129	108,395
1968	1,665		96,337	127,881	170	79	334	226,467
1969	42,283		42,863	71,625	3,594	1,251	125	161,741
1970	69,760		17,076	18,146	2,370	957	190	108,499
1971	54,116		24,202	8,338	1,293	1,558	286	89,791
1972	25,265	567	44,308	17,580	6,066	37,594	254	131,635
1973	68,218	34	28,863	27,357	5,714	4,526		134,712
1974	66,545		24,826	17,853	5,578	16,417		131,219
1975	1,190		12,849	9,421	816	7,029		31,306
1976	2,948		28,337	9,751	91	8,707		49,834
1977	1,587		81,478	3,878		2,948		89,891
1978	8,163		61,179	2,766		3,401		75,510
1979	3,855		46,984	2,041		2,993		55,873
1980	3,084		29,651	1,542				34,277
1981	1,400		49,371	1,200				51,971
1983	6,500		1,100	2,100	220			9,920
1984	50,550		74,015	78,050		25,000		227,615
1985	24,056	225	72,858	220,474	615	420,048	3,485	741,761
1986	10,456		69,121	209,124	300	418,248	3,485	710,766
1987	12,724		81,690	25,448	391	41,825	4,845	166,923
1988	13,297		80,938	41,368				135,603
1989	35,345		80,167	14,690	3,054	12,218		145,475
1990	6,818		50,280	3,005	470	1,361		61,934
1991			40,000	20,000				60,000
1992	2,633		79,180	33,959				111,993
1993	20,092		61,727	38,040			12,670	137,338
1994			73,200					73,200
1995			44,200	39,000				83,200

4.0 RECOMMENDATIONS

It is recommended that for the Peace-Athabasca Delta a monitoring program be established utilizing the following Ecosystem Indicators:

1. The climate of Fort Chipewyan and surrounding area follows recognized annual and longer-term patterns and their variability. This variability is not measurably affected by regional or global input of human generated substances such as green-house gases (carbon dioxide, water vapour, methane) or industrial smoke.

2. Quality of water flowing into the Peace-Athabasca Delta from the Peace and Athabasca rivers is free of contaminants and toxic substances, and levels of nutrients, major ions, and metals are within natural ranges and limits. In not more than one in ten samples, total dissolved phosphorous should not exceed 0.4 mg/L, dissolved sulphate (SO_4) 39 mg/L, and dissolved oxygen not less than 8.0 mg/L. Total dissolved solids (TDS) should not exceed 148 and 272 mg/L for the Athabasca and Peace rivers, respectively, also in not more than 1 in 10 samples.

3. Water levels for Lake Claire, the largest lake in the Peace-Athabasca Delta, follow annual and long-term natural patterns and elevations unaffected by flow regulation on the Peace or other rivers; or natural levels are maintained by structures.

4. The freshwater clam-shrimp Caenestheriella belfragei maintains a viable population within Mamawi Lake.

5. The fish community in Mamawi-Claire lakes of the Peace-Athabasca Delta during early summer is dominated by goldeye; the other fish species in order of decreasing relative abundance are: northern pike > flathead chub ≃ lake whitefish > walleye > longnose sucker > white sucker > burbot.

6. The mean catch-per-unit-effort of goldeye during late June in the Mamawi-Claire lakes is not significantly less than 10 goldeye per hour for a 100 m survey gill-net (SD = 6).

7. The annual commercial harvest of walleye from the Alberta portion of Lake Athabasca is 45,400 kg in at least 7 of 10 years, and contaminant levels will: A) not significantly affect the mortality, growth, and fecundity of the walleye, and B) not affect their "table" quality for human consumption.

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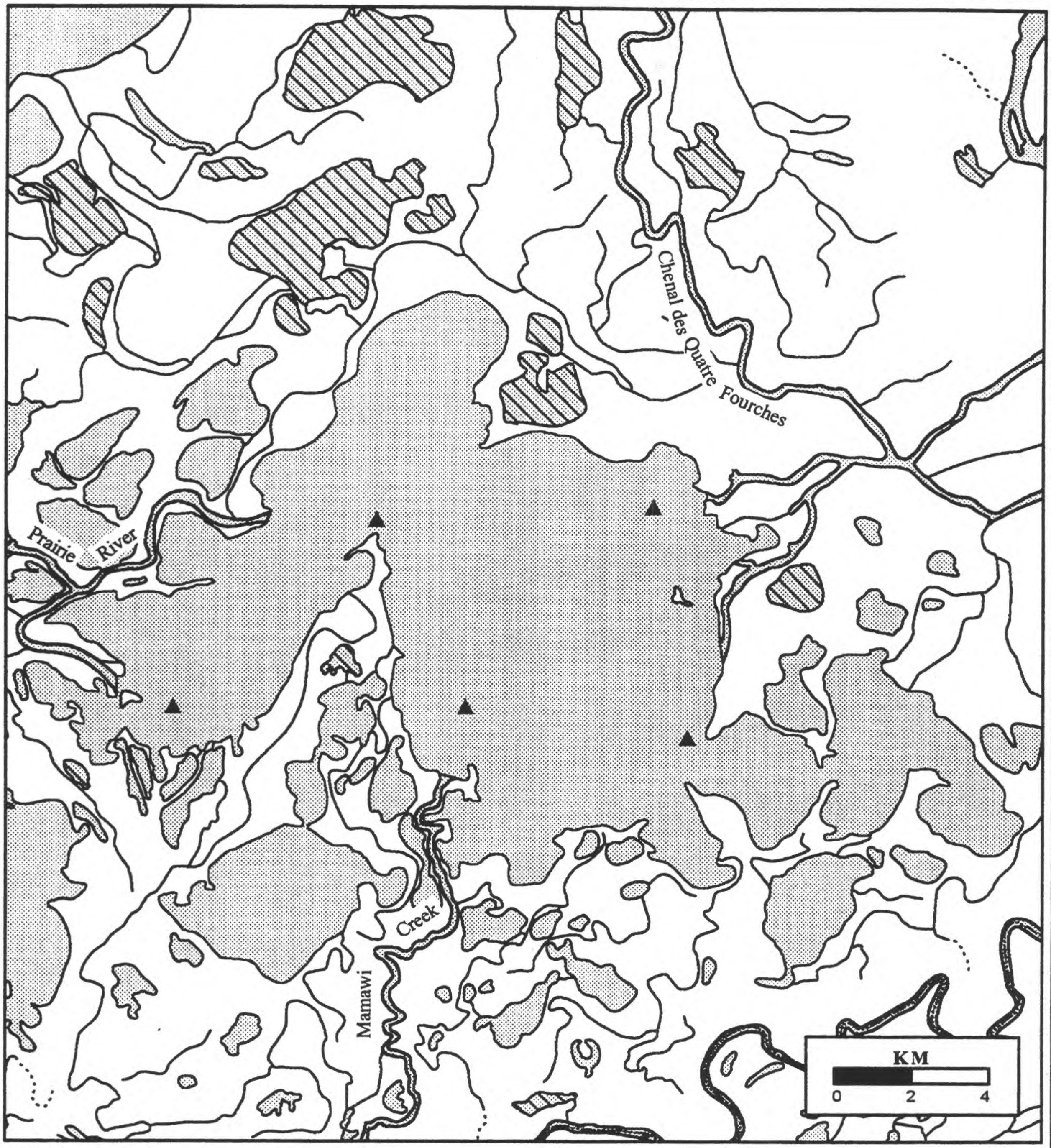
APPENDICES

Appendix A. Water Quality for Mamawi Lake, 1971 (from Reeder and Fee, 1973).

Parameter	Units	10/05/71	24/05/71	02/07/71	30/08/71	05/10/71	28/10/71	28/10/71	23/02/71
Al	(mg/L)	<0.10	<0.10	0.21	<0.10	<0.10	<0.10	<0.10	0.14
B	(mg/L)	0.07	0.10	0.14	0.08	0.11	0.05	0.07	–
Ba	(mg/L)	0.12	0.06	0.06	0.09	0.085	0.07	0.08	0.14
Ca	(mg/L)	39.1	52.8	28.3	43.5	99.9	55.6	60.3	–
Cd	(mg/L)	<0.0005	0.001	<0.0005	<0.0005	<0.0005	0.014	0.014	<0.0005
Co	(mg/L)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.003
Cr	(mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cu	(mg/L)	0.002	0.002	0.005	0.005	0.002	0.003	0.003	0.005
Fe	(mg/L)	0.02	0.01	0.18	<0.01	0.03	<0.01	<0.01	0.86
Pb	(mg/L)	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Li	(mg/L)	0.015	0.029	0.002	0.013	0.027	0.0078	0.031	0.020
Hg (total)	(mg/L)	<0.00005	<0.00005	0.0006	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Hg (dissovlved)	(mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	–
Mn	(mg/L)	<0.015	<0.015	<0.015	0.014	<0.015	<0.015	<0.015	0.38
Mg	(mg/L)	8.9	14.1	5.9	9.6	19.8	11.2	14.9	–
Mo	(mg/L)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	(mg/L)	<0.006	0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.026
K	(mg/L)	2.95	2.5	1.3	2.2	3.5	3.5	4.0	–
Si02	(mg/L)	1.6	0.6	3.6	4.3	3.8	5.0	5.6	–
Na	(mg/L)	26.0	57.6	4.4	22.3	52.3	53.0	60.0	–
Sr	(mg/L)	0.20	0.35	0.15	0.24	0.30	0.32	0.48	0.37
Tl	(mg/L)	<0.15	<0.15	<0.15	0.15	<0.15	<0.15	<0.15	<0.15
Zn	(mg/L)	0.004	<0.001	0.004	0.003	0.001	0.001	0.001	0.005
Total Cations	(mg/L)	3.8907	6.3647	2.1318	3.9867	–	6.0908	6.9469	–
Cl	(mg/L)	36.0	88.0	1.4	26.0	71.0	75.6	81.4	–
F	(mg/L)	0.11	0.13	0.10	0.13	0.19	0.20	0.22	–
HCO3	(mg/L)	107.3	123.1	90.0	140.2	115.8	124.3	142.6	–
N	(mg/L)	1.42	1.22	1.03	0.95	0.95	0.84	0.95	–
NO3 + NO2	(mg/L)	0.03	<0.01	0.06	<0.01	0.04	0.05	0.05	–
PO4 (ortho filt)	(mg/L)	0.02	0.01	0.02	0.01	0.02	0.02	0.02	–
PO4 (inorg filt)	(mg/L)	0.03	0.01	0.03	0.02	0.03	0.03	0.03	–
PO4 (total)	(mg/L)	1.00	0.37	1.10	0.53	0.95	0.50	0.55	–
SO4	(mg/L)	55.3	97.7	23.5	42.5	90.0	93.4	109.0	–
Total Anions	(mg/L)	3.929	6.5339	2.0105	3.9218	–	6.1204	6.9092	–
Total Diss Solids	(mg/L)	222.9	374.1	113.1	219.6	397.7	359.0	405.9	–
Total Organic C	(mg/L)	15	16	8	11	14	19	21	–
Total Inorganic C	(mg/L)	21	22	15	26	19	16	17	–
Sampling	(C)	11.8	17.2	18.4	15.8	4.4	–	–	0.5
Conductivity (field)	(uohms/cm)	–	–	287	357	800	–	–	380
Conductivity (lab)	(uohms/cm)	416	670	162	403	525	616	705	–
pH (field)		–	–	7.1	7.2	6.4	–	–	7.6
pH (lab)		7.6	7.6	7.8	8.1	7.9	7.9	8.0	–
Colour		12	8	45	27	15	20	20	–
Turbidity	(JTU)	118	46	78	56	160	85	98	–
Residue NF (105 C)	(mg/L)	415	74	350	115	218	130	167	–
Residue NF (550 C)	(mg/L)	371	64	318	104	188	113	146	–
Alkalinity	(tot CaCO3)	88.0	101.0	73.8	115.0	95.0	102.0	117.0	–
Hardness	(tot CaCO3)	135	191	95.3	149	169	186	213	–
Discharge est.	(1000Ac Ft.)	15	12.5	30	50	10	10	10	12

Appendix B. Water quality data for Mamawi Lake, Peace-Athabasca Delta, 1994

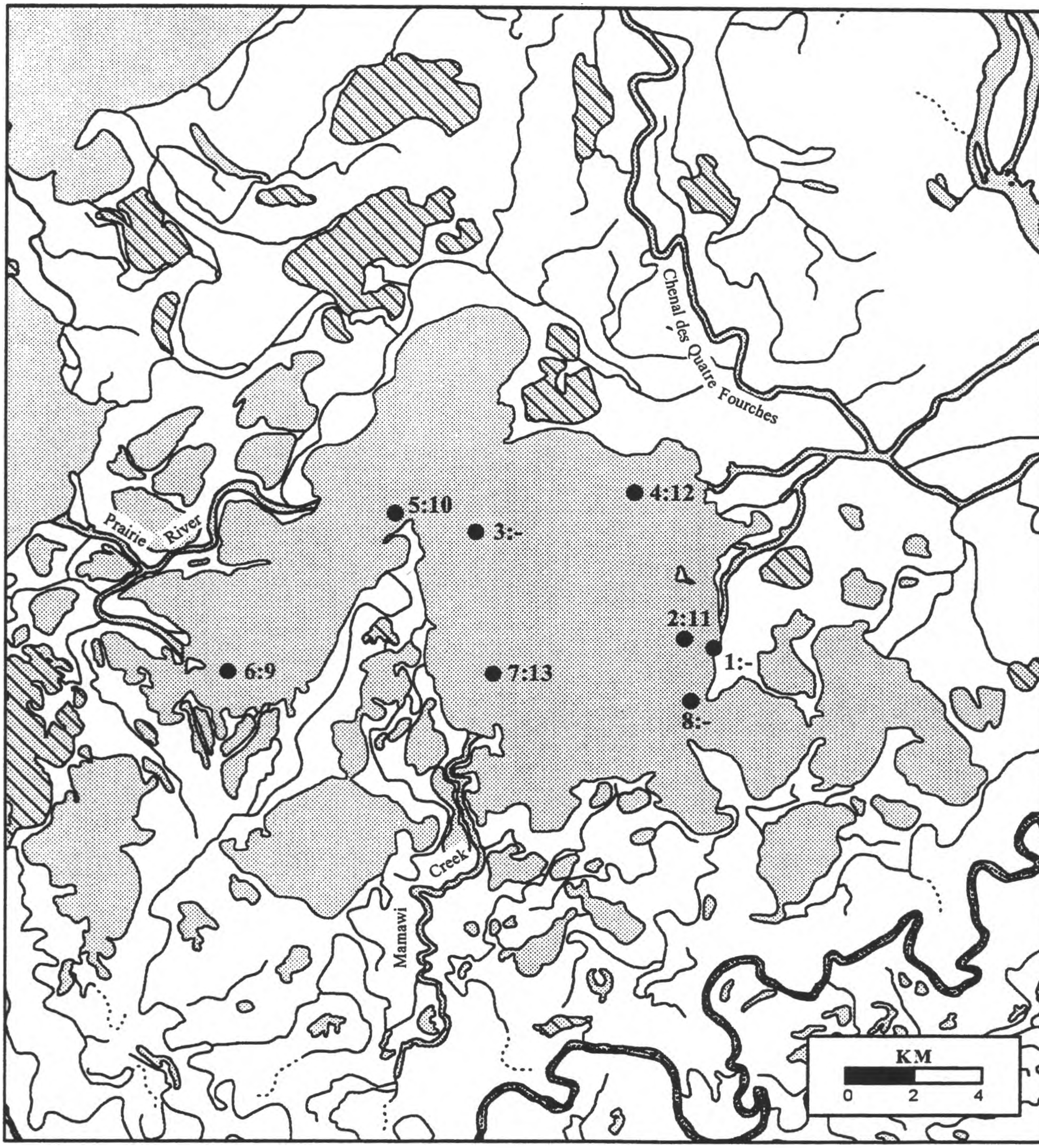
Station	Pelican Creek		Beaver Ass Point		North Channel		Mamawi Creek		Poplar Island	
Latitude	58 35 24.9		58 38 22.3		58 38 17.9		58 35 26.4		58 35 01.8	
Longitude	111 37 01.5		111 24 07.7		111 24 06.8		111 29 08.4		111 23 08.3	
Date	June 20	Sept 15	June 20	Sept 15	June 20	Sept 15	June 20	Sept 15	June 20	Sept 15
TDS* 00201L mg/L	261	313	260	311	231	313	138	169	143	169
Sat Index* 00210L pH Units	-1.145	-.608	-1.158	-.519	-1.013	-.563	-1.109	-.531	-1.157	-.445
Stab Index* 00211L pH units	9.76	8.76	9.75	8.66	9.62	8.69	9.82	8.8	9.86	8.64
Cond. 02041L usie/cm	469.	548.	459.	546.	417.	549.	244.	311.	258.	296.
B-diss 100211 mg/L	.062	.066	.054	.032	.042	.07	.022	.024	.018	.025
Chlorophyll - a µg/L	145.47	—	137.61	—	121.62	—	43.92	—	485.92	—
TOC* 06002L mg/L	20.2	21.37	15.45	20.09	15.57	19.39	15.87	6.77	8.77	12.68
DOC 06104L mg/L	15.0	17.0	10.4	16.9	11.9	16.5	10.7	6.23	6.70	10.5
HCO3* 06201L mg/L	116.8	135.3	124.3	136.5	121.9	139	115.7	132.9	116.5	152.4
CO3* 06301L mg/L	0	0	0	0	0	0	0	0	0	0
Free CO2* 06401L mg/L	6.28	6.19	7.33	5.19	4.96	6.07	4.6	3.82	5.21	4.28
POC 06901L mg/L	5.20	4.37	5.05	3.19	3.67	2.89	5.17	0.539	2.07	2.18
TN* 07603L mg/L	1	1.09	1.28	.95	0.96	.93	0.85	.31	0.56	.69
DN 07657L mg/L	1.24	.524	0.441	.525	0.393	.537	0.485	.229	0.263	.455
PN 07901L mg/L	0.767	0.562	0.834	0.420	0.569	0.392	0.364	0.082	0.301	0.236
OH* 08501L mg/L	0	0	0	0	0	0	0	0	0	0
F-diss 09117L mg/L	.16	.24	.15	.24	.16	.24	.09	.13	.09	.13
Alk-tot 10111L mg/L	95.8	111.	102.	112.	100.	114.	94.9	109.	95.6	125.
Alk-p 10151L mg/L	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
pH 10301L pH units	7.47	7.54	7.43	7.62	7.59	7.56	7.6	7.74	7.55	7.75
Hard-tot* 10602L mg/L	148.9	171.3	148.1	173.2	140.8	175.9	108.5	122.5	111.3	126.9
Hard-nonCO3 10650L mg/L	53.1	60.3	46.1	61.2	40.8	61.9	13.6	13.5	15.7	1.9
Na-diss 11103L mg/L	38.2	44.2	36.	44.7	30.6	44.1	9.92	16.8	10.1	13.4
%Na* 11250L %	35.4	35.5	34.2	35.5	31.7	34.9	16.4	22.8	16.3	18.5
Mg-diss 12102L mg/L	11.3	13.1	11.1	13.2	10.	13.3	7.37	9.19	8.06	9.48
SiO2 14108L mg/L	3.43	4.03	3.58	3.38	3.61	2.93	5.13	4.32	3.8	1.68
P-diss ortho 15265L mg/L	0.006	0.005	0.005	0.005	0.004	0.005	0.006	0.002	0.003	0.004
P-tot 15423L mg/L	0.222	0.173	0.203	0.121	0.146	0.102	0.148	0.022	0.061	0.078
P-diss 15465L mg/L	0.009	0.013	0.010	0.014	0.009	0.013	0.009	0.008	0.010	0.013
P-part* 15901L mg/L	0.213	.16	0.193	.107	0.137	.089	0.139	.014	0.051	.065
SO4-diss 16306L mg/L	60.9	79.6	59.5	78.6	47.9	79.3	20.2	23.3	24.2	22.6
Cl-diss 17206L mg/L	46.	55.2	45.4	53.6	36.9	53.8	6.	15.2	6.65	9.91
K-diss 19103L mg/L	2.27	2.69	2.16	2.65	2.05	2.7	1.07	1.12	1.11	1.4
Ca-diss 20103L mg/L	41.	47.	41.	47.6	39.9	48.5	31.3	33.9	31.3	35.2
Mn-diss 100204 mg/l	L.001	L.001	L.001	L.001	L.001	L.001	.001	L.001	L.001	L.001
Fe-diss 100202 mg/L	.026	.009	.023	.01	.015	.016	.109	.025	.033	.068
Al-diss 100195 mg/L	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02
Ba-diss 100196 mg/L	.041	.05	.046	.053	.046	.057	.047	.052	.046	.061
Be-diss 100197 mg/L	L.5	L.5	L.5	L.5	L.5	L.5	L.5	L.5	L.5	L.5
Cd-diss 100198 mg/L	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001
Co-diss 100199 mg/L	.001	L.001	L.001	L.001	L.001	.001	L.001	.001	L.001	L.001
Cr-diss 100200 mg/L	.001	L.001	L.001	L.001	L.001	.001	L.001	L.001	L.001	L.001
Cu-diss 100201 mg/L	.003	.003	.002	.003	.002	.003	.001	L.001	.001	.001
Li-diss 100203 mg/L	.02	.024	.019	.024	.015	.025	.006	.008	.006	.008
Mo-diss 100205 mg/L	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
Ni-diss 100206 mg/L	.002	L.002	.002	.002	.002	.003	.002	L.002	L.002	L.002
Pb-diss 100207 mg/L	.002	.004	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002
Sr-diss 100208 mg/L	.225	.28	.237	.286	.211	.291	.178	.233	.188	.218
V-diss 100209 mg/L	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001
Zn-diss 100210 mg/L	.002	L.002	.003	L.002	L.002	L.002	.002	L.002	L.002	L.002



Appendix C. Water quality sites at Mamawi Lake, 1994.

Appendix D. Percent composition of zooplankton species in samples collected on June 19, June 20 (samples 1to 8) and September 15, (samples 9 to 13), 1994 from Mamawi Lake, Alberta.

	Percent Composition												
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13
Latitude (Deg. Min. Sec.)	58 35 51	58 36	58 37	58 38	58 37	58 35 25	58 35	58 35 0.6	58 35 18	58 37 50	58 35 00	58 38 15	58 35 26
Longitude (Deg. Min. Sec.)	111 22	111 23	111 29	111 24	111 32	111 37	111 29	111 23	111 36	111 32	111 22	111 24	111 28
Daphnia retrocurva	3	2	10	14	12	8	<1	7	2	3		3	4
Daphnia pulex				1	<1		4		<1	<1	87	<1	5
Daphnia galeata										1			
Daphnia ambigua			<1					<1					
Diaphanosoma leuchtenbergianum	3	4	4	8	7	3	<1	4	1	1		2	
Ceriodaphnia reticulata							<1		<1				
Chydorus sphaericus			<1				3	<1					
Leptodora kindtii				<1		<1							
Bosmina longirostris	20	16	7	10	4	10	12	38	28	16	1	44	37
Eurycercus glacialis				<1						<1			
Alona affinis		<1			<1		<1				<1		<1
Epischura lacustris		1	1	1	2	2				1	<1	<1	
Epischura nevadensis	21	15	8	5	13	13	3	3	1	2	1	1	<1
Diaptomus sicilis	4	5	17	8	15	12	<1	3					
Diaptomus oregonensis									3	5	5	11	3
Cyclops vernalis	4	38	41	24	36	39	76	40	65	71	5	38	40
nauplii	45	19	12	29	11	13		4	<1		1	1	
Ostracods				<1		<1	2	1				<1	11
Number Counted	956	593	796	685	553	586	210	425	730	569	822	628	434



Appendix E. Zooplankton collection sites for Mamawi Lake (June:September), 1994.

Appendix F. Abundance[1] of macroinvertebrates for Mamawi Lake, June 18 to 26, 1994.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15	Site 16
Lumbriculidae																
Stylodrilus sp.	1	16	7	9	4	5	8	0	1	1	14	11	25	68	2	0
Tubificidae	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0
Gastropoda																
Prosobranchia																
Valvatidae																
Valvata tricarinata	1	2	4	1	2	2	0	0	1	0	0	0	0	0	0	0
Valvata sincera helicoidea	0	0	0	0	0	0	1	2	1	0	1	0	0	0	0	0
Hydrobiidae																
Probythinella lacustris	0	0	0	1	0	0	0	0	3	0	0	1	0	0	0	5
Pulmonata																
Planorbidae																
Promenetus umbilicatellus	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Physidae																
Physa sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pelecypoda																
Sphaeriidae																
Pisidium sp	0	28	14	21	21	4	47	4	20	15	1	1	0	0	2	15
Sphaerium sp.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda	0	0	1	0	0	0	1	0	0	1	1	1	0	1	0	0
Arthropoda																
Crustacea																
Conchosrtaca																
Caenestherella belfragei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0
Amphipoda																
Diporeia hoyi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Insecta																
Hemiptera																
Corixidae (imm.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera																
Leptoceridae																
Oecetis sp.	0	0	1	0	2	0	0	1	1	0	0	0	0	0	0	0
Molannidae																
Molanna sp.	0	0	0	5	0	0	1	2	0	0	0	0	0	0	0	0
Ephemeroptera																
Tricorythodidae																
Tricorythodes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Diptera																
Chironomidae (pupae)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomini	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Chironomus	0	0	0	0	0	0	0	0	2	0	0	0	0	1	5	0
Cryptochironomus	0	2	1	0	0	0	5	4	2	0	0	1	0	0	0	0
Cryptotendipes	0	3	2	2	0	0	1	2	0	0	0	0	1	0	0	0
Dicrotendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harnischia	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Polypedilum	0	0	0	0	0	0	0	0	1	0	0	0	0	13	0	0
Tanytarsini																
Tanytarsini type 1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0
pupae	0	0	0	2	0	0	0	1	0	0	0	0	0	1	0	0
Orthocladiinae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cricotopus	0	0	9	0	0	0	0	25	0	0	0	0	0	0	0	0
Orthoclad unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanypodinae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Ablabesmyia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Procladius	2	1	0	2	0	0	1	1	1	5	0	0	2	0	0	0
Ceratopogonidae																
Bezzia sp.	0	2	0	1	0	0	0	0	0	0	0	1	2	19	0	1

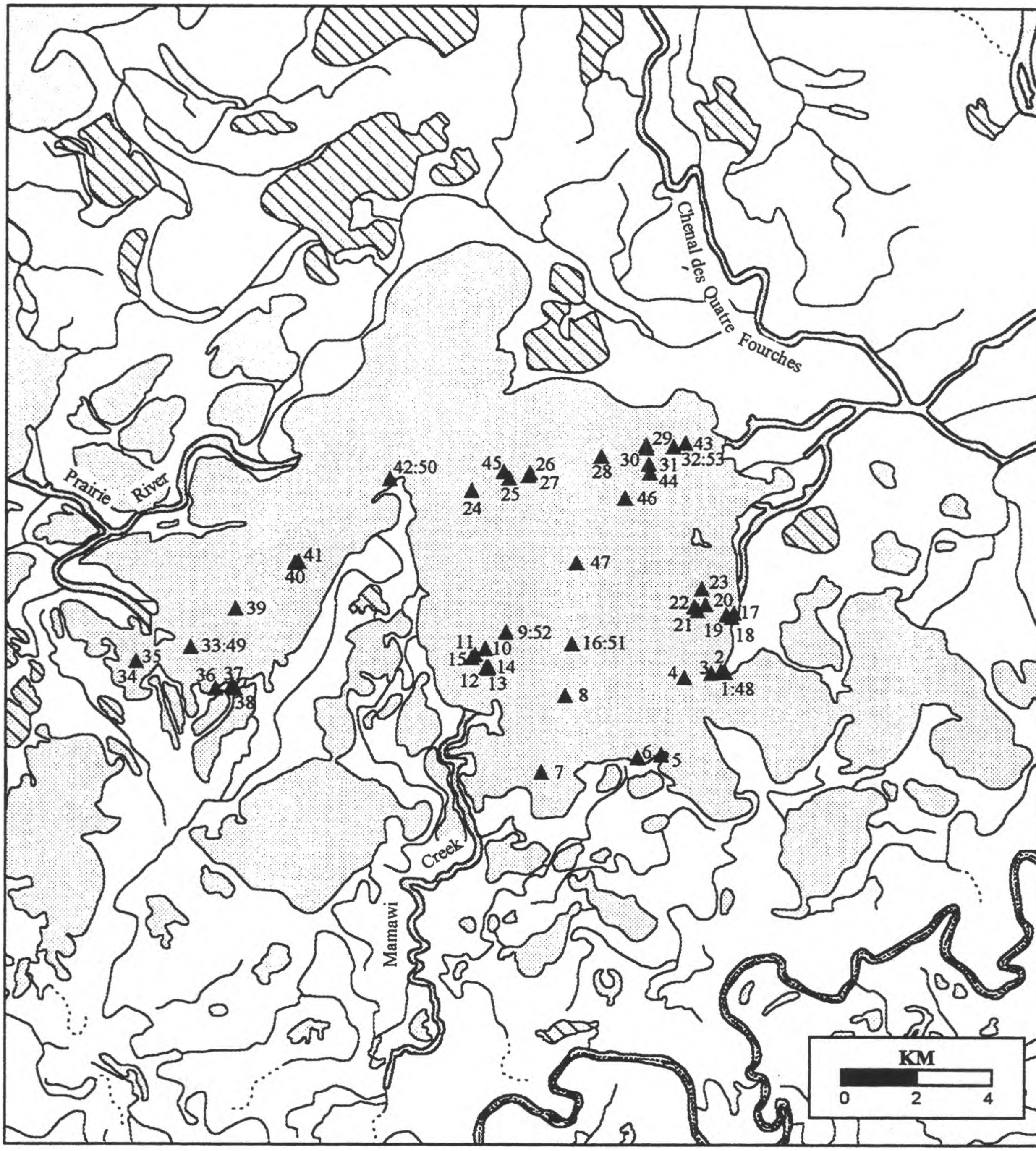
[1] Single specimens were also collected of Chaetogaster (Oligocheata), Helobdella stagnalis (Hirudinea), Pyralidae (Lepidoptera), Simulium (Simuliidae), Glyptotendipes (Chironomidae), Derotanypus (Chironomidae), Tanypus (Chironomidae), Paracladius (Chironomidae) and Stempellinella (Chironomidae).

Appendix F. Abundance of macroinvertebrates for Mamawi Lake, June 18 to 26, 1994,

Taxa	Site 17	Site 18	Site 19	Site 20	Site 21	Site 22	Site 23	Site 24	Site 25	Site 26	Site 27	Site 28	Site 29	Site 30	Site 31	Site 32
Lumbriculidae																
Stylodrilus sp.	13	0	9	6	7	3	1	0	0	2	2	0	9	4	0	10
Tubificidae	0	0	1	0	2	0	0	0	0	0	0	0	0	0	1	0
Gastropoda																
Prosobranchia																
Valvatidae																
Valvata tricarinata	0	3	1	0	2	1	0	0	0	0	0	0	0	0	0	0
Valvata sincera helicoidea	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Hydrobiidae																
Probythinella lacustris	0	1	0	0	0	0	0	0	1	0	0	0	0	0	2	0
Pulmonata																
Planorbidae																
Promenetus umbilicatellus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physidae																
Physa sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pelecypoda																
Sphaeriidae																
Pisidium sp	0	27	11	6	3	5	0	10	34	3	13	1	41	19	13	9
Sphaerium sp.	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda	2	0	2	1	0	4	0	0	0	1	0	1	2	0	0	0
Arthropoda																
Crustacea																
Conchosrtaca																
Caenestherella belfragei	0	0	0	0	0	0	0	0	1	0	2	1	0	0	1	0
Ostracoda	0	1	0	2	0	1	1	0	0	0	0	0	0	0	0	0
Amphipoda																
Diporeia hoyi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Insecta																
Hemiptera																
Corixidae (imm.)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Trichoptera																
Leptoceridae																
Oecetis sp.	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Molannidae																
Molanna sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ephemeroptera																
Tricorythodidae																
Tricorythodes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera																
Chironomidae (pupae)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomini	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomus	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Cryptochironomus	1	3	4	3	3	0	3	0	0	1	0	0	0	0	0	1
Cryptotendipes	0	11	13	3	0	0	12	0	1	0	0	0	0	0	0	0
Dicrotendipes	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Harnischia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polypedilum	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0
Tanytarsini																
Tanytarsini type 1	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
pupae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Orthocladiinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cricotopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orthoclad unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanypodinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ablabesmyia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Procladius	0	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae																
Bezzia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

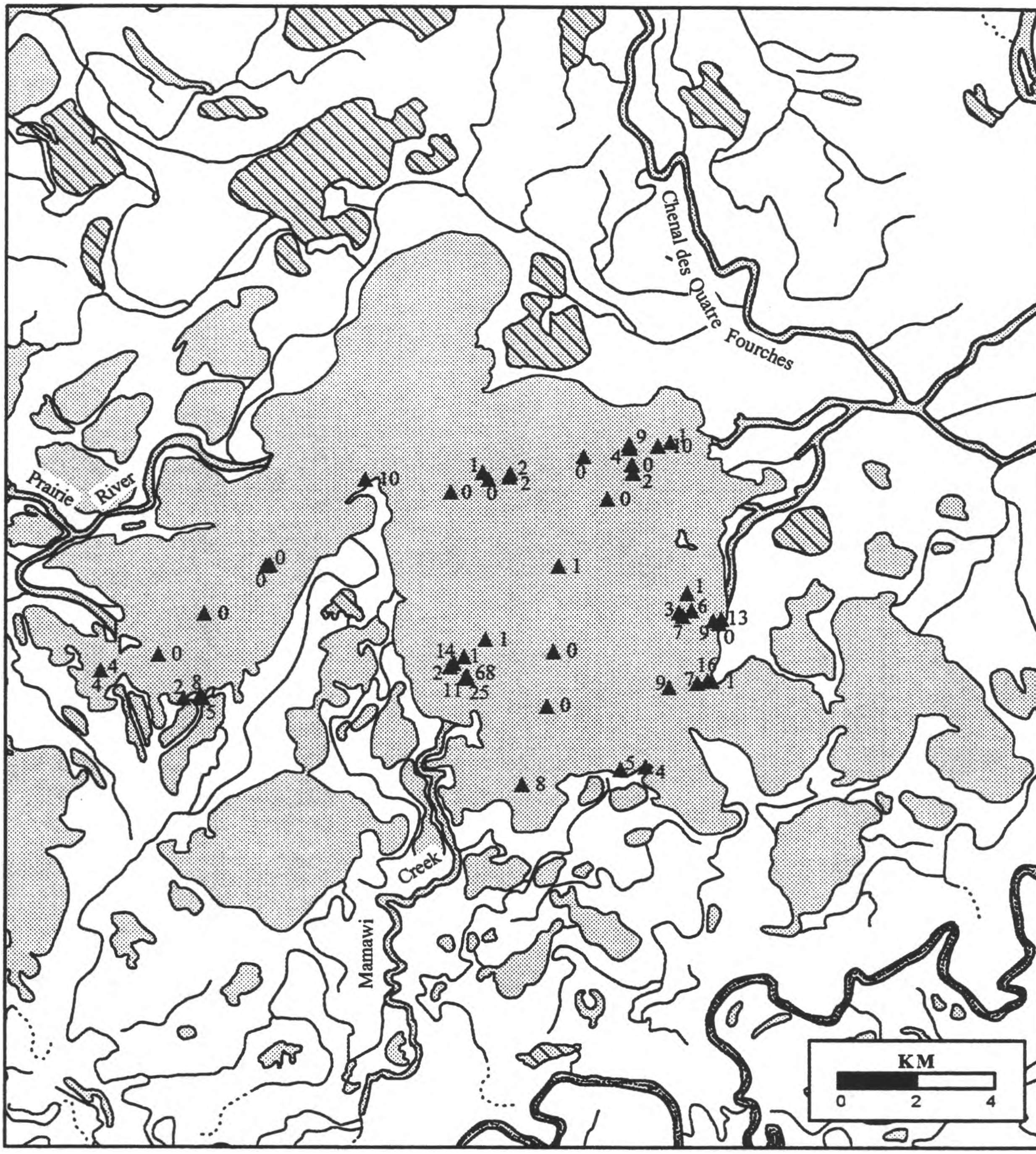
Appendix F. Abundance of macroinvertebrates for Mamawi Lake, June 18 to 26, 1994,

Taxa	Site 33	Site 34	Site 35	Site 36	Site 37	Site 38	Site 39	Site 40	Site 41	Site 42	Site 43	Site 44	Site 45	Site 46	Site 47
Lumbriculidae															
Stylodrilus sp.	0	4	4	2	8	5	0	0	0	10	1	2	1	0	1
Tubificidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gastropoda															
Prosobranchia															
Valvatidae															
Valvata tricarinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valvata sincera helicoidea	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobiidae															
Probythinella lacustris	0	0	1	0	0	0	0	0	0	5	0	0	0	0	0
Pulmonata															
Planorbidae															
Promenetus umbilicatellus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physidae															
Physa sp.	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Pelecypoda															
Sphaeriidae															
Pisidium sp	0	23	5	32	0	0	14	2	1	4	0	3	5	16	7
Sphaerium sp.	1	2	0	0	0	0	0	0	0	5	0	0	0	0	0
Nematoda	0	0	1	0	2	3	0	0	0	0	0	1	0	0	0
Arthropoda															
Crustacea															
Conchosrtaca															
Caenestherella belfragei	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0
Ostracoda	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Amphipoda															
Diporeia hoyi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Insecta															
Hemiptera															
Corixidae (imm.)	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Trichoptera															
Leptoceridae															
Oecetis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Molannidae															
Molanna sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Ephemeroptera															
Tricorythodidae															
Tricorythodes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera															
Chironomidae (pupae)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Chironomini	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Chironomus	0	3	2	1	1	0	0	0	0	0	0	0	0	0	1
Cryptochironomus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cryptotendipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dicrotendipes	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Harnischia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polypedilum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanytarsini															
Tanytarsini type 1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orthocladiinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cricotopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orthoclad unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanypodinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ablabesmyia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Procladius	8	6	1	0	0	2	0	0	0	0	0	0	0	1	0
Ceratopogonidae															
Bezzia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

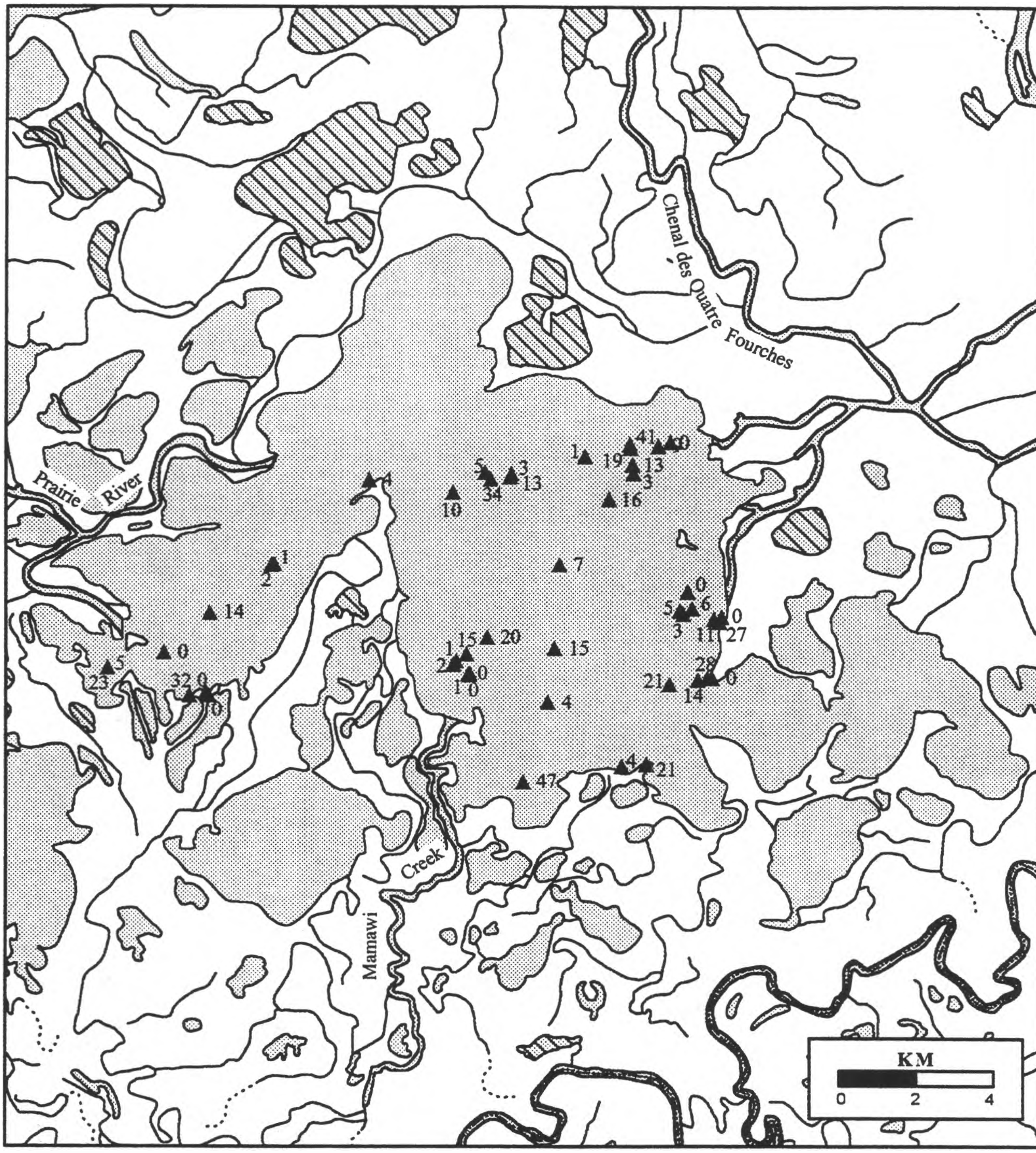


Appendix G. Collection sites for macrobenthic invertebrates

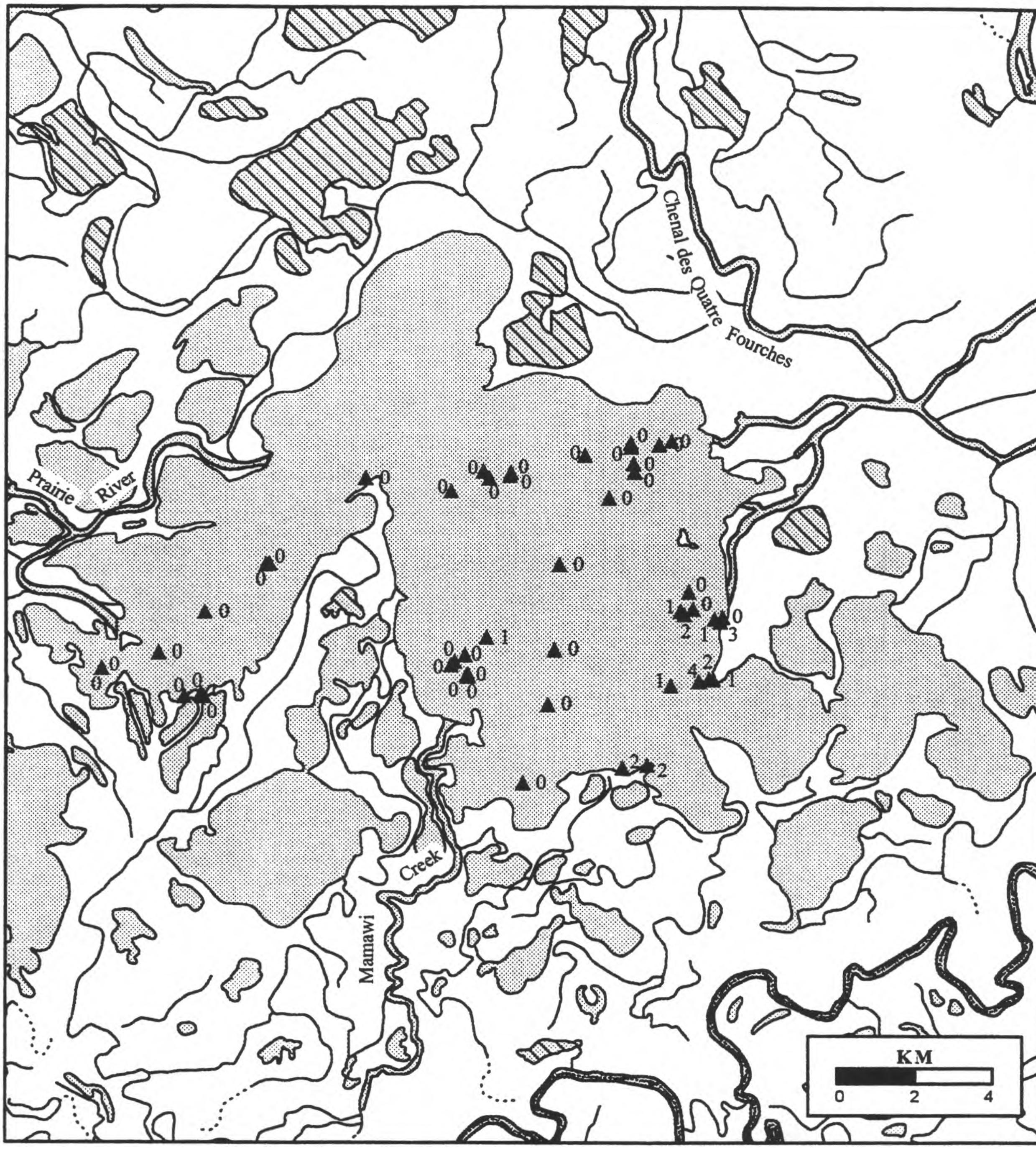
Mamawi Lake, 18-26 June 1994 (15x15 cm Ekman grab).



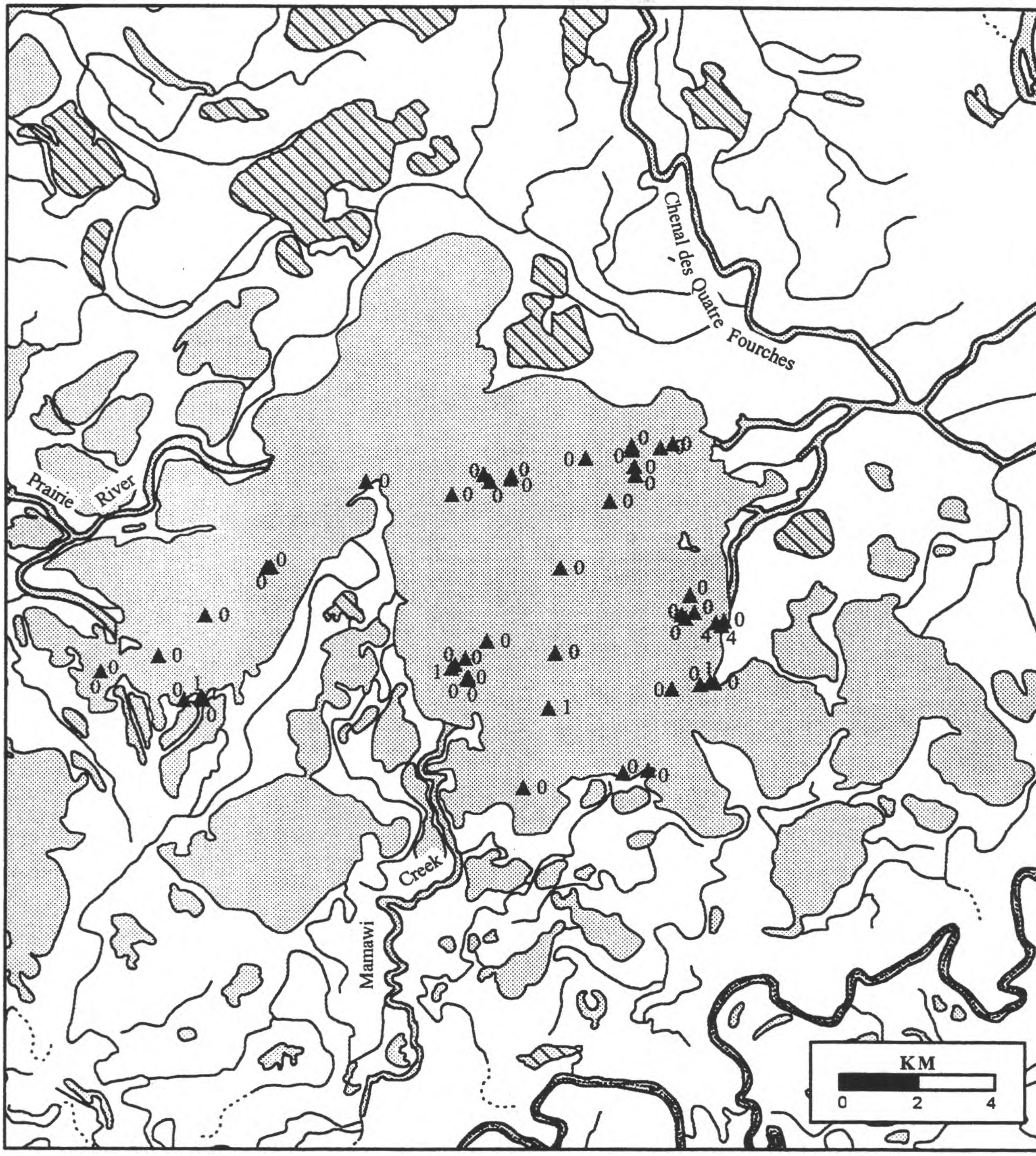
Appendix H1. Distribution and number per sample of Stylodrilus sp. in Mamawi Lake, June 1994.



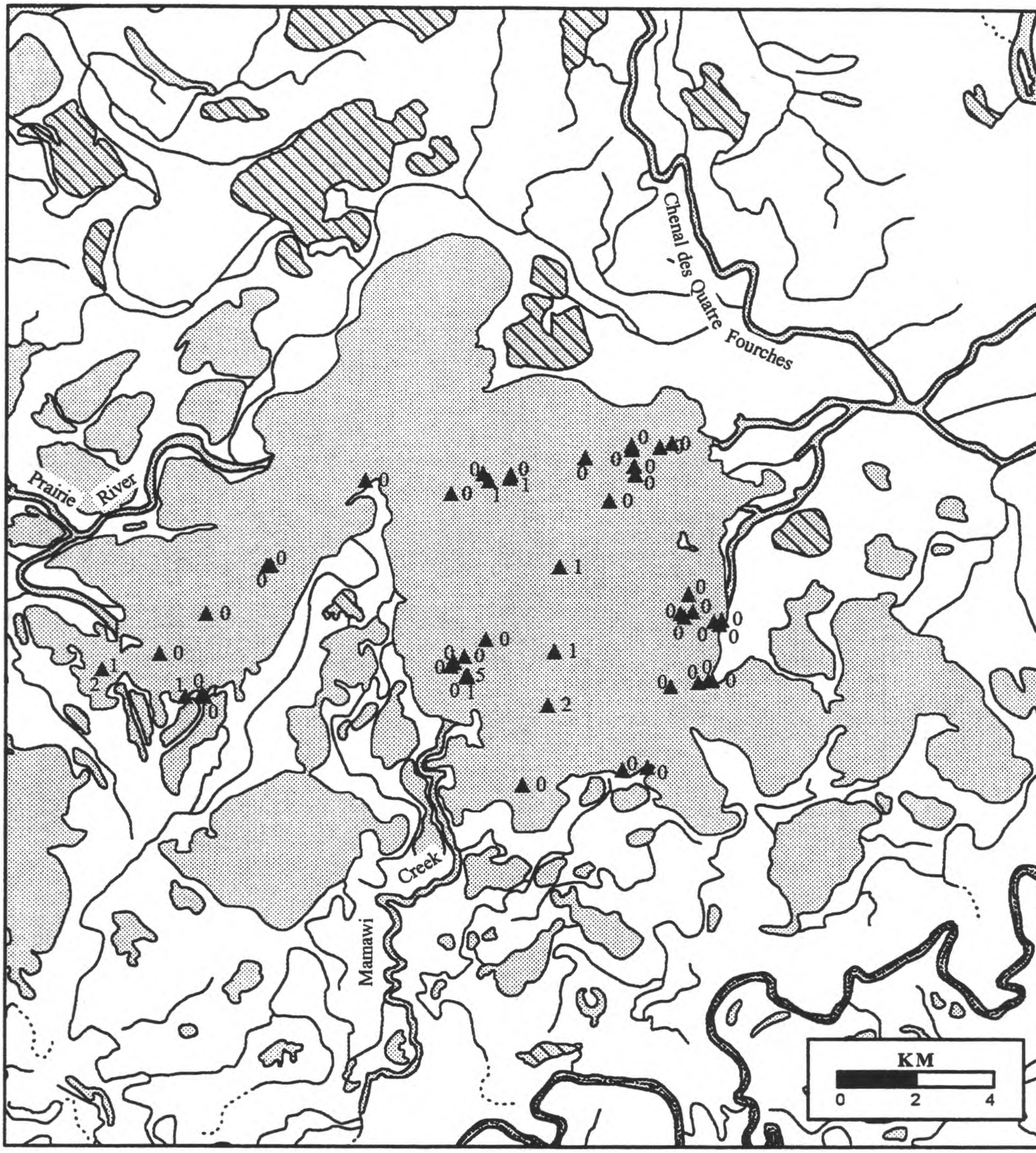
Appendix H2. Distribution and number per sample of Pisidium sp. in Mamawi Lake, June 1994.



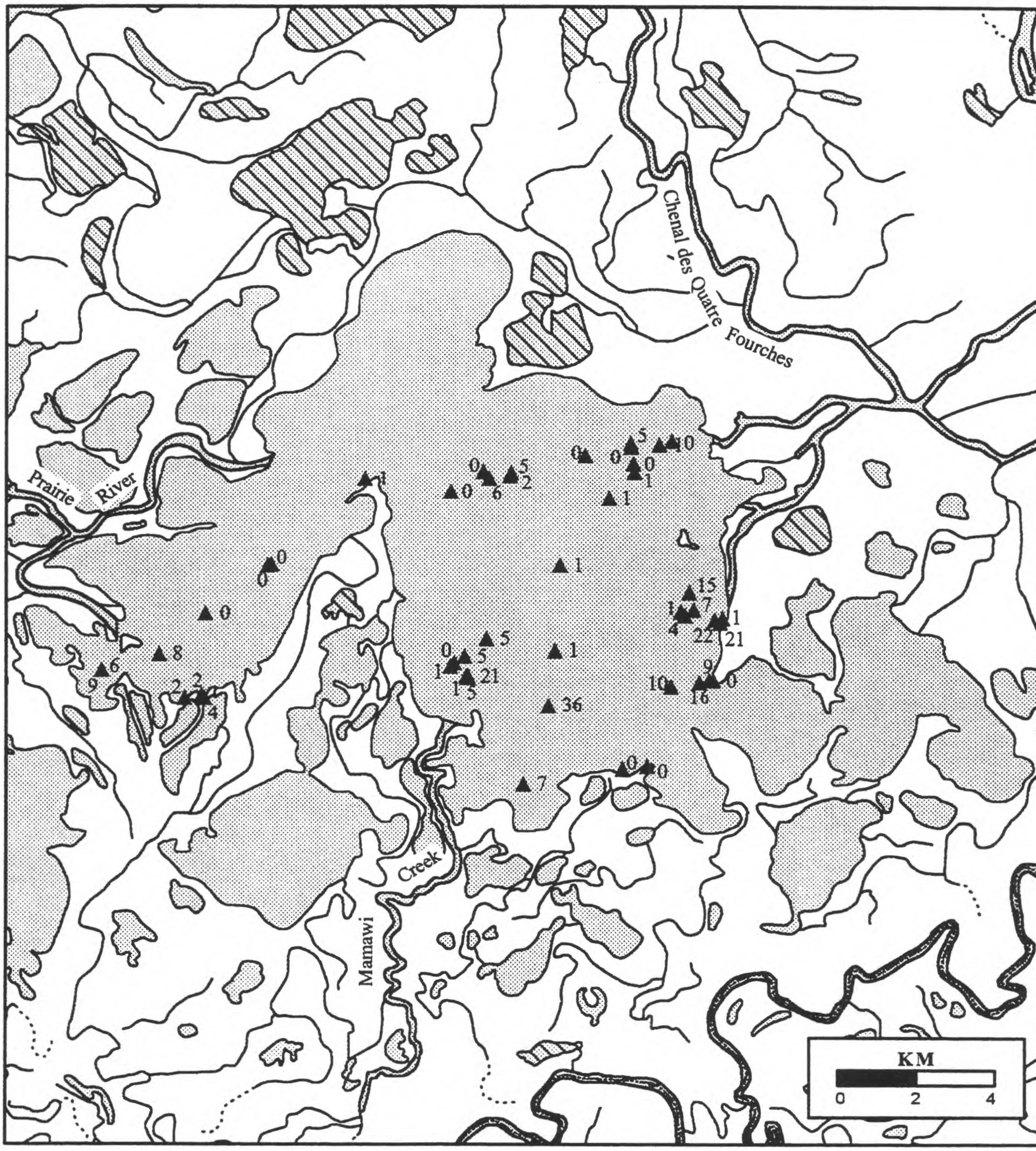
Appendix H3. Distribution and number per sample of Valvata tricarinata perconfusa in Mamawi Lake, June 1994.



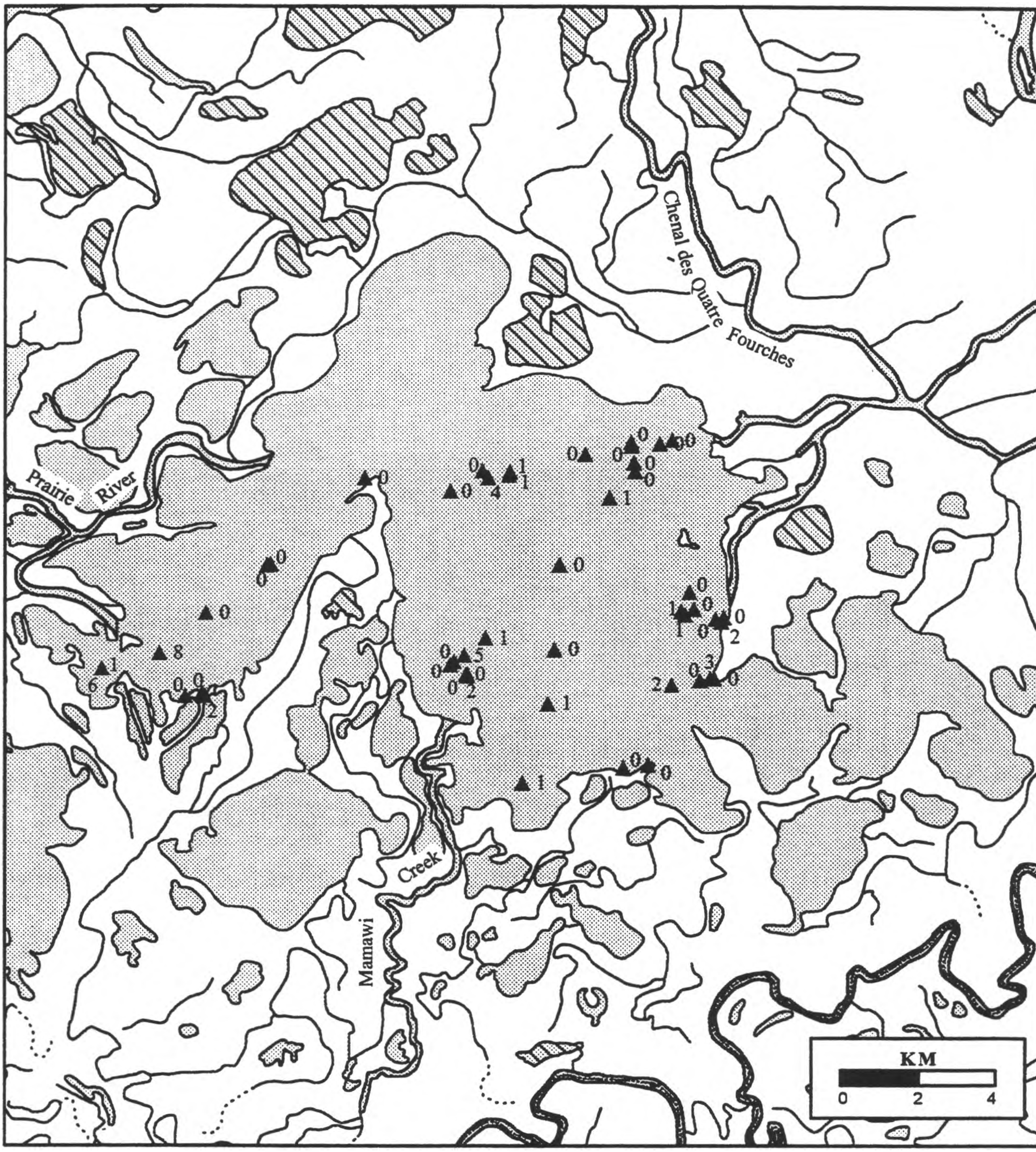
Apendix H4. Distribution and number per sample of Tanytarsini type 1 in Mamawi Lake, June 1994.



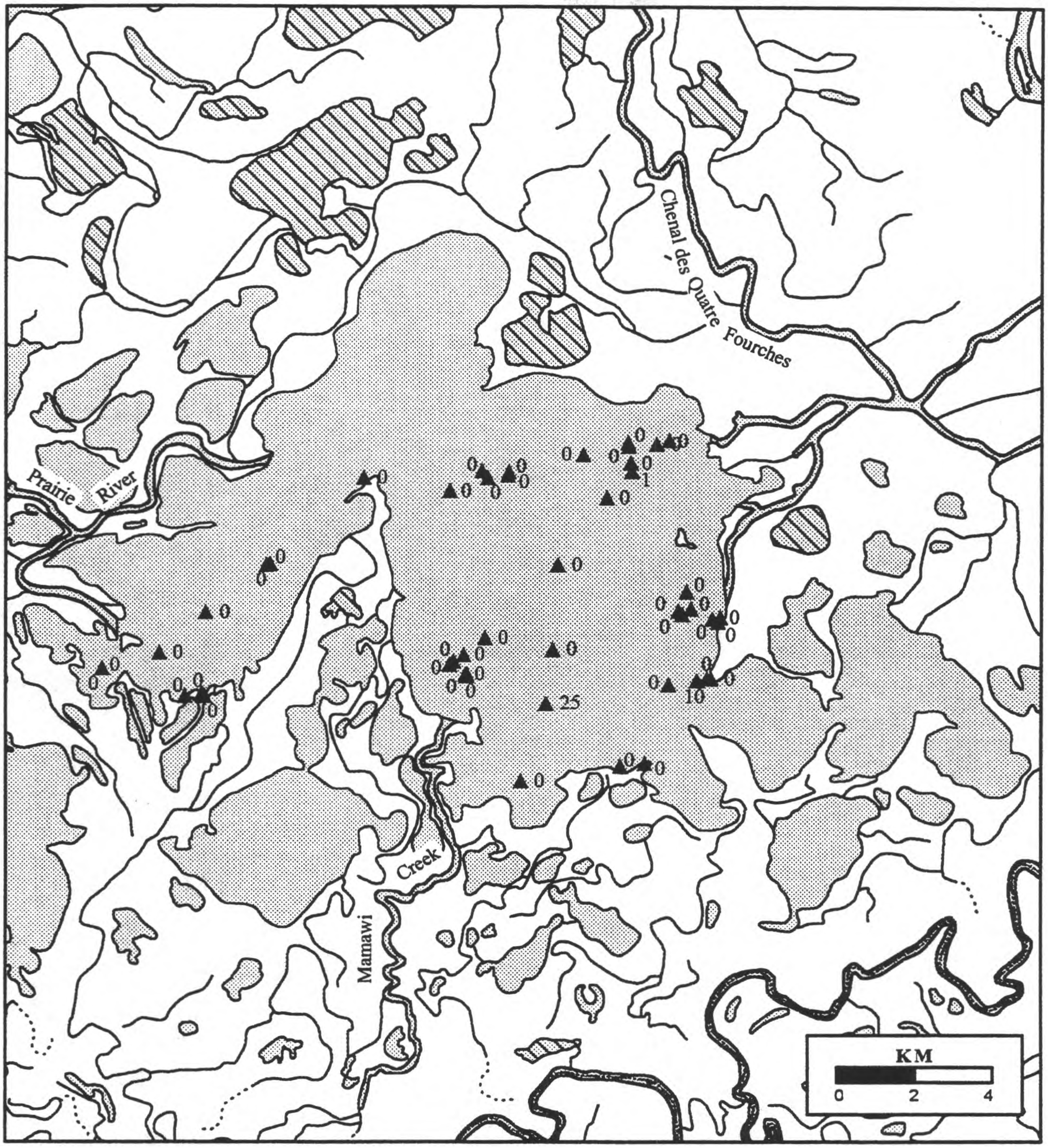
Appendix H5. Distribution and number per sample of Chironomus in Mamawi Lake, June 1994.



Appendix H6. Distribution and total number per sample of Chironominae in Mamawi Lake, June 1994.

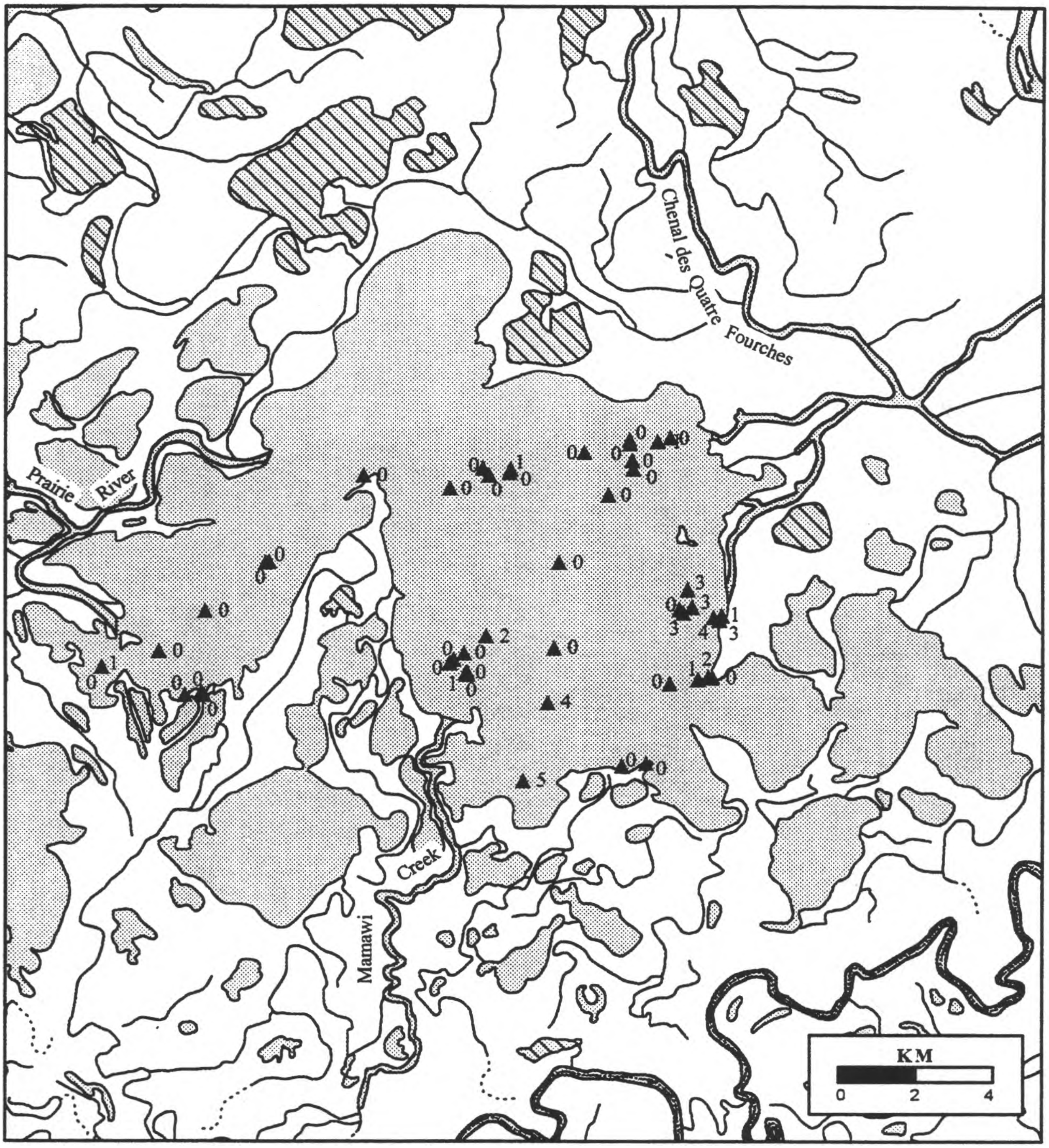


Appendix H7. Distribution and number per sample of Procladius in Mamawi Lake, June 1994.

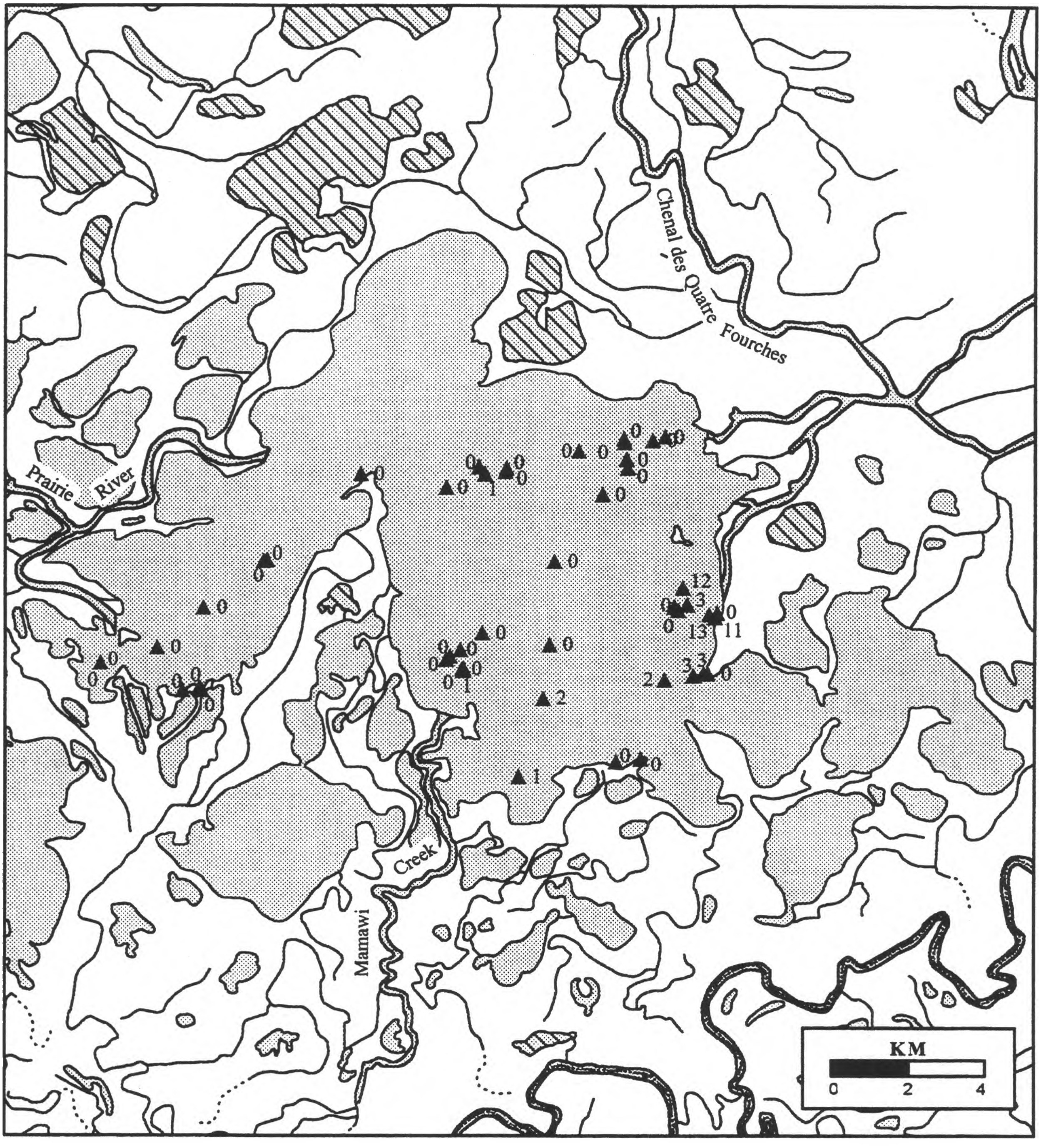


Appendix H8. Distribution and number per sample of

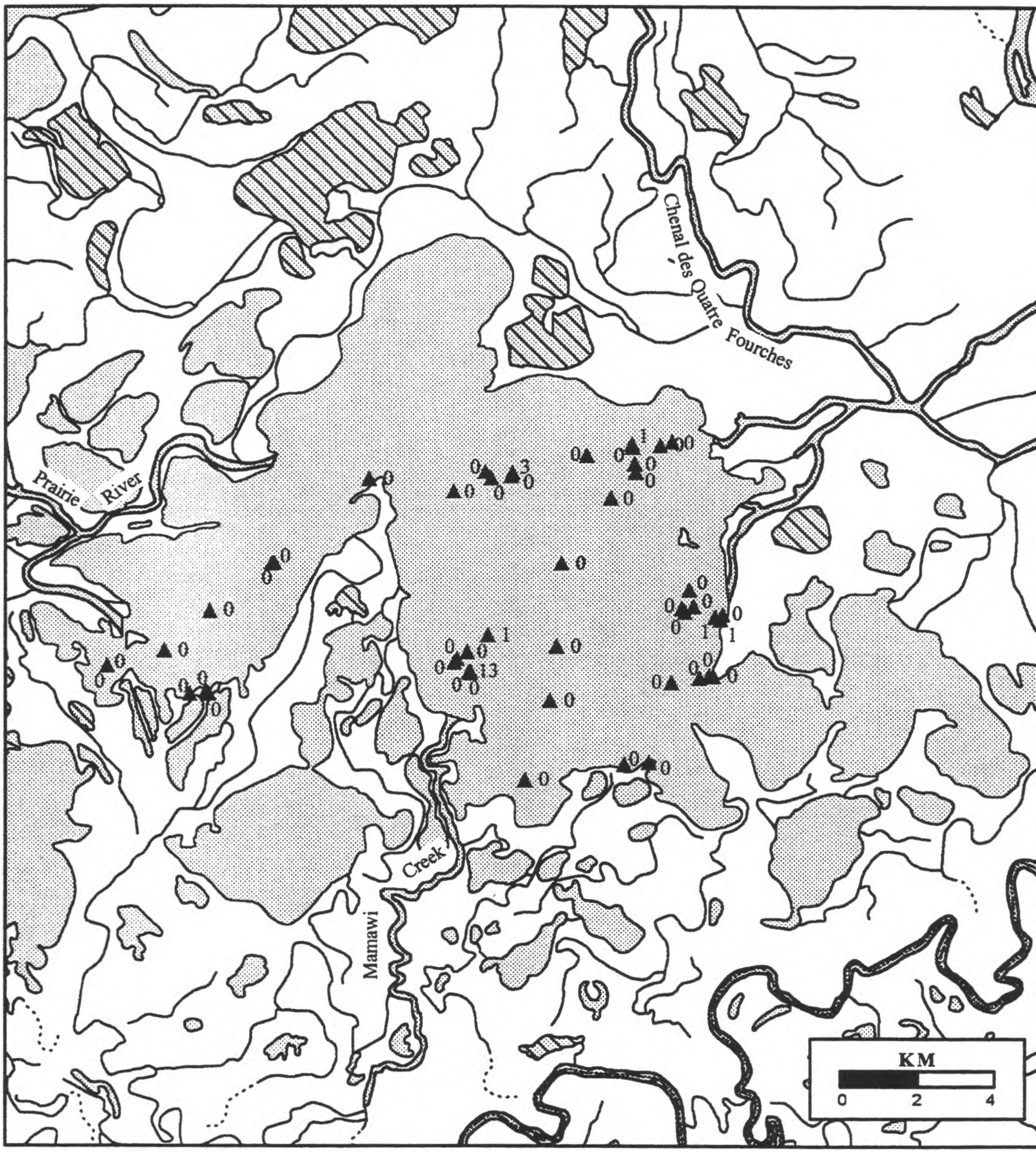
Cricotopus in Mamawi Lake, June 1994.



Appendix H9. Distribution and number per sample of Cryptochironomus in Mamawi Lake, June 1994.



Appendix H10. Distribution and number per sample of Cryptotendipes in Mamawi Lake, June 1994.



Appendix H11. Distribution and number per sample of Polypedilum in Mamawi Lake, June 1994.

NORTHERN RIVER BASINS STUDY

APPENDIX I - TERMS OF REFERENCE

Project 5212-D1: Goldeye as an Indicator Species for the Peace-Athabasca Delta

I. BACKGROUND

Goldeye are a dominant and valued fish species that spawn and feed in the Peace-Athabasca Delta. This population has been monitored in an ad hoc manner since 1971, and fundamental knowledge on feeding, migration, growth, and recruitment patterns have bee assembled (Donald and Kooyman 1977, Kristensen and Summer 1978, Kristensen 1981, and Donald et al. 1992). Furthermore, these studies have shown that to determine effects of Peace River regulation on the vitality of the goldeye population requires long-term monitoring.

Results from the study proposed here would contribute to an assessment of the effects of Peace River regulation on the Delta goldeye population.

At present, monitoring of biological aspects of Peace and Athabasca river ecosystems is restricted to regular assessments of metal contaminants in fish species of commercial value in the west end of Lake Athabasca, and the ad hoc assessment of goldeye populations described above. Both of these could be integrated into long-term monitoring programs under recommendations of the Northern River Basins Study. Goldeye in particular are a suitable candidate for an indicator species for assessing health of the Peace-Athabasca Delta because they are:

1. an abundant species,
2. a valued component of the Delta ecosystem, and
3. sensitive to environmental contaminants (MFO induction - Brownlee unpublished data).

In addition to goldeye, relative abundance of all fish species caught in gill-nets would be recorded.

A detailed account of the distribution abundance of benthic invertebrates in Mamawi Lake would be determined. Mamawi Lake was chosen over other delta lakes because it is directly connected to the Athabasca River, and is the first delta lake to receive water from the Peace River when high Peace River water levels reverse flow in outlet channels or when floods occur.

Results from the study proposed here would contribute to the development of a long-term monitoring program for indicator species for the Peace-Athabasca Delta with goldeye and one or more benthic invertebrates the target species.

II. OBJECTIVES

To determine the catch-per-unit-effort (CPUE) of goldeye from the Mamawi-Claire lakes area of the Peace-Athabasca delta in 1994, and compare 1994 CPUE and relative abundance of other fish species with similar data obtained from the delta before and after the effects of flow regulation.

To determine and record the occurrence, relative abundance, and population characteristics of fish, zooplankton, and benthic invertebrate species. From these data develop an effective and efficient long-term monitoring program to assess the health of the Delta ecosystem.

III. PROJECT REQUIREMENTS

FISH

1) Using survey gill-nets with mesh size ranging from 3.8 to 10.2 cm determine the CPUE of goldeye (number of goldeye caught per 100 m of net per hour) at 10 established catch sites within Mamawi and Claire lakes. Produce a map of the catch sites for 1994 and earlier years, and geo-reference the location of the sites.

2) Capture a minimum of 200 goldeye and measure their fork length and total length in addition to determining sex and reproductive status. Collect scales and an operculum from each fish.

3) Record the geo-referenced location number and species of all other fish caught in gill-nets.

4) Determine the overall CPUE and the length, weight, and age frequency of goldeye from the 1994 catch, and compare these data with similar information collected in the 1970s, 1980s, and 1990s. Identify any long-term trends or patterns that are evident in this assessment.

5) Develop and recommend a long-term cost effective monitoring program that would assess the status and health of the fish community of Mamawi and Claire lakes.

INVERTEBRATES

6) Collect a statistically significant number of water quality and zooplankton samples from Mamawi Lake. Geo-reference the collection site of all samples.

7) Collect up to 100 benthic samples from Mamawi Lake, focusing on areas near the outlet of Cree Creek, Quatre Fourche, and Prairie River. Produce a map of the collection sites, and geo-reference the location of all sample sites.

8) Benthic samples collections are to be stratified by area, by 0.5 m depth contours, by absence of submergent and emergent aquatic macrophytes, and by distance from the shoreline.

9) Determine the number and genera (or species) of benthic invertebrates in an appropriate number of samples for each site and strata.

10) Using statistical procedures and common sense, develop and recommend a cost effective long-term monitoring program that would assess the health of the benthic and zooplankton communities in Mamawi Lake, and where appropriate, identify links between the benthic invertebrate/zooplankton and the fish communities to the Peace-Athabasca Delta.

11) Utilize local contractors and services for the field studies.

IV. REPORTING REQUIREMENTS

1). All sampling locations presented in report and electronic format should be geo-referenced. This is to include decimal latitudes and longitudes (to six decimal places) and UTM coordinates. The first field for decimal latitudes / longitudes should be latitudes (10 spaces wide). The second field should be longitude (11 spaces wide).

2) All figures and maps are to be delivered in both hard copy (paper) and digital formats. Acceptable formats include: DXF, uncompressed E⊘⊘, VEC/VEH, Atlas and ISIF. All digital maps must be properly geo-referenced.

3) Prepare a comprehensive report documenting field work, analysis and synthesis of the project.

Ten copies of the Draft Report, along with an electronic copy, are to be submitted to the Project Liaison Officer by November 30, 1994.

4) Three weeks after the receipt of review comments on the draft report, submit ten cerlox bound copies and two unbound, camera-ready copies of the final report to the certification officer. At the same time submit an electronic copy, in Word Perfect 5.1 Dos or Word Perfect 6.0 Windows format on 5¼ or 3½ inch floppy disk, of the final report to the certification officer. Please follow the report format standard as stated in the NRBS "A Guide for the Preparation of Reports". An electronic copy (Dbase IV format on floppy disk) of data used to develop figures, tables and appendices in the final report is also to be submitted to the Project Liaison Officer. The final report is to include a Project Summary, Table of Contents, List of Tables, List of Figures and an Appendix which includes the Terms of Reference for this project.

Text for the report should be set up in the following format:

a) Times Roman 12 point (Pro) or Times New Roman (WPWIN60) font.
b) Margins; are 1" at top and bottom, 7/8" on left and right.
c) Headings; in the report body are labelled with hierarchical decimal Arabic numbers.

d) Text; is presented with full justification; that is, the text aligns on both left and right margins.

e) Page numbers; are Arabic numerals for the body of the report, centred at the bottom of each page and bold.

- If photographs are to be included in the report text they should be high contrast black and white.
- All tables and figures in the report should be clearly reproducible by a black and white photocopier.
- Electronic copies of tables, figures and data appendices in the report are also to be submitted to the Project Liaison Officer along with the final report. These should be submitted in a spreadsheet (Quattro Pro preferred, but also Excel or Lotus) or database (dBase IV) format. Where appropriate, data in tables, figures and appendices should be geo-referenced.

V. PROJECT ADMINISTRATION

The Scientific Authority for this project is:

David Donald
Head, Surveys and Objectives Division
Environment Canada
Room 300, Park Plaza
2365 Albert Street
Regina, Saskatchewan S4P 4K1
phone: (306) 780-6723
fax: (306) 780-5311

Questions of a scientific nature should be directed to him.

The NRBS Study Office Liaison Officer for this project is:

Ken Crutchfield
Associate Science Director
Office of the Science Director
Northern River Basins Study
690 Standard Life Centre
10405 Jasper Avenue
Edmonton, Alberta T5J 3N4
phone: (403) 427-1742
fax: (403) 422-3055

Administrative questions related to this project should be directed to him.

VI. REFERENCES

Donald, D.B., and A.H. Kooyman. 1977. Migration and population dynamics of the Peace-Athabasca delta goldeye population. Canadian Wildlife Service Occasional Paper 31.

Donald, D.B., J.A. Babaluk, J.F. Craig, and W.A. Musker. 1992. Evaluation of the scale and operculum methods to determine age of adult goldeyes with special reference to a dominant year-class. Transactions of the American Fisheries Society 121:792-796.

Kristensen, J. 1981. Investigations of goldeye and other fish species in the Wood Buffalo National Park section of the Peace-Athabasca delta, 1977. Canadian Manuscript Report of Fisheries and Aquatic Sciences 1560.

Kristensen, J., and S.A. Summers. 1978. Fish populations in the Peace-Athabasca delta and the effects of water control structures on fish movements. Canada Fisheries and Marine Service Manuscript Report 1465.