THE UNIVERSITY OF MANITOBA

Relative Abundance and Biomass, Age, and Growth of Yellow Perch, *Perca flavescens* (Mitchill), in Four Adjacent Man-Made Lakes in Southern Manitoba

by

Raymond A. Ratynski

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RELATIVE ABUNDANCE AND BIOMASS, AGE,

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ABSTRACT

Characteristics of populations of yellow perch, *Perca flavescens* (Mitchill), in four adjacent man-made lakes in southern Manitoba were examined during the open water periods of 1978 and 1979. Studies of the physical and chemical regimes of the Fort Whyte lakes during 1977-1978 indicated greatest eutrophy in Lakes I and II and lowest in Lakes III and IV. Relative perch abundance and biomass values in 1979 were highest in Lake I but were similar for Lakes II, III, and IV. Dissimilarity of recruitment of the 1977 and 1978 year classes between Lake I and the other three lakes is attributed to intraspecific predation of young perch by numerous adult perch in Lake I. Older perch dominated the catch in Lake I while the newly recruited one-year-olds formed 9% of the population in 1978 and 3% in 1979. In the other lakes there were fewer old perch. In 1978, age 1 perch made up 33%, 44% and 26% of the population in Lakes II, III, and IV respectively. In 1979, they represented 65% of the population in Lake II, 64% in Lake III, and 69% in Lake IV. Among Lakes II, III, and IV, mean length of perch at time of annulus formation in 1978 was highest in Lake II and lowest in Lake IV for all ages.

In comparison to the other lakes, yellow perch in Lake I had the highest mean length for ages less than 3 but the lowest mean length for ages greater than 3. These differences were not great in magnitude. At the time of annulus formation in 1979, there were no significant differences in mean lengths at each age. In comparison to other North American waters, growth of perch at Fort Whyte was slow. The major response of the perch population in Lake I to greater eutrophy was to increase its biomass but this was by increasing population size rather than by increasing growth. The perch population of Lake II failed to respond similarly perhaps because nutrient input to the lake is sporadic and sustained loading is required for increased productivity. A greater magnitude of difference in perch biomass than in perch abundance between Lake I and Lakes II, III, and IV is attributed to higher incidence of older, larger fish in Lake I.

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INTRODUCTION

Analyses of the characteristics of populations of yellow perch, Perca flavescens (Mitchill), are common but comparisons between populations are less frequent. Grimaldi and Leduc (1973) investigated growth of perch in six areas of Quebec and attempted to relate growth differences to environmental dissimilarities of the habitats. Nakashima and Leggett (1975) related differences in perch biomass of the north and south basins of Lake Memphremagog, Quebec-Vermont, to differences in basin productivity. Recently, Hopky (1982) compared perch population characteristics between two saline-eutrophic lakes in southwestern Manitoba.

The Fort Whyte lakes, located in southwestern Winnipeg, Manitoba, are small man-made lakes resulting from dredging activities extending over a seventy year period. Although adjacent to one another, the four lakes differ in their physical and chemical regimes (Ward and Loadman MS 1981). Loadman (1980) found that zooplankton abundance and timing of seasonal maxima of zooplankton varied among lakes. For instance, the total numbers of zooplankton per unit volume from June 1977 to June 1978 were always highest in Lake I, second highest in Lake II, and lowest in Lake IV (Loadman 1980).

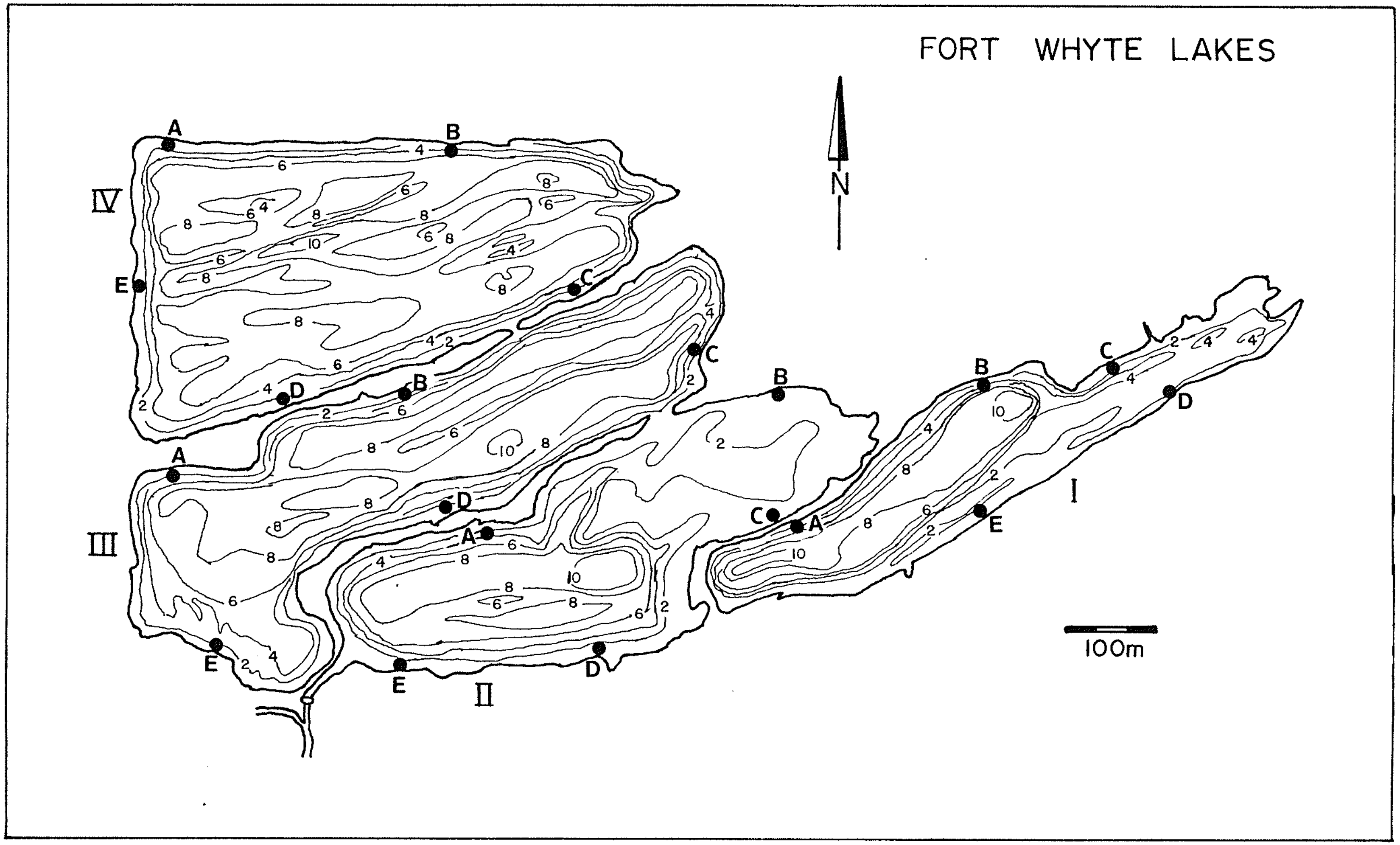
The perch populations at Fort Whyte were investigated to determine if they had distinct characteristics associated with each lake. The main objectives of this research were to determine relative abundance and biomass of perch in each lake, to define the age and length structures of the populations, and to estimate the growth characteristics of the four perch populations. Comparisons of the above parameters were made among the lakes. The results of this investigation will be related to lake characteristics and to the characteristics of the zooplankton populations. Sampling was performed during the ice-free periods of 1978 and 1979.

LAKE DESCRIPTIONS

Fort Whyte is located at the southwestern extremity of Winnipeg, Manitoba. The four lakes investigated are located on land owned by the Canada Cement Lafarge, Ltd. and were originally excavated for clay used in cement making. Recorded history of the system is sparse and incomplete. Lake I was completed by 1920. Lake II was completed in the late 1940's. Excavation of Lake III began in 1951 and ended in 1962. Work on Lake IV began in the latter part of 1962 and dredging of its north shore currently continues. The two oldest lakes were partly dug by horse-drawn draglines, which accounts for their shallow east ends (Fig. 1). The deeper western portions of their basins and Lakes III and IV were formed entirely by mechanical draglines.

Lakes II, III, and IV are sometimes joined by shallow channels (Fig. 1). These developed between II and III during the period of 1957-1967 and between III and IV during 1967-1977. A drainage ditch empties into the southwest end of Lake II in spring in years when lake levels are low. When lake levels are high, water may flow out through the ditch. As well, all four lakes are joined when high spring water levels overfill the lake basins, as occurred in the spring of 1979. Lake I receives runoff from waterfowl ponds located on its south shore.

Figure 1. Contour map of the Fort Whyte lakes indicating the main sampling stations. Depths are in m.



FORT WHYTE LAKES
N
100m
I
II
III
IV
A
B
C
D
E

Lake I is maintained as a reservoir for water utilized as a coolant in the nearby cement plant. Water is pumped from and then returns slightly warmed to the east part of the lake. Some is lost in the process and water is pumped from Lake II into the extreme west end of Lake I to replenish supplies. However, since pumping does not begin until the water level in Lake I drops by 1 m or more, fluctuations in level occur.

Except for the short periods as mentioned above, the Fort Whyte lakes are isolated entities with little exchange of water between them and with little flow from the surrounding area.

The lakes differ in most morphometric measurements, although maximum depth is the same (Table 1). Area and volume increase from Lake I to Lake IV. Mean depth is lowest in Lakes I and II and highest in Lakes III and IV. Where excavation by a mechanically operated dragline occurred, the lake basins are steep sided. As a result, the littoral zone of Lakes III and IV and of the west ends of Lakes I and II are not large in extent. For their surface areas, the lakes are very deep.

Ice usually leaves the Fort Whyte lakes between late April and mid May with the east part of Lake I the first area to clear (possibly the flow of water returning from the cement plant accelerates ice breakup). Lake I is completely open one or two weeks before Lake II and two or three weeks

Table 1. Morphometry of the Fort Whyte Lakes (1977-78).

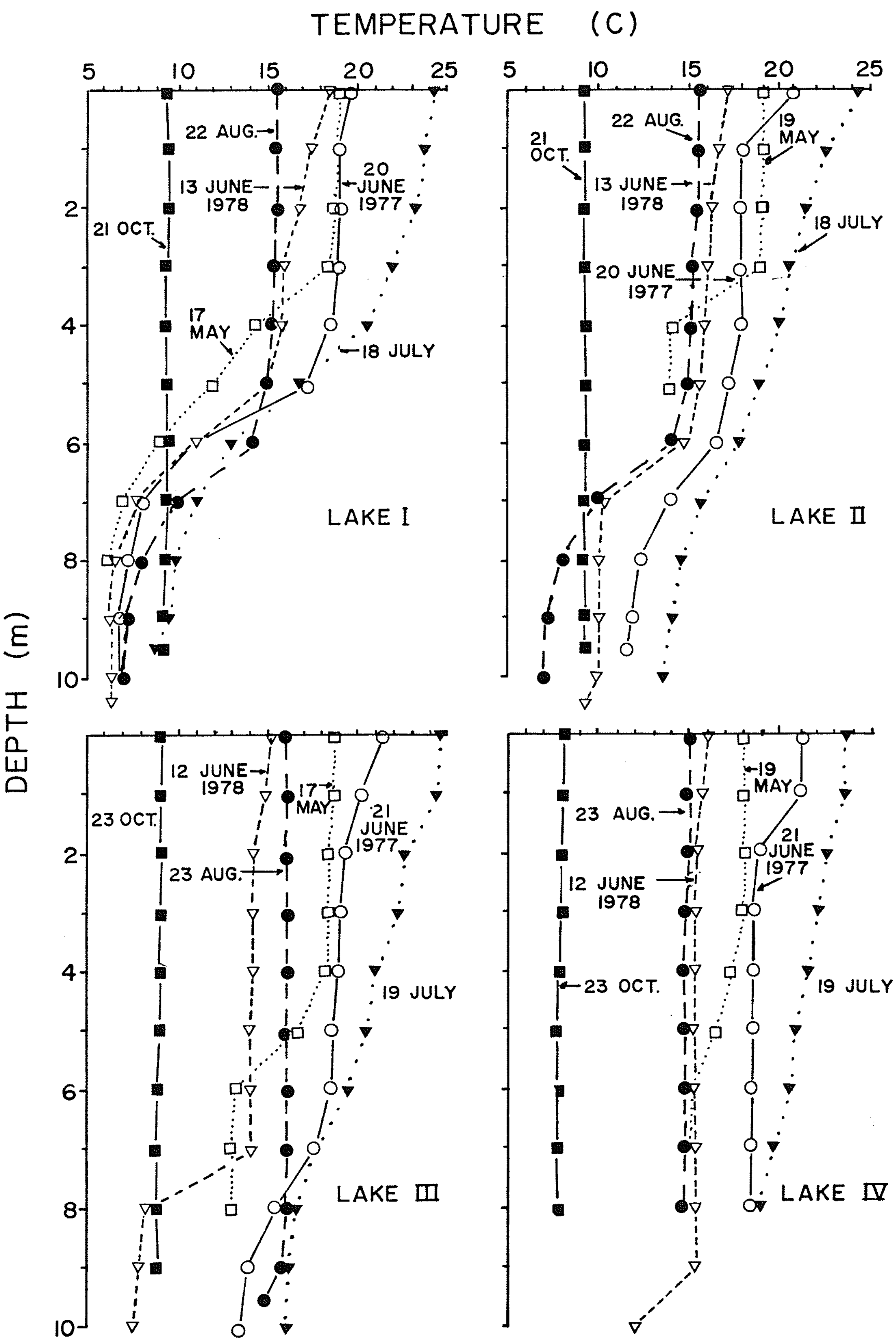
	LAKE			
	I	II	III	IV
Maximum length (km)	.72	.64	.75	.65
Maximum width (km)	.14	.22	.28	.32
Maximum depth (m)	10	10	10	10
Area (ha)	6.43	9.26	11.27	13.35
Mean depth (m)	4.31	4.12	6.07	6.07
Volume (m^3)	276,000	383,000	686,000	807,000

before Lakes III and IV. In 1977, thermal stratification in Lake I was well established by mid May (Fig. 2). Epilimnion temperature was about 20°C to a depth of 3 m. Temperature of the metalimnion, which extended from 3 m to 7 m, dropped from 20°C to 7°C at the lower limit (Ward *et al*., unpublished). The hypolimnion extended below 7 m. Thermal stratification continued to develop during the summer. In mid July the epilimnion extended to 4 m and the surface temperature was 24°C. By the end of August the epilimnion began to cool, and by October 21 the entire water column was presumably mixing at a constant 9°C.

In Lake II the temperature regime was similar, although thermal stratification was not so pronounced. In July, the boundary of the epilimnion and metalimnion was obscure, indicating that mixing was occurring at greater depths than in Lake I (Fig. 2). Lake III stratified only briefly during calm periods. The hypolimnion temperature, always above 12°C in spring and summer, indicates some mixing was occurring. Lake IV showed the least evidence for thermal stratification. Constant mixing, as indicated by the relatively uniform temperature of the water column, occurred throughout the ice-free season (Fig. 2).

After vernal and autumnal circulation, oxygen levels below 4 m (4 m was the depth of the epilimnion in Lake I during stratification and is used as a basis for making comparisons with the other lakes which failed to stratify

Figure 2. Temperature profiles of the Fort Whyte lakes during the ice-free period of 1977 and in June, 1978.


TEMPERATURE (C)
DEPTH (m)
LAKE I
22 AUG.
13 JUNE 1978
20 JUNE 1977
21 OCT.
17 MAY
18 JULY
LAKE II
22 AUG.
21 OCT.
13 JUNE 1978
19 MAY
18 JULY
20 JUNE 1977
LAKE III
12 JUNE 1978
17 MAY
23 OCT.
21 JUNE 1977
23 AUG.
19 JULY
LAKE IV
19 MAY
23 AUG.
21 JUNE 1977
12 JUNE 1978
23 OCT.
19 JULY

strongly) declined rapidly in Lake I but with decreasing rapidity in Lakes II, III, and IV (Fig. 3), indicating that the highest levels of biochemical oxidation were in Lake I and the lowest in Lake IV. These temperature and oxygen data indicate that fish in Lake I may be restricted to the epilimnion for much of the year while in Lake IV they may be able to utilize the entire lake for a longer period.

Major differences among the lakes also existed in the mean values of other chemical parameters during 1977-1978. Ammonia levels were highest in Lake I, second highest in Lake II, and lowest in Lake IV at both 0-4 m and 4 m-bottom (Table 2). The high ammonia concentration below 4 m in Lake I is partly the result of well developed thermal stratification and hypolimnial anoxia (Ward and Loadman MS 1981). Lake IV had the least highly developed thermal stratification.

High levels of total dissolved phosphorus in Lake I were probably caused by nutrient enriched wastewater entering from the waterfowl enclosures. The mean total dissolved phosphorus value at 4 m-bottom in Lake I was more than twice that of Lake II and more then eleven times the level in Lake IV at the same depth range (Table 2). However, these concentrations were generally unavailable to the phytoplankton. Above 4 m, total dissolved phosphorus was highest in Lake II, second highest in Lake I, and lowest in Lake IV (Table 2).

Figure 3. Monthly mean epilimnion and hypolimnion values for oxygen in the Fort Whyte lakes, 1977-1978.

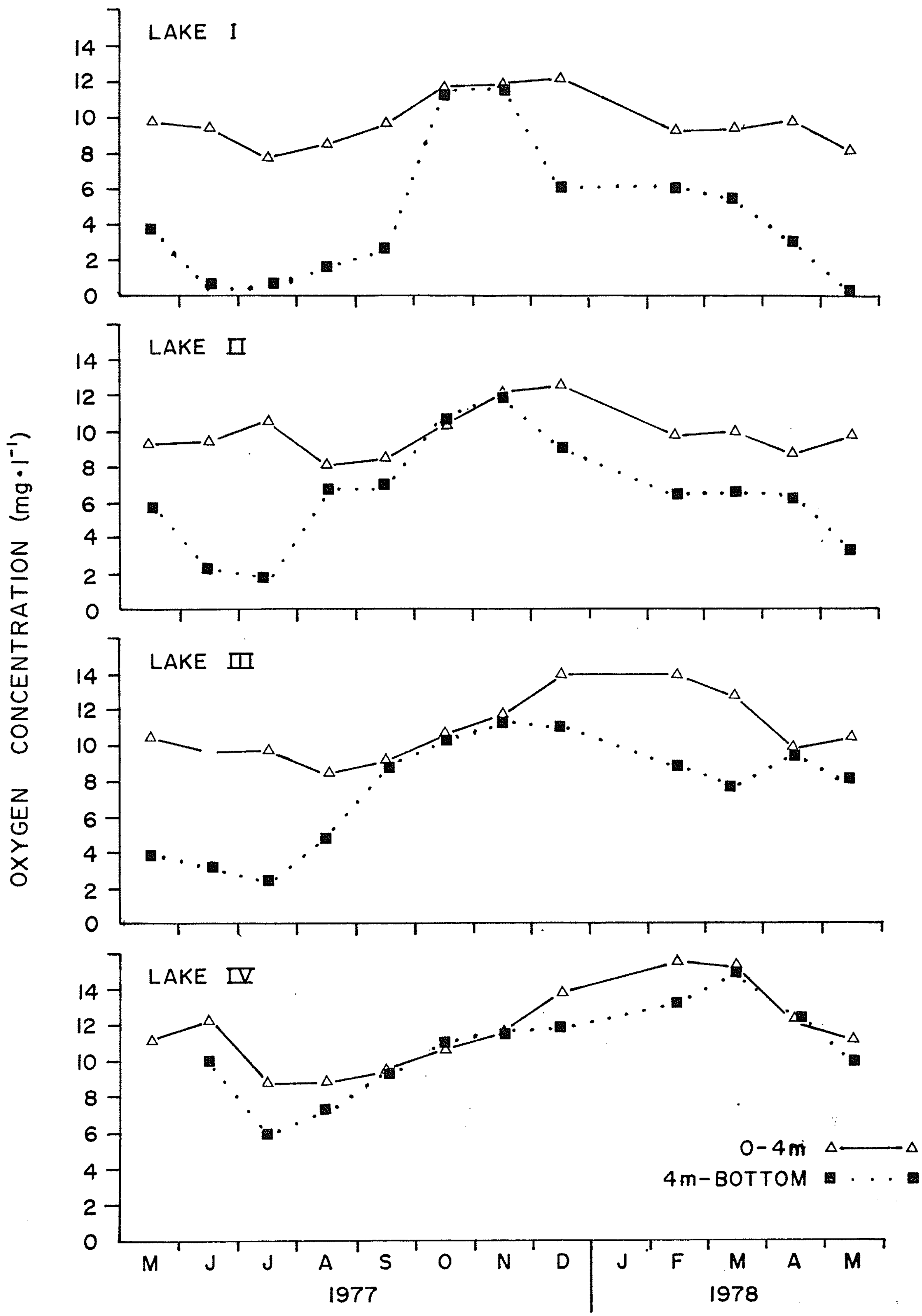

LAKE I
LAKE II
LAKE III
LAKE IV
OXYGEN CONCENTRATION (mg·l⁻¹)
14
12
10
8
6
4
2
0
0-4m
4m-BOTTOM
M J J A S O N D J F M A M
1977
1978

Table 2. Annual mean values of chemical parameters in the Fort Whyte lakes (June 1977 - October 1978)[a].

	LAKE							
	I		II		III		IV	
Parameter	0-4m	4m-bottom	0-4m	4m-bottom	0-4m	4m-bottom	0-4m	4m-bottom
Ammonia (mg. m^{-3})	127	1124	113	350	94	204	35	57
Total dissolved phosphorus (mg. m^{-3})	20	124	27	49	17	13	12	11
Chlorophyll (mg. m^{-3})	7.6	4.8	14.1	4.2	6.9	3.6	5.2	4.2
Total dissolved solids (mg. m^{-3})	576	692	330	360	379	392	456	467
pH	8.5	7.9	8.4	8.0	8.5	8.1	8.5	8.4

[a] Data taken from Ward and Loadman MS (1981).

The surface waters of Lake II had the highest mean value of chlorophyll (Table 2). This was the result of a bloom of blue-green algae which occurred in 1977 (Ward and Loadman MS 1981). A less intense bloom also occurred in Lake III. In the spring of 1977 there was an influx of fertilizer-enriched water from the farm field drainage ditch into Lake II with some spillover into Lake III. No algal blooms or influx of nutrient-enriched waters occurred in 1978 or 1979. Lake I had the second highest levels of chlorophyll, probably the result of nutrient-rich water entering the lake from the waterfowl ponds. Lake IV had the lowest chlorophyll levels (Table 2).

Mean total dissolved solids were highest in Lake I at both depth ranges (Table 2). A higher value in Lake IV than in Lakes II and III probably results from more frequent wind caused mixing and also from high levels of suspended organic matter caused by dredging activity (Ward and Loadman MS 1981). pH was high in all lakes (Table 2).

A more detailed description of the limnology of the Fort Whyte lakes can be found in Ward and Loadman (MS 1981).

In summary, the lakes showed differences in age, morphometry, thermal stratification, oxygen deficits, and nutrient levels. Lake I, the smallest and oldest lake, had a lower mean depth, a well developed thermal stratification, high hypolimnial biochemical oxygen demand, and high nutrient levels resulting from a year round flow of nutrient-enriched water from a waterfowl enclosure. Lake II also had high nutrient levels because of an occasional influx of nutrient-rich water from a drainage ditch. Some spills over into Lake III. Lake IV, the largest and youngest lake, had a higher mean depth, poorly developed thermal stratification, and higher hypolimnial oxygen levels. Nutrient levels were low because there was no direct input of fertilized water as there was to the other lakes.

Eight species of fish are known to occur in the Fort Whyte lakes (Table 3). All species were present in Lake I, six in Lake II, five in Lake III, and only four in Lake IV. The yellow perch was the most abundant species with northern pike, carp, and largemouth bass also numerous. The remaining species were rarely encountered. It is unknown how or when the various species first entered the lakes. Some may have entered naturally via the drainage ditch which ultimately joins the Red River. Others, like the bass, were introduced by man. It is known, however, that fish have been present in Lake I for many years. A largemouth bass in the Fish Museum, Dept. of Zoology, University of Manitoba, was reported captured from Lake I in 1946. The populations in the new lakes, III and IV, are obviously the result of more recent plantings or movements.

Table 3. Fish species occurring (x) in the Fort Whyte lakes[a].

Scientific Name	Common Name	Lake I	Lake II	Lake III	Lake IV
Esox lucius Linnaeus	northern pike	x	x	x	x
Cyprinus carpio Linnaeus	common carp	x	x	x	x
Pimephales promelas Rafinesque	fathead minnow	x	x	x	
Catostomus commersoni (Lacépède)	white sucker	x			
Ictalurus nebulosus (Lesueur)	brown bullhead	x			
Culaea inconstans (Kirtland)	brook stickleback	x	x		
Micropterus salmoides (Lacépède)	largemouth bass	x	x	x	x
Perca flavescens (Mitchill)	yellow perch	x	x	x	x

[a] Scientific and common names of fishes taken from Robins *et al*. (1980).

MATERIALS AND METHODS

In 1978, hoop nets and seines were used to sample yellow perch, all with 6.4 mm mesh size (stretched-mesh measure). In 1979, a fine mesh (12 meshes per cm) trap net (Beamish 1972; 1973) modified with 10 m wings was used almost exclusively. All hoop and trap nets were fished parallel to shore usually in 2-4 m of water, with one wing tied onshore and the other anchored offshore, with no leader. They were checked daily. A standard seine haul consisted of setting the seine at 90^{o} to the shore and making a sweep in an arc to shore.

Fork length was measured on all specimens to the nearest millimetre. Weight was measured to 0.1 g. Sex was ascertained by gross examination of the gonads. All measurements were performed with fresh fish. Young-of-the-year perch were not examined.

Relative abundance and biomass of perch in the Fort Whyte lakes was estimated, in 1979, from weekly catch-per-unit-effort (CPUE) data expressed as numbers and as weight(g) of perch caught per hour. Weights were calculated from fork lengths and the weight-length relation pooled by sex for fish in the particular lake. Standardized trap nets were utilized to obtain data. Nets were set in 2-4 m water (above the thermocline) and checked daily. With only three nets available, it was impossible to fish all four lakes in the same 24 hour period. In each week four fishing periods were defined. Each lake was fished for three of these approximately 24 hour periods each week with a different combination of three lakes fished during each period. Lakes I, II, and III were fished during the first period; I, II, and IV in the second; I, III, and IV in the third; and II, III, and IV in the fourth. This sequence was repeated for ten weeks from late June to late August. Each lake was fished at the same location for the entire week. Five equidistant locations along the shoreline of every lake were previously determined (Stations A to E) (Fig. 1). Beginning with a northwest location (Station A) trap nets were moved weekly to the next location in a clockwise rotation. Thus, each location was fished for two three-day periods over the ten-week sampling program. Under the above conditions CPUE values reflect population abundance (Moyle 1948). Changes in perch distribution, possibly caused by high surface water temperatures, required that the weekly rotation of locations be abandoned in Lake I. Only Stations A and B were fished in Lake I for the last five weeks of the experiment. Comparisons of CPUE were made among lakes by analysis of variance (Steel and Torrie 1980). A randomized complete block design was utilized for comparing numbers of perch and a completely randomized design for comparing weight of perch caught per hour.

Perch were aged from scales removed from the left side of the fish, below the lateral line, near the tip of the pectoral fin (laid flat against the body). Scale impressions were made on acetate slides with a roller press (Smith 1954). Usually at least three scales were pressed per fish. Slides were viewed with a Bausch and Lomb projector at a magnification of 45X. Scales were examined twice without reference to fish size or sex and assigned an age. An annulus was assumed to be present on the edge of scales obtained in spring before growth had begun (Jobes 1952; el-Zarka 1959; Berg and Grimaldi 1967). Validity of the scale method of ageing was described for yellow perch by Jobes (1952) and Joeris (1957).

Length and age compositions of the Fort Whyte yellow perch populations were examined. Percent length frequency distributions (5 mm length intervals were used) were constructed from samples collected over a short period of time in each lake in both 1978 and 1979. From subsamples, length frequency distributions separated by age and sex were constructed and the percentage of the total sample represented by each year class calculated. It was assumed that the number of individuals in any age class found in a particular length interval in the subsample was proportional to the number of individuals of that age class and length in the sample (Ketchen 1950). In 1978 subsamples were randomly selected except that there was a tendency to include more of