INITIAL EFFECTS OF TERTIARY WASTEWATER TREATMENT ON GROWTH AND FOOD EATEN BY YELLOW PERCH *Perca flavescens* (Mitchill) IN SHAGAWA LAKE, MINNESOTA

by

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ABSTRACT

Abundance, growth and food of yellow perch (*Perca flavescens*) were studied from 1974-1976 to evaluate the effects of a tertiary wastewater treatment plant which began operation in 1973 on eutrophic Shagawa Lake, Ely, Minnesota. Trawl, seines and gill nets were used in sampling. No conclusive results were obtained to relate tertiary wastewater treatment to changes observed in abundance, growth and food of yellow perch in Shagawa Lake.

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INTRODUCTION

Shagawa Lake (964 ha.) receives the sewage effluent from Ely, Minnesota (population 5000 in 1977). In 1973, an experimental tertiary wastewater treatment plant was put into operation by the U.S. Environmental Protection Agency (EPA) to control eutrophication in Shagawa Lake and to study the processes by which culturally enriched lakes may be returned to a more mesotrophic condition. The plant was tested from January-March, 1973, and in April, 1973, it commenced operation to remove more than 99% of the phosphorus from all municipal wastewater effluent (Schults, *et al*., 1976; Dunst, *et al*., 1974). Schults, *et al*. (1976) estimated that the treatment would reduce total phosphorus loading to the lake by 70-80%.

I studied abundance, growth and food of yellow perch (*Perca flavescens*) to determine the effects of the tertiary wastewater treatment plant. My study was part of a larger investigation to describe changes in the fish community of Shagawa Lake (Swenson, 1974; EPA Grant R-803673).

The hydraulic residence time (lake water volume replacement time) in Shagawa Lake is 0.65 year (Schults, *et al*., 1976). Therefore, in 1974-1976, the period of this study, the lake should have been reversing its trophic condition and becoming more mesotrophic (Schults, *et al*., 1976). However, internal cycling of nutrients has reduced the speed of recovery, and Shagawa Lake reached its lowest eutrophic condition during 1974 (Corvallis Environmental Research Laboratory, 1977).

Description of the Lake

Shagawa Lake, 964 ha., has mean and maximum depths of 6.2 m and 14.7 m (Larsen and Malueg, 1976; Figure 1). Lake volume is 59.5 million m^3. The Burntside River on the western end of Shagawa Lake is the major tributary, and provides approximately 70% of the yearly inflow from oligotrophic Burntside Lake (Larsen and Malueg, 1976). The Shagawa River is the only outlet and is located on the western end of the lake. The tertiary wastewater treatment plant is located midway along the southern shore.

A survey in 1937 indicated that the substrate was 70% muck, 29% sand, and 1% submerged rock outcroppings (Moyle, 1957). Numerous small rocky islands occur throughout the lake basin.

Surface temperatures generally reached 22°C in summer during this study, and bottom temperatures reached 20°C (Table 1). The lake is dimictic, stratifying at 3-6 m during summer (Bradbury and Megard, 1972; Larsen and Malueg, 1976). The thermocline is subject to breakdown by cold fronts and strong winds (Schults, *et al*., 1976). Anaerobic conditions occurred in deep areas during summer stratification (Table 1) and late winter under ice cover

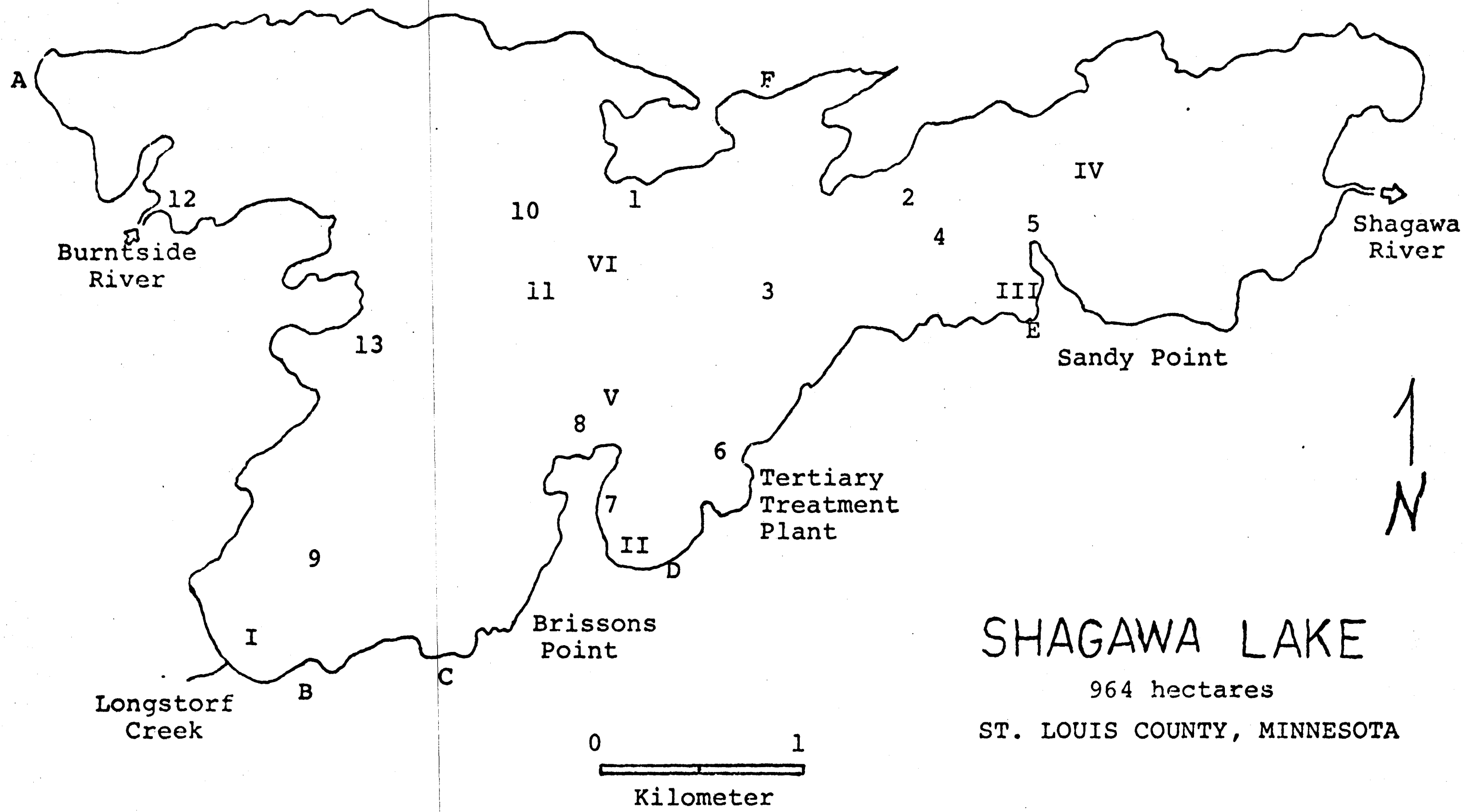

Fig. 1. Map of Shagawa Lake, Minnesota, showing trawl (roman numerals), gill net (arabic numerals), and seine (lettered) stations.

TABLE 1. SAMPLING EFFORT, SAMPLING STATIONS, WATER DEPTH, TEMPERATURE AND OXYGEN CONCENTRATION IN THE SAMPLING ZONE

Days	Stations[a]	Sampling Effort: Seine 15 m	Sampling Effort: Seine 61 m	Sampling Effort: Trawl Hauls	Sampling Effort: Gill Net Sets	Trawling Depth Range (m)	Temperature °C and Oxygen (ppm)[b] Surface	Temperature °C and Oxygen (ppm)[b] Bottom
1974								
June 5, 6	I,II,III,A,B,D,E,1,3	4	--	16	2	1.5 - 10	16(10.5)	12(2.8)
July 12	II,III,B,D,E,1,2,	3	--	11	2	1.5 - 6	22(9.0)	15(3.8)
Aug. 21, 22	II,III,B,E,4,5	2	--	9	2	1.5 - 9	21(9.6)	20(4.5)
Sept. 20	II,III,E,8	2	--	7	2	1.5 - 11	13(8.4)	12(8.3)
1975								
May 29, 30	II,III,IV,A,E,F	2	2	11	--	1.5 - 12	19(10.2)	10(5.1)
June 10-12	II,III,IV,C,E,1	2	--	10	3	1.8 - 12	16(9.9)	8(1.3)
June 27, 28	II,III,IV,VI,A,E	2	--	16	--	1.5 - 13	20(8.9)	12(0.5)
July 11, 12	II,III,IV,VI,C,E	2	--	13	--	2.4 - 13	21(8.1)	11(0.3)
July 29-31	II,III,IV,VI,1	--	--	16	3	1.5 - 9	22(9.0)	19(0.2)
Aug. 20, 21	II,III,IV,VI,1,8	--	--	15	3	1.5 - 13	20(8.6)	20(0.8)
Sept. 12, 13	II,III,IV,V,8,11	--	--	14	3	1.5 - 10	15(8.6)	15(8.0)
Sept. 26-28	I,II,III,IV,V	--	--	22	--	1.5 - 12	13(8.5)	13(7.3)
Oct. 27-28	II,III,IV,V,9,11	--	--	9	3	1.2 - 10	8(10.0)	8(10.1)
Nov. 13, 14	II,III,V,6,10,12	--	--	6	4	1.8 - 9	5(10.8)	5(10.6)
1976								
June 2-4	I,II,III,V,A,E	3	--	18	--	1.5 - 11	21(9.1)	12(0.7)
June 18, 19	I,II,III,9	--	--	14	2	1.5 - 7	18(8.2)	16(6.6)
July 8-10	II,III,C,D,E	5	--	22	--	1.5 - 8	23(10.0)	19(1.4)
July 22, 23	III,IV,8,11	--	--	11	3	1.8 - 9	22(9.7)	20(3.5)
Aug. 4, 5	I,II,III,IV,C,D,E	4	--	16	--	1.8 - 12	22(7.1)	22(0.2)
Aug. 19, 20	I,II,VI,1,8	--	--	6	3	1.8 - 8	22(9.9)	21(3.7)
Sept. 1-3	I,II,III,IV,C,D,E	4	--	20	--	1.5 - 8	19(7.4)	19(5.0)
Sept. 17, 18	II,III,V,4,5	--	--	11	3	1.8 - 11	18(11.5)	17(5.5)
Oct. 6,7	II,III,VI,C,D,E	4	--	14	--	1.8 - 10	12(8.8)	11(8.4)
Oct. 20,21	II,VI,7,13	--	--	3	3	1.8 - 12	4(11.0)	7(9.7)
Total: 52		39	2	310	42			

[a]Trawl stations are denoted by Roman numerals, seine stations by letters and gill net stations by Arabic numerals. Locations are identified in Figure 1.

[b]Oxygen concentrations at Brissons Point (Station 8) for 1974, 1975 and June 1976 were determined by E. P. A. project staff.

(Larsen and Malueg, 1976). The lake is ice covered approximately five months each year.

Large blooms of diatoms and green algae develop in spring, and blue-green algal blooms dominate in late summer (Larsen and Malueg, 1976). Phytoplankton production of Shagawa Lake was unusually high compared to regional lakes (Bradbury and Megard, 1972; Larsen and Malueg, 1976; Megard and Smith, 1974).

Fish species caught during 1974-1976 sampling included:

Yellow perch	*Perca flavescens* (Mitchill)
Walleye	*Stizostedion v. vitreum* (Mitchill)
Cisco or Lake herring	*Coregonus artedii* (Lesueur)
Northern pike	*Esox lucius* (Linnaeus)
Smallmouth bass	*Micropterus dolomieui* (Lacépedè)
Burbot	*Lota lota* (Linnaeus)
Bluegill	*Lepomis macrochirus* (Rafinesque)
Black crappie	*Pomoxis nigromaculatus* (Lesueur)
Rockbass	*Ambloplites rupestris* (Rafinesque)
Rainbow smelt	*Osmerus mordax* (Linnaeus)
Mottled sculpin	*Cottus bairdi* (Girard)
White sucker	*Catostomus commersoni* (Lacépedè)
Bullhead	*Ictalurus sp.*
Redhorse	*Moxostoma sp.*
Tadpole madtom	*Noturus gyrinus* (Mitchill)
Troutperch	*Percopsis omiscomaycus* (Walbaum)
Logperch	*Percina caprodes* (Rafinesque)
Johnny darter	*Etheostoma nigrum* (Rafinesque)
Iowa darter	*Etheostoma exile* (Girard)
Fathead minnow	*Pimephales promelas* (Rafinesque)
Spottail shiner	*Notropis hudsonius* (Clinton)
Golden shiner	*Notemigonus crysoleucas* (Mitchill)
Common shiner	*Notropis cornutus* (Mitchill)

MATERIALS AND METHODS

Three kinds of gear were used to capture yellow perch during the ice free period, May-November, 1974-1976 (Table 1). Perch were caught day and night in various areas and depths throughout the lake basin.

About 70% of the yellow perch (all ages) were caught in a 7.6 m head-rope, semiballoon otter trawl of 3 cm bar-mesh with a 0.6 cm mesh cod liner. Trawl hauls generally lasted 5 min., covered about 970 m^2, and filtered approximately 1600 m^3 at depths of 1-15 m. The trawl was towed at 3-3.5 mph by an 18 ft tri-hull boat powered by a 40 horsepower outboard motor. Trawl distance was recorded occasionally during 1974 and 1975, and during each tow in 1976.

About 10% of the yellow perch (mostly ages IV-VII) were caught in experimental gill nets, 77 m by 1.8 m with five 15.4 m panels, each of 1.25, 1.9, 2.5, 3.8, and 5.1 cm bar-measure. Gill nets were set at near surface, midwater and on bottom.

About 20% of the yellow perch (mostly ages 0-III) were caught in seines. A 15.4 m by 1.9 m seine with 1 m^2 bag of 0.6 cm bar-mesh was used in most shore area seining. A 62 m by 1.9 m seine of 1.9 cm bar-mesh was used infrequently.

The number of age 0 and older perch in each net catch was recorded. Representative samples from most catches were measured for total length in the field. Perch were selected by eye from the catch on the basis of size in an attempt to represent each age group, 0-VIII. For each scale or stomach sample taken, the following data were recorded: date, time, depth captured, fish length, fish weight, collector, gear used and sample station. Weather conditions, water temperatures, and dissolved oxygen concentrations during sampling were recorded daily. Water temperatures and dissolved oxygen concentrations, taken with a temperature/dissolved oxygen meter, were recorded at 1 m depth intervals (Table 1, Appendix A).

Scales were taken from the left side in the key-scale area, about two scales ventral from the fifteenth lateral line scale, and were placed in labeled scale envelopes. Most stomachs were removed and placed separately in labeled plastic whirl-pak bags containing 5-10% formalin solution. Ventral incisions were made on some of the perch which were preserved whole.

Age, Growth and Abundance

Age was determined and total length was back-calculated from scales of 669 perch from the 1974-1976 trawl, seine and gill net collections. Scales were pressed on cellulose acetate (Hile, 1941; Regier, 1962), and the impressions were read at least twice on an Eberbach scale projector (100 X). Growth was back-calculated for nine year classes from body-scale relationships and nomographs (Carlander and Smith, 1944). Males and females were combined.

Growth of age 0 perch was determined from length frequency distributions from each sampling period, and total lengths were plotted against time to obtain growth curves for July-September of 1974, 1975 and 1976.

Yellow perch abundance was determined as trawl catch per 100 m^3 for ages 0 and 1, and ages 2-8. Abundance was described separately for depths above and below 5 m.

Food

Food habits were determined from 642 stomach samples collected from May 29-November 28, 1975, and June 2-October 21, 1976. Food items were counted and identified at least to order under a dissecting microscope. I identified contents from the upper esophagus to the pyloric sphincter using keys by Becker and Johnson (1970), Hilsenhoff (1975), Penak (1953), and Usinger (1973). Volumes were determined by water displacement after excess moisture had been removed by blotting. Only stomachs containing food were included in determinations of percent frequency of occurrence and percent total volume.

The food of yellow perch under and including 70 mm total length (TL) and over 70 mm TL were described separately. This length was selected arbitrarily as the stage at which Shagawa Lake yellow perch switched from a predominantly zooplankton diet to one of other invertebrates and fish. This or similar lengths have been used by other authors (Alm, 1946; Smyly, 1952; Clady, 1974) as the size at which feeding of perch undergoes a change, and it approximates the length attained at age I by Shagawa Lake yellow perch.

RESULTS AND DISCUSSION

Abundance and Distribution

Abundance (catch per effort) of ages 0 and 1 yellow perch was greater in 1975 and 1976 than in 1974 (Table 2) indicating that one or two year classes produced after 1973 were stronger than the two previous year classes. However, since variation in year class strength is not uncommon in yellow perch (Hile and Jobes, 1941; Forney, 1971), the difference in abundance observed in this study may or may not be related to operation of the tertiary wastewater treatment plant.

Most yellow perch were found in the upper 7 m of water throughout the sampling periods. More accurate distribution profiles were not obtainable for perch due to variability in trawl depth and gill net catches.

Age and Growth

The linear functional regression (Ricker, 1973) of the body length-scale radius relationship for 669 yellow perch caught in 1974-1976 from Shagawa Lake was:

$$Y = 29.380 + 0.589 X$$

where Y is total length (mm) and X is anterior scale radius (mm under 100 X magnification).

TABLE 2. Yellow perch abundance (number caught/100 m^3) from 1974-1976 trawl samples for ages 0-1 and 2-8. Numbers in parenthesis indicate lifts or catch in depths over 5 m.

Period	Days Sampled	Net Lifts	Number per 100 m^3 Ages 0 and 1	Ages 2-8
1974				
June	2	14 (2)	0.0 (0.0)	0.8 (1.8)
July	1	8 (3)	24.2 (7.3)	0.3 (0.1)
August	2	8 (1)	61.5 (3.0)	0.9 (0.5)
September	1	4 (3)	3.2 (1.0)	0.4 (0.2)
1975				
June	5	13 (13)	19.5 (0.8)	0.6 (0.2)
July	5	11 (18)	38.3 (25.1)	0.9 (0.5)
August	2	7 (8)	111.4 (11.1)	0.4 (0.3)
September	2	22 (14)	28.2 (11.3)	0.5 (0.7)
October	2	6 (3)	66.9 (1.7)	0.1 (0.2)
November	2	4 (2)	1.8 (0.9)	0.2 (0.4)
1976				
June	5	26 (6)	4.3 (1.8)	0.3 (0.4)
July	5	22 (11)	90.9 (33.4)	0.7 (0.2)
August	4	18 (4)	45.3 (24.3)	0.3 (0.1)
September	5	28 (3)	45.6 (3.2)	0.1 (0.2)
October	4	12 (5)	31.6 (1.6)	0.2 (0.2)

The functional regressions (Ricker, 1973) of the length-weight relationships for 641 yellow perch caught in 1974-1976 from Shagawa Lake were:

1974 (73) $\ln W = -12.79 + 3.27 \ln L$,

1975 (181) $\ln W = -12.21 + 3.17 \ln L$,

1976 (387) $\ln W = -11.82 + 3.11 \ln L$,

where natural log W is weight (g) and natural log L is length (mm).

Annulus formation began in mid June for age classes I-IV, and in mid to late June for older perch. All fish had formed an annulus by the second week in July. Kelso and Ward (1976) found annulus formation to be completed by July for yellow perch in West Blue Lake, Manitoba.

Perch growth in Shagawa Lake was generally greater than perch growth in area lakes. The growth rate of yellow perch in Shagawa Lake was higher than in Red Lakes and Lake of the Woods, Minnesota; Green Bay, Wisconsin; Northwestern Lake Michigan; Mill Lake, Michigan; Red Deer Lake and the Bay of Quinte, Ontario; and Heming Lake, Manitoba (Table 3). Growth of yellow perch in Shagawa Lake was similar to that in Wilson Lake, Minnesota; West Okoboji Lake, Iowa; and Saginaw Bay, Lake Huron; and lower than in Lake Erie and the Severn River, Maryland. Shagawa Lake age 0 yellow perch empirical growth in 1974, 1975 and 1976 was greater than age 0 yellow perch empirical growth in 1969 and 1970 in Lake of the Woods, Minnesota (Figure 2).

TABLE 3. Mean back-calculated total lengths (mm) at each annulus of yellow perch (sexes combined) captured in Shagawa Lake in 1974, 1975 and 1976; and comparison with means for other waters.

Year Class	Age Group I	II	III	IV	V	VI	VII	VIII	No. in Sample
1967	65	115	169	221	248	268	282		7
1968	62	109	168	214	246	269	290	309	11
1969	65	116	179	228	255	273	286		13
1970	66	108	170	215	237	251			76
1971	66	121	175	213	238				53
1972	65	118	166	206					239
1973	61	107	157						54
1974	59	103							161
1975	61								55
Mean	63	112	169	216	245	265	286	309	669
Wilson Lake, N.E. Minne.	67	117	157	181	246	268			Minne. D.N.R. (1975)
Red Lakes Minne.	74	132	173	201	221	234			Heyerdahl & Smith (1971)
Lake of the Woods, Minne.	84	118	154	177	199	219	229	243	Carlander (1949)
Green Bay, Wisconsin	61	99	134	166	191	220	239		Hile & Jobes (1942)
N.W. Lake Michigan	61	96	128	154	183	212			Hile & Jobes (1942)
Mill Lake, S. Michigan	76	119	150	170	196	226	241		Schneider (1971)
Saginaw Bay	65	115	170	208	234	265	284		Hile & Jobes (1941)
Red Deer Lake, Ontario	53	85	112	144	176	178			Chadwick (1976)
Heming Lake, Manitoba	71	86	124	142	170	213	231	259	Lawler (1953)
Lake Erie, Ontario	--	168	196	216	251	274	279		Harkness (1922)
Bay of Quinte, Ontario	--	158	172	182	202	216	209	257	Sheri & Power (1969)
Severn River, Maryland	108	166	202	230	253	271	283	293	Muncy (1962)
West Okoboji Lake, Iowa	53	127	183	216	244	264			Moen (1964)

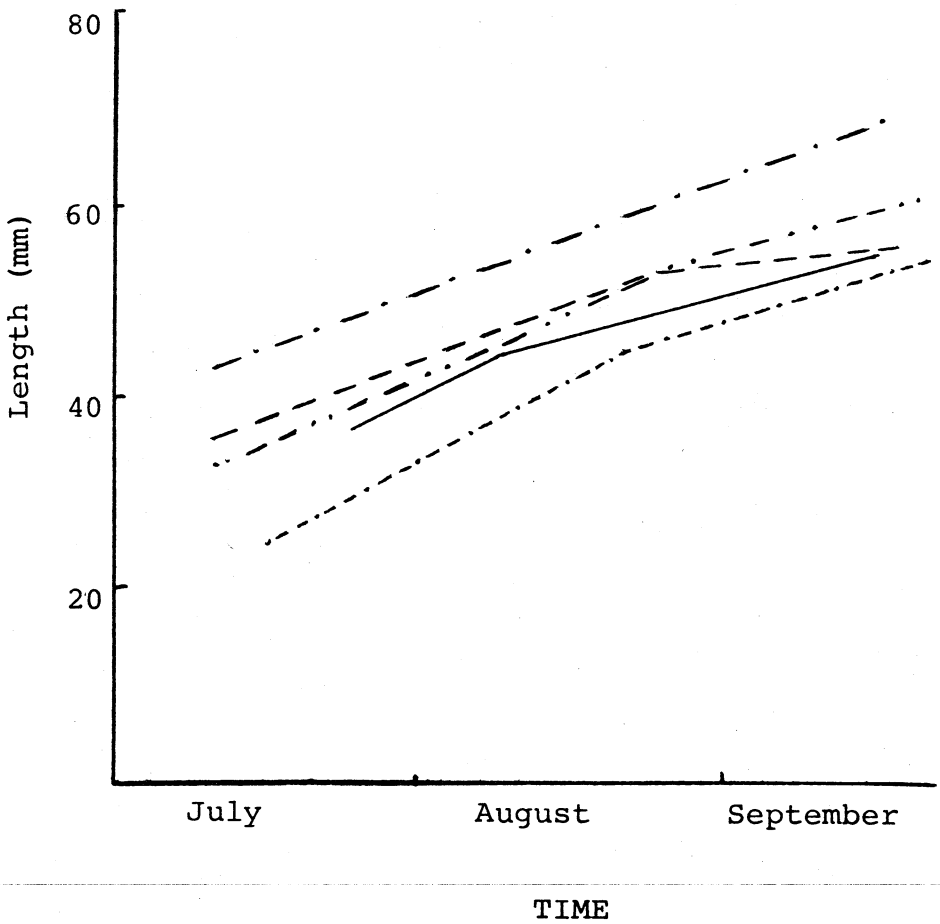

Figure 2. Growth of young-of-the-year yellow perch in Shagawa Lake during 1974 (__ __), 1975 (··---) and 1976 (-·-) and in Lake of the Woods, Minnesota, during 1969 (·---·) and 1970 (____). (Swenson, 1974-1977).

A relation of growth of yellow perch to tertiary wastewater treatment was obscure. Growth rate (annual increment) in 1974 and 1975, the years following tertiary wastewater treatment, was significantly lower ($P > 0.01$) than in earlier years for all ages except 6-7, where the differences were not significant ($F = 0.14$; 19 d.f.; $P < 0.05$) (Table 4). This trend is to be expected if the waste treatment reduced the trophic state of the lake sufficiently to affect growth of yellow perch. However, length increments were greater in 1975 than in 1974 for four of the six age groupings (Table 4), a trend not to be expected if the treatment were influential.

Growth of age 0 yellow perch also was greater in later than earlier years. Increments for age 0 perch determined from measured lengths (Figure 2; Appendix B) agreed with the back-calculated increments (Table 4). Lengths at or near the end of the growing season were similar (57 mm empirical, 59 mm back-calculated in 1974; and 61 mm empirical, 61 mm back-calculated in 1975). For both determinations, the increment was greater in 1975 than in 1974. Also, empirically determined growth for age 0 perch in 1976 (70 mm at end of September) for which there was no comparison with back-calculated lengths, was greater than in 1975 (Figure 2), and it was greater than the back-calculated growth of young-of-the-year perch (Table 4) before operation of the tertiary wastewater treatment plant.

TABLE 4. Yearly increments (mm), standard deviations (in parenthesis), and sample sizes [in brackets] for back-calculated lengths of 669 yellow perch caught in 1974, 1975 and 1976.

Year Classes	Ages						
	0-1	1-2	2-3	3-4	4-5	5-6	6-7
1967	65.43 (4.54) [7]	49.29 (11.22) [7]	54.43 (10.60) [7]	51.71 (4.64) [7]	27.14 (7.80) [7]	20.00 (4.32) [7]	13.57 (2.07) [7]
1968	62.45 (6.55) [11]	46.45 (9.97) [11]	59.27 (8.79) [11]	45.45 (10.67) [11]	32.18 (6.90) [11]	22.73 (3.44) [11]	14.67 (5.09) [6]
1969	64.92 (5.77) [13]	51.23 (10.16) [13]	62.69 (10.11) [13]	48.85 (9.51) [13]	27.77 (5.02) [13]	17.69 (4.29) [13]	11.57 (1.27) [7]
1970	65.71 (5.47) [76]	42.07 (10.08) [76]	62.28 (8.07) [76]	44.99 (7.64) [76]	23.21 (5.66) [48]	17.60 (2.80) [15]	
1971	65.51 (5.30) [53]	55.15 (12.87) [53]	54.79 (10.50) [53]	37.98 (10.75) [46]	23.48 (4.17) [25]		
1972	64.52 (5.96) [239]	53.13 (9.94) [239]	48.20 (9.13) [202]	40.65 (7.05) [119]			
1973	61.43 (4.71) [54]	46.10 (7.51) [51]	51.00 (6.66) [34]				
1974	58.81 (4.64) [161]	44.93 (7.46) [138]					
1975	60.53 (5.12) [55]						
Mean (1967-1975)	62.76 (5.37) [669]	49.14 (9.58) [588]	52.94 (9.00) [394]	42.34 (8.18) [272]	25.06 (5.57) [104]	19.22 (3.65) [46]	13.20 (3.11) [20]

The increased growth of young-of-the-year in 1976 over 1975, and the fact that most increments for all ages were higher in 1975 than 1974, suggests that the significantly lower growth in 1974 and 1975 compared with earlier years may have been fortuitous and not related to tertiary wastewater treatment plant operation.

Although growth of yellow perch has been found to be related to temperature (Coble, 1966) the lower growth in 1974 and 1975 could not have been caused by lower water temperatures in those years (Appendix A). One-way analysis of variance of temperature comparing years 1971-1973 (before wastewater treatment) to years 1974-1975 (after wastewater treatment) were not significantly different ($P < 0.05$) with groupings of: May-August ($F = 0.20$; 414 d.f.); May-September ($F = 0.13$; 510 d.f.); June-August ($F = 2.46$; 310 d.f.); and June-September ($F = 0.34$; 406 d.f.).

Growth of yellow perch was not clearly related to levels of chlorophyll A. Although chlorophyll A declined in Shagawa Lake following tertiary wastewater treatment (Corvallis Environmental Research Laboratory 1977), I could not find a consistent relation between growth of various age groups and chlorophyll A levels. Nakashima and Leggett (1975) found growth of yellow perch in Lake Memphremagog, Quebec-Vermont, to be independent of production at lower trophic levels.

Instantaneous growth rates G_x, G and $\bar{G}$ from the 1974, 1975 and 1976 samples were similar (Appendix C), and were not significantly different when tested with the Wilcoxon Sign Rank test (Zar, 1974) at the 95% level of significance. Instantaneous growth rate G_x varied from 1.998 to 0.194, G varied from 1.923 to 0.121, and $\bar{G}$ varied from 1.888 to 0.181 during the years 1974-1976.

Food Habits

Changes in foods eaten by yellow perch in Shagawa Lake could not be related to tertiary wastewater treament plant operation.

Young perch, ages 0 and 1, of 70 mm TL or less in 1975 ate zooplankton predominantly, followed in order by Diptera and Ephemeroptera (Table 5). In 1976, young perch ate Diptera predominantly, followed by zooplankton and Ephemeroptera (Table 6). In both years zooplankton had the highest frequencies of occurrence.

Young perch in 1976 ate several items not found in stomachs in 1975, including Trichoptera, Odonata, Hemiptera, Hydracarina, Nematoda and yellow perch. Young perch ate less Hexagenia and more other Ephemeroptera in 1976 than in 1975. Mean food volume of young perch in 1976 was about three times greater than in 1975, in part because of the larger volume of insects eaten in 1976. The mean food volume of perch 70 mm TL or less in 1975 was 0.018 ml, and 0.054 ml in 1976. The difference in food diversity and volume may be attributed to lack of samples in June, 1975; and also to sampling in June-July, 1976, of age 1 (not age 0) perch, which tended to eat macroinvertebrates rather than zooplankton.

Larger perch, over 70 mm TL, in 1975 ate Ephemeroptera predominately, followed in order by Diptera and fish (Table 7). In 1976, larger perch ate Ephemeroptera predominantly, followed by fish and Diptera (Table 8). In

TABLE 5. Food in 101 yellow perch 70 mm TL or less in 1975 expressed as percent frequency of stomachs containing food, percent of total food volume (in parenthesis) and food volume (ml). Mean length of perch, 55 mm.

Collection Date	July 11	July 28-29	August 21	Sept. 12	Sept. 26	Oct. 27-28	Nov. 14	All Dates
Stomachs Containing Feed	16	14	14	14	14	12	10	94
Stomachs Empty	1	0	0	0	0	2	4	7
CRUSTACEA								
Cladocera								
Daphnia	75 (30)	93 (26)	79 (46)	79 (21)	93 (29)	100 (60)	80 (47)	85 (33)
Leptodora	6 (1)	36 (19)	50 (22)	64 (29)	86 (21)	50 (9)	10 (1)	44 (15)
Copepoda	38 (1)	71 (10)	64 (19)	93 (37)	71 (28)	58 (6)	70 (34)	66 (19)
Amphipoda								
Hyallela	25 (20)	--	--	7 (1)	--	--	--	5 (5)
Gammarus	--	--	--	--	--	--	--	--
Ostracoda	--	57 (5)	36 (3)	50 (2)	21 (tr.)	--	--	24 (1)
Decapoda	--	--	--	--	--	--	--	--
INSECTA								
Diptera								
Chironomidae								
larvae	25 (6)	7 (20)	7 (7)	14 (5)	29 (19)	8 (5)	--	14 (9)
pupae	13 (3)	--	--	--	--	--	--	2 (1)
Chaoboridae								
larvae	6 (tr.)	--	--	--	--	25 (20)	20 (13)	6 (3)
pupae	--	--	--	7 (1)	--	--	--	1 (tr.)
Ephemeroptera								
Hexagenia	13 (14)	7 (20)	--	--	7 (3)	--	--	4 (7)
Other	13 (23)	--	--	--	--	--	--	2 (5)
Trichoptera	--	--	--	--	--	--	--	--
Odonata	--	--	--	--	--	--	--	--
Hemiptera	--	--	--	--	--	--	--	--
OTHER								
Hydracarina	--	--	--	--	--	--	--	--
Nematoda	--	--	--	--	--	--	--	--
Pelycopoda	--	--	--	--	--	--	--	--
Annelida								
Hirudinea	--	--	--	--	--	--	--	--
Gastropoda	--	--	--	--	--	--	--	--
Unidentified	6 (2)	--	21 (2)	7 (3)	--	--	10 (5)	6 (2)
FISH								
Yellow Perch	--	--	--	--	--	--	--	--
White Sucker	--	--	--	--	--	--	--	--
Jonnny Darter	--	--	--	--	--	--	--	--
Spottail Shiner	--	--	--	--	--	--	--	--
Trout-perch	--	--	--	--	--	--	--	--
Unidentified	--	--	--	--	--	--	--	--
PLANT	--	--	7 (1)	--	--	--	--	--
Total Volume (ml.)	.3961	.2467	.1445	.3490	.2708	.1748	.1515	1.7334

TABLE 6. Food in 105 yellow perch 70 mm TL or less in 1976 expressed as percent frequency of stomachs containing food, percent of total food volume (in parenthesis) and food volume (ml.). Mean length of perch, 59 mm.

Collection Date	June 2-4	June 18-19	July 8-9	July 22	Aug. 4-5	Aug. 19	Sept. 1-2	Sept. 18	Oct. 7	Oct. 21	All Dates
Stomachs Containg Food	20	10	10	8	9	8	10	9	9	3	96
Stomachs Empty	0	0	0	3	1	2	0	2	1	0	9
CRUSTACEA											
Cladocera											
Daphnia	65 (38)	40 (1)	100 (52)	100 (47)	89 (17)	25 (7)	80 (35)	22 (7)	78 (52)	100 (82)	68 (24)
Leptodora	30 (1)	--	50 (14)	13 (6)	78 (22)	50 (16)	90 (30)	--	22 (10)	--	35 (8)
Copepoda	25 (8)	10 (tr.)	90 (13)	88 (39)	44 (7)	63 (25)	40 (10)	22 (3)	22 (1)	100 (2)	44 (7)
Amphipoda											
Hyallela	25 (5)	30 (3)	10 (4)	--	11 (2)	--	--	--	--	--	10 (3)
Gammarus	--	--	--	--	--	--	--	--	--	--	--
Ostracoda	--	10 (tr.)	40 (6)	13 (1)	33 (3)	13 (2)	--	11 (3)	11 (tr.)	--	13 (1)
Decapoda	--	--	--	--	--	--	--	--	--	--	--
INSECTA											
Diptera											
Chironomidae											
larvae	45 (12)	20 (1)	10 (3)	--	33 (10)	25 (7)	70 (19)	78 (51)	56 (33)	34 (16)	39 (11)
pupae	35 (20)	40 (81)	10 (5)	--	22 (24)	25 (30)	10 (1)	11 (5)	11 (4)	--	20 (34)
Chaoberidae											
larvae	5 (1)	10 (1)	10 (3)	25 (7)	11 (1)	13 (3)	20 (1)	11 (10)	--	--	10 (2)
pupae	--	10 (1)	--	--	--	--	--	--	--	--	1 (tr.)
Ephemeroptera											
Hexagenia	5 (2)	--	--	--	11 (14)	13 (10)	--	11 (21)	--	--	4 (3)
Other	20 (11)	10 (6)	--	--	--	--	10 (2)	--	--	--	6 (5)
Trichoptera	5 (1)	--	--	--	--	--	--	--	--	--	1 (tr.)
Odonata	--	--	--	--	--	--	10 (2)	--	--	--	1 (tr.)
Hemiptera	5 (1)	--	--	--	--	--	--	--	--	--	1 (tr.)
OTHER											
Hydracarina	5(tr.)	10(tr.)	--	--	--	--	--	--	--	--	2 (tr.)
Nematoda	5(tr.)	--	--	--	--	--	--	--	--	--	1 (tr.)
Pelycopoda	--	--	--	--	--	--	--	--	--	--	--
Annelida											
Hirudinea	--	--	--	--	--	--	--	--	--	--	--
Gastropoda	--	--	--	--	--	--	--	--	--	--	--
Unidentified	--	--	--	--	--	--	--	--	--	--	--
FISH											
Yellow Perch	--	10 (5)	--	--	--	--	--	--	--	--	1 (2)
White Sucker	--	--	--	--	--	--	--	--	--	--	--
Johnny Darter	--	--	--	--	--	--	--	--	--	--	--
Spottail Shiner	--	--	--	--	--	--	--	--	--	--	--
Trout-perch	--	--	--	--	--	--	--	--	--	--	--
Unidentified	--	--	--	--	--	--	--	--	--	--	--
PLANT	--	--	--	--	--	--	--	--	--	--	--
Total Volume (ml.)	1.446	1.589	.1233	.135	.502	.200	.6065	.193	.2611	.1238	5.1797

TABLE 7. Food in 133 yellow perch over 70 mm TL in 1975 expressed as percent frequency of stomachs containing food, percent of total food volume (in parenthesis) and food volume (ml.). Mean length of perch, 190 mm.

Collection Date	May 29	July 11	July 28-29	Aug. 20-21	Sept. 12-13	Sept. 26-28	Oct. 27-28	Nov. 13-14	Nov. 28	All Dates
Stomachs Containing Food	3	5	3	22	27	37	7	11	1	116
Stomachs Empty	1	0	0	4	1	8	1	2	0	17
CRUSTACEA										
Cladocera										
Daphnia	--	20 (2)	--	14 (1)	--	5 (tr.)	29 (1)	--	--	6.9 (0.3)
Leptodora	--	--	--	14 (tr).	7 (tr.)	30 (4)	29 (3)	--	--	15.5 (1.2)
Copepoda	--	--	--	--	--	--	--	--	--	--
Amphipoda										
Hyallela	100(56)	40 (3)	33 (tr.)	5 (tr).	--	--	14 (2)	9 (tr.)	--	7.8 (2.0)
Gammarus	--	--	--	--	--	--	--	9 (tr.)	--	1.7 (0.1)
Ostracoda	--	--	--	--	--	--	--	--	--	--
Decopoda	--	--	--	--	4 (tr.)	--	--	--	--	0.9 (0.2)
INSECTA										
Diptera										
Chironomidae										
larvae	67 (2)	80 (42)	33 (1)	59 (17)	44 (31)	39 (19)	57 (40)	73 (6)	100(100)	54.3(21.5)
pupae	--	20 (2)	---	55 (16)	15 (1)	5 (1)	14 (2)	--	--	17.2(3.3)
Chaoboridae										
larvae	33 (3)	20 (2)	--	23 (tr.)	7 (tr.)	11 (1)	43 (2)	18 (tr.)	00	15.5(0.4)
pupae	33 (3)	--	--	5 (tr.)	--	--	14 (tr.)	--	--	2.6(0.2)
Ephemeroptera										
Hexagenia	100(36)	40 (11)	100 (46)	32 (36)	67 (31)	49 (53)	29 (33)	55 (92)	--	50.8(45.2)
Other	--	40 (13)	33 (1)	--	--	--	--	--	--	2.6(0.7)
Trichoptera	--	20 (2)	33 (42)	18 (2)	--	8 (1)	14 (15)	--	--	8.6(2.1)
Odonata	--	--	--	--	4 (tr.)	--	--	9 (2)	--	1.7(0.2)
Hemiptera	--	--	--	--	--	--	--	--	--	--
OTHER										
Hydracarina	--	20 (tr.)	--	--	--	--	--	--	--	0.9(tr.)
Nematoda	--	20 (tr.)	--	--	18 (1)	--	--	--	--	5.2(0.3)
Pelycopoda	--	--	--	--	--	--	--	--	--	--
Annelida										
Hirudinea	--	20 (2)	--	--	--	--	--	--	--	0.9(0.1)
Gastropoda	--	--	--	--	--	3 (1)	--	--	--	0.9(0.2)
Unidentified	--	--	--	--	4 (tr.)	--	--	--	--	0.9(tr.)
FISH										
Yellow Perch	--	20 (23)	33 (10)	9 (13)	4 (15)	5 (7)	--	--	--	6.0(9.6)
White Sucker	--	--	--	5 (15)	4 (17)	--	--	--	--	1.7(7.9)
Johnny Darter	--	--	--	--	4 (3)	5 (4)	--	--	--	2.6(1.8)
Spottail Shiner	--	--	--	--	--	3 (5)	--	--	--	1.7(1.3)
Trout-perch	--	--	--	--	--	3 (2)	--	--	--	0.9(0.4)
Unidentified	--	--	--	--	--	5 (2)	--	--	--	1.7(0.5)
PLANT	--	--	--	--	--	--	--	--	--	--
Total Volume (ml.)	3.040	4.730	2.392	16.426	29.220	20.846	2.641	14.682	.400	94.377

TABLE 8. Food in 303 yellow perch over 70 mm TL in 1975 expressed as percent frequency of stomachs containing food, percent of total food volume (in parenthesis) and food volume (ml.). Mean length of perch, 185 mm.

Collection Date	June 2-4	June 18-19	July 8-10	July 22	Aug. 4-5	Aug. 19	Sept. 1-3	Sept. 17-18	Oct. 6-7	Oct. 21	All Dates
Stomachs Containing Food	37	28	28	20	25	23	29	29	32	4	255
Stomachs Empty	4	1	6	7	13	3	0	6	3	5	48
CRUSTACEA											
Cladocera											
Daphnia	16 (4)	18 (2)	--	--	--	--	--	--	--	75(60)	5.5(1.1)
Leptodora	--	4 (tr.)	4 (tr.)	--	4 (tr.)	9 (1)	10 (tr.)	31 (1)	38 (5)	75(12)	12.5(0.5)
Copepoda	5(tr.)	7 (tr.)	--	--	--	--	--	3 (tr.)	---	--	2.0(tr.)
Amphipoda											
Hyalella	51 (5)	43 (9)	11 (4)	--	4 (tr.)	9 (1)	7 (tr.)	7 (tr.)	3 (tr.)	--	16.5(2.1)
Gammarus	--	--	--	--	--	--	--	--	--	--	--
Ostracoda	--	--	--	5 (tr.)	--	--	--	--	--	--	0.4(tr.)
Decapoda	11 (22)	7 (13)	4 (1)	--	4 (2)	--	7 (7)	--	--	--	3.9(7.6)
INSECTA											
Diptera											
Chironomidae											
larvae	54 (3)	79 (23)	39 (6)	25 (2)	16 (2)	48 (13)	86 (31)	93 (61)	56 (16)	75(28)	57.3(15.8)
pupae	54 (2)	32 (2)	7 (1)	25 (18)	20 (1)	35 (3)	38 (2)	45 (7)	9 (1)	--	29.8(4.8)
Chaoboridae											
larvae	--	39 (2)	7 (tr.)	--	4 (tr.)	--	--	7 (tr.)	13 (tr.)	--	7.8(0.3)
pupae	--	36 (4)	7 (tr.)	5 (tr.)	--	--	--	--	--	--	5.1(0.3)
Ephemeroptera											
Hexagenia	81 (60)	36 (19)	36 (11)	5 (tr.)	44 (52)	87 (72)	72 (26)	38 (29)	63 (55)	--	52.5(37.0)
Other	14 (tr.)	7 (1)	4 (1)	--	--	--	--	--	--	--	3.1(0.2)
Trichoptera	27 (2)	29 (6)	--	10 (tr.)	16 (2)	13 (1)	10 (tr.)	--	25 (5)	--	14.9(1.8)
Odonata	5 (tr.)	11 (1)	--	--	--	--	3 (tr.)	--	3 (1)	--	2.7(0.2)
Hemiptera	8 (tr.)	--	7 (tr.)	--	--	--	--	--	--	--	2.0(0.1)
OTHER											
Hydracarina	5 (tr.)	25 (1)	7 (1)	--	--	--	--	--	--	--	4.3(0.2)
Nematoda	8 (tr.)	14 (1)	--	5 (tr.)	--	22 (1)	--	7 (tr.)	3 (1)	--	6.3(0.3)
Pelycopoda	3 (tr.)	7 (1)	--	--	--	--	--	--	--	--	1.2(0.1)
Annelida											
Hirudinea	11 (tr.)	--	--	5 (1)	--	--	--	--	--	--	2.0(0.2)
Gastropoda	3 (tr.)	11 (1)	--	--	--	--	--	--	--	--	1.6(0.1)
Unidentified	3 (tr.)	7 (2)	7 (tr.)	--	4 (tr.)	--	--	--	--	--	2.4(0.2)
FISH											
Yellow Perch	--	7 (11)	50 (74)	70 (67)	36 (33)	9 (8)	17 (33)	3 (1)	3 (10)	--	18.8(24.5)
White Sucker	--	--	--	5 (7)	--	--	--	--	--	--	0.4(1.0)
Johnny Darter	--	--	--	--	4 (7)	--	--	--	6 (5)	--	1.2(1.0)
Spottail Shiner	--	--	--	--	--	--	--	--		--	--
Trout-perch	--	--	--	5 (3)	--	--	--	--	--	--	0.4(0.4)
Unidentified	3 (tr.)	--	4 (tr.)	--	--	--	3 (tr.)	--	3 (1)	--	1.6(0.1)
PLANT	3 (tr.)	4 (tr.)	--	5 (tr.)	20 (tr.)	4 (tr.)	3 (tr.)	--	--	--	3.9(0.1)
Total Volume (ml.)	50.597	16.035	12.722	30.767	19.930	14.415	34.909	18.720	16.530	0.250	214.875

both years Diptera, especially Chironomidae, had the highest frequencies of occurrence.

The diet of the larger perch was more diverse in 1976 than in 1975, which could have been caused by lower prey availability or increased diversity of the Shagawa Lake invertebrate community. Fish occurred in 22.4% of stomachs containing food in 1976 and comprised 27% of the food volume, compared with 16% occurrence and 21.5% volume in 1975. Cannibalism was greater in 1976 when age 0 perch comprised 24.5% of the volume in comparison with 6% occurrence and 9.6% volume in 1975 (Tables 7 and 8). Since the greatest cannibalism in 1976 occurred in July and August, the 1975 data may not be comparable since only 12 perch were sampled for stomach analysis before August 20, 1975. This low number of early to mid summer 1975 samples may also have resulted in the differences in food volumes and diversity between the two years.

Food volumes were similar in both years for perch over 70 mm long. Mean food volumes in older perch in 1975 and 1976 were 0.8136 ml and 0.8426 ml for stomachs containing food; and 0.7096 ml and 0.7092 ml respectively, for all perch over 70 mm TL.

Any changes in the eutrophic state of Shagawa Lake that may have occurred, did not appear to be of sufficient magnitude to be evident in the abundance, growth, or feeding of yellow perch in the first three years following tertiary wastewater treatment. Results of this study may be compared with those from future investigations of yellow perch from Shagawa Lake. If reverse eutrophication occurs, comparison of future data with those of this study could show changes in abundance, growth or feeding that may occur over time.

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APPENDICES

Appendix A Mean monthly temperature (°C) recorded daily at 0.1, 1.5, 3.0 and 6.0 m intervals for 1968-1976 from Brissons Point in Central Shagawa Lake (unpublished U.S.E.P.A. data).

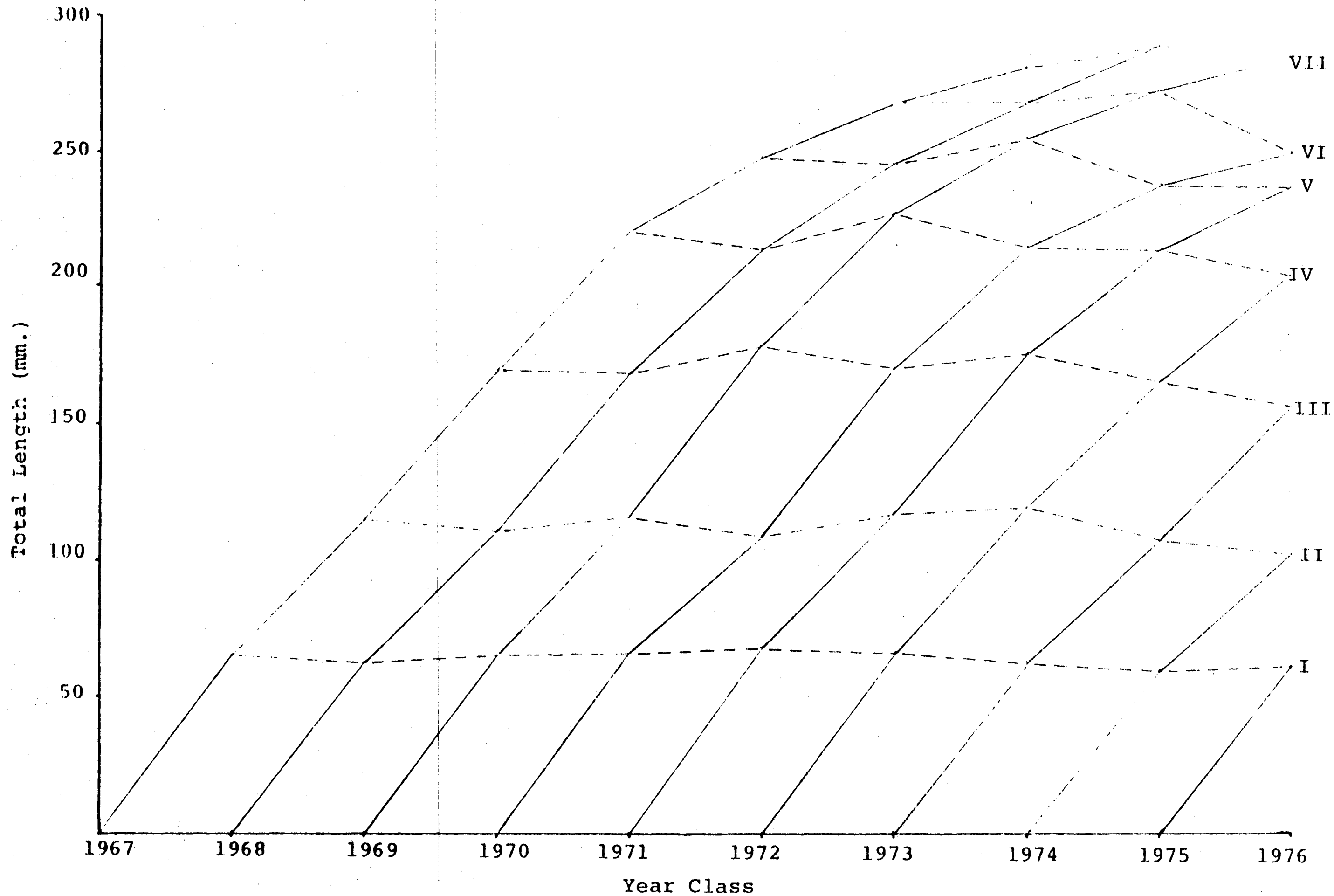
Appendix B Back-calculated total lengths (mm) of 669 yellow perch captured in 1974-1976 sampling in Shagawa Lake.

Appendix C Instantaneous growth rates (Ricker, 1975) for population growth (G_x), mean individual growth (G), and true mean growth ($\bar{G}$) for Shagawa Lake yellow perch of all age intervals in 1974, 1975 and 1976.

Appendix D Mean back-calculated total lenghts (mm) at each annulus, of yellow perch, sexes combined, captured in 1974, 1975 and 1976.

APPENDIX A. Mean monthly temperature (°C) recorded daily at 0.1, 0.5, 3.0, and 6.0 m intervals for 1968-1976 from Brissons Point in central Shagawa Lake. (Unpublished E.P.A. data, Shagawa Lake Project)

Month	Year								
	1968	1969	1970	1971	1972	1973	1974	1975	1976
January	--	--	--	1.6	2.2	3.0	1.5	2.1	3.2
February	--	--	--	1.5	2.3	2.5	1.7	2.1	3.3
March	--	--	--	1.5	2.3	3.1	1.7	2.3	3.1
April	2.1	--	--	1.9	2.6	5.4	1.8	2.6	6.5
May	9.5	12.0	5.7	8.3	10.3	10.2	6.8	10.3	11.0
June	14.3	15.4	15.9	16.9	15.9	18.0	14.4	16.0	19.5
July	--	20.0	21.1	20.2	18.8	21.3	20.3	21.2	22.2
August	--	22.1	20.1	19.5	19.7	21.8	19.0	20.7	21.4
September	--	18.7	14.6	17.5	15.7	17.4	13.1	15.7	16.9
October	--	7.6	9.5	12.2	7.3	10.4	6.7	10.2	9.9
November	--	--	4.6	4.4	3.0	3.1	6.5	6.9	3.0
December	--	1.3	1.8	1.8	2.4	1.5	1.5	--	--



APPENDIX B. Back-calculated total lengths (mm.) of 669 yellow perch captured in 1974-1976 sampling in Shagawa Lake.

APPENDIC C. Instantaneous growth rates (Ricker, 1975) for population growth (G_x), mean individual growth (G), and true mean growth ($\bar{G}$) for Shagawa Lake yellow perch of all age intervals in 1974, 1975 and 1976.

Age Interval	1974	1975	1976	1974	1975	1976	Unweighted			Weighted		
							1974	1975	1976	1974	1975	1976
	G_x	G_x	G_x	G	G	G	$\bar{G}$	$\bar{G}$	$\bar{G}$	$\bar{G}$	$\bar{G}$	$\bar{G}$
1-2	1.998	1.977	1.708	1.896	1.923	1.761	1.870	1.831	1.758	1.840	1.888	1.779
2-3	1.457	1.327	1.279	1.058	1.076	1.220	1.300	1.324	1.304	1.346	1.212	1.258
3-4	.609	.727	.845	.756	.562	.689	.720	.720	.804	.760	.746	.733
4-5	--	.302	.447	--	.213	.317	.432	.384	.385	.370	.295	.429
5-6	--	.508	.165	.305	.219	.230	.272	.333	.286	.285	.451	.248
6-7	.265	.194	.407	.167	.168	.121	.216	.181	.252	.203	.181	.317

APPENDIX D. Mean back-calculated total lengths (mm.), at each annulus, of yellow perch (sexes combined) captured in 1974, 1975 and 1976.

Year Class	No. in Sample	Age Group I	II	III	IV	V	VI	VII	VIII
1967	7	65	115	169	221	248	268	282	
1968	5	60	102	160	207	237	260		
1969	0	--	--	--	--	--			
1970	28	65	110	173	218				
1971	7	71	131	181					
1972	39	65	116					1974	
1973	3	63							
Weighted Mean	89	65	114	172	217	243	265	282	
Unweighted Mean	89	65	115	171	213	243	264	282	

Year Class	No. in Sample	Age Group I	II	III	IV	V	VI	VII	VIII
1968	5	65	115	175	217	251	273	288	
1969	6	64	110	174	224	253	271		
1970	33	66	108	171	216	231			
1971	21	66	123	176	210				
1972	81	66	119	167					
1973	17	60	110					1975	
1974	23	59							
Weighted Mean	186	64	116	170	215	236	272	288	
Unweighted Mean	186	64	114	173	217	245	272	288	

Year Class	No. in Sample	Age Group I	II	III	IV	V	VI	VII	VIII
1968	1	64	111	177	234	264	290	303	309
1969	7	66	121	183	231	258	275	286	
1970	15	63	103	162	208	233	251		
1971	25	64	116	173	215	238			
1972	119	64	116	165	206				
1973	34	62	106	157				1976	
1974	138	59	104						
1975	55	61							
Weighted Mean	394	62	110	165	209	240	260	288	309
Unweighted Mean	394	63	111	169	219	248	272	295	309