A BIOLOGICAL-LIMNOLOGICAL SURVEY OF THE NINTH STREET IMPOUNDMENT, ALPENA, MICHIGAN

Thesis for the Degree of M. S.
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ABSTRACT

A BIOLOGICAL-LIMNOLOGICAL SURVEY OF THE NINTH STREET IMPOUNDMENT, ALPENA, MICHIGAN

By

Thomas Edward Mears

During the summer months of 1968 a study was undertaken to gather basic ecological information concerning the Ninth Street Impoundment of the Thunder Bay River at Alpena, Michigan. Prior to this study 50,000 chinook salmon (*Oncorhynchus tschawytscha*) smolts had been introduced to Fletcher Creek, a tributary of the reservoir.

Invertebrates were collected primarily from Petersen dredge samples and fish stomach analysis. Experimental gill nets were used to secure most of the fish collected. Aquatic plants were collected incidental to other operations.

The maximum water temperature recorded in the Ninth Street Impoundment was 26 C. A shoreline development of 2.20 and an insulosity of 22% indicate that the reservoir is dominated by littoral areas. Dissolved oxygen concentrations lower than 5.0 ppm were rarely encountered. Methyl orange alkalinity ranged from 120 to 180 mg/l as $CaCO_3$. Phenolphthalein alkalinities were as high as 26 mg/l as $CaCO_3$.

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pH varied from 8.1 to 8.85. Total hardness (EDTA) ranged from 186 to 242 mg/l as $CaCO_3$.

Four of nineteen aquatic plant genera collected were indicators of hard, alkaline waters. Several of the invertebrate taxa collected were organisms intolerant of organic enrichment of their environment. Northern pike (*Esox lucius*), rockbass (*Ambloplites rupestris*), and pumpkinseed (*Lepomis gibbosus*) had growth rates less than the Michigan state averages. Yellow perch (*Perca flavescens*), and bluegill (*Lepomis macrochirus*) less than age III were smaller than average while fish older than III were larger than average. Yellow perch, northern pike, rockbass, large bluegill, black crappie (*Pomoxis nigromaculatus*), bowfin (*Amia calva*), and largemouth bass (*Micropterus salmoides*) were potential predators on the introduced chinook salmon smolts. A summary of all available data indicated that the probability of a successful introduction of chinook salmon would be increased if the smolts were planted in the Thunder Bay River below the Ninth Street Impoundment rather than in Fletcher Creek.

A BIOLOGICAL-LIMNOLOGICAL SURVEY OF THE NINTH STREET IMPOUNDMENT, ALPENA, MICHIGAN

By

Thomas Edward Mears

A THESIS

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INTRODUCTION

During May, 1968, approximately 50,000 chinook salmon smolts, Oncorhynchus tschawytscha (Walbaum), were introduced into Fletcher Creek, a tributary of the Ninth Street Impoundment of the Thunder Bay River in Alpena, Michigan. The smolts were reared at the Alpena Community College hatchery from eyed-eggs donated by Dr. Lauren Donaldson of the University of Washington. The eggs provided by Dr. Donaldson were from a strain of chinook salmon that have been selectively bred for early sexual maturity and maximum growth (Donaldson and Menasveta, 1961).

The fish were released less than two miles upriver from Thunder Bay. However, before the smolts could migrate into Thunder Bay they had to pass through the Ninth Street Impoundment and over the spillways or through the turbines of the Ninth Street power dam.

The purpose of this study is to describe some basic ecological features of the Thunder Bay River and especially the Ninth Street Impoundment. This study should serve as a basis for future ecological investigations of the lower Thunder Bay River system because this study is a summarization of previous limnological and biological studies done on the Thunder Bay River system and a description of the physical, chemical, and biological characteristics of the Ninth Street Impoundment. The major objectives of this study are:

1) to provide a morphological description of the Ninth Street Impoundment;

2) to describe the relative abundance, distribution, and diversity of aquatic plants, invertebrates, and fish in the Ninth Street Impoundment;

3) to evaluate the sport fishery of the Ninth Street Impoundment by comparing the growth rates of several fish species with growth rates reported from other locations;

4) to make recommendations for the management of both native and exotic fish species.

This study was initiated 12 June, 1968 and terminated 28 February, 1969.

REGIONAL CHARACTERISTICS

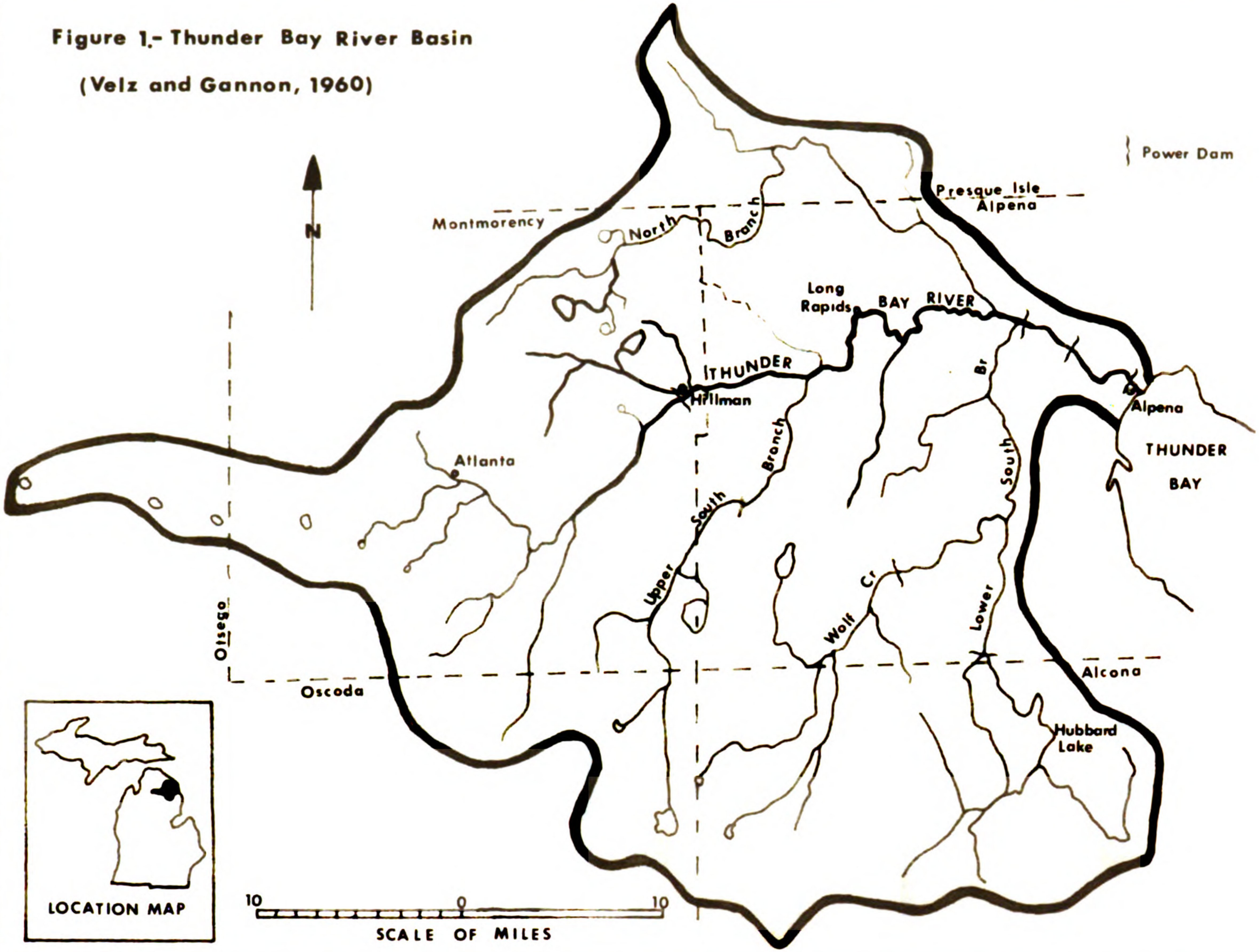
The Thunder Bay River Basin

"The Thunder Bay Basin, with a drainage area of approximately 1,118 square miles, lies in the northeastern part of Michigan's Lower Peninsula comprising parts of Presque Isle, Montmorency, Otsego, Oscoda, Alcona, and Alpena Counties. The basin, irregular in shape, measures approximately 40 miles long and 34 miles wide measuring at the longest and widest points. The Thunder Bay River flows mostly easterly to its mouth in Thunder Bay, an arm of Lake Huron" (Velz and Gannon, 1960). The largest city in the basin, Alpena (15,000 population), is situated at the mouth of the Thunder Bay River. The major tributaries of the Thunder Bay River are the North Branch, draining the northern area of the basin, and the Upper and Lower South Branches, draining the southern area of the basin (Figure 1).

Several hydroelectric dams, run-of-the-river type with small storage capacity, are scattered throughout the Thunder Bay River Basin and supply all of the electric power for the region. "In general, hydro-power operation induces diurnal fluctuations in flow during the hours of the day and curtailed discharge during weekend shut-downs" (Velz and

Figure 1.- Thunder Bay River Basin

(Velz and Gannon, 1960)



Gannon, 1960). In most Michigan river systems it has been possible to relate the size of a drainage area to the most probable and the once in 10 year minimum consecutive 30-day average flows (Velz and Gannon, 1960). In the Thunder Bay River neither relationship could be computed because of the tremendous influence of power plant operations upon discharge (Velz and Gannon, 1960).

Geological Characteristics

The basin is underlain primarily by three different geological formations (Figure 2). The northern area is underlain by crystalline, hard Alpena Limestone. The main branch is underlain by the Thunder Bay Rocks which are alternating layers of various types of limestones and shales, with limestones comprising the upper 30 feet of the bedrock. The southern area of the basin is underlain by dense sedimentary rock called Antrim shale (Ver Wiebe, 1927). There are presently limestone quarries in the northern area and shale quarries in the southern area of the basin. Numerous limestone sinkholes and "underground rivers" are found throughout the northern area.

The entire northern lower peninsula of Michigan was intensively glaciated several times during different geologic periods. The Thunder Bay drainage is in the Northern Upland Physiographic Province (Scott, 1921), an area of great glacial accumulation with extensive moraines, till

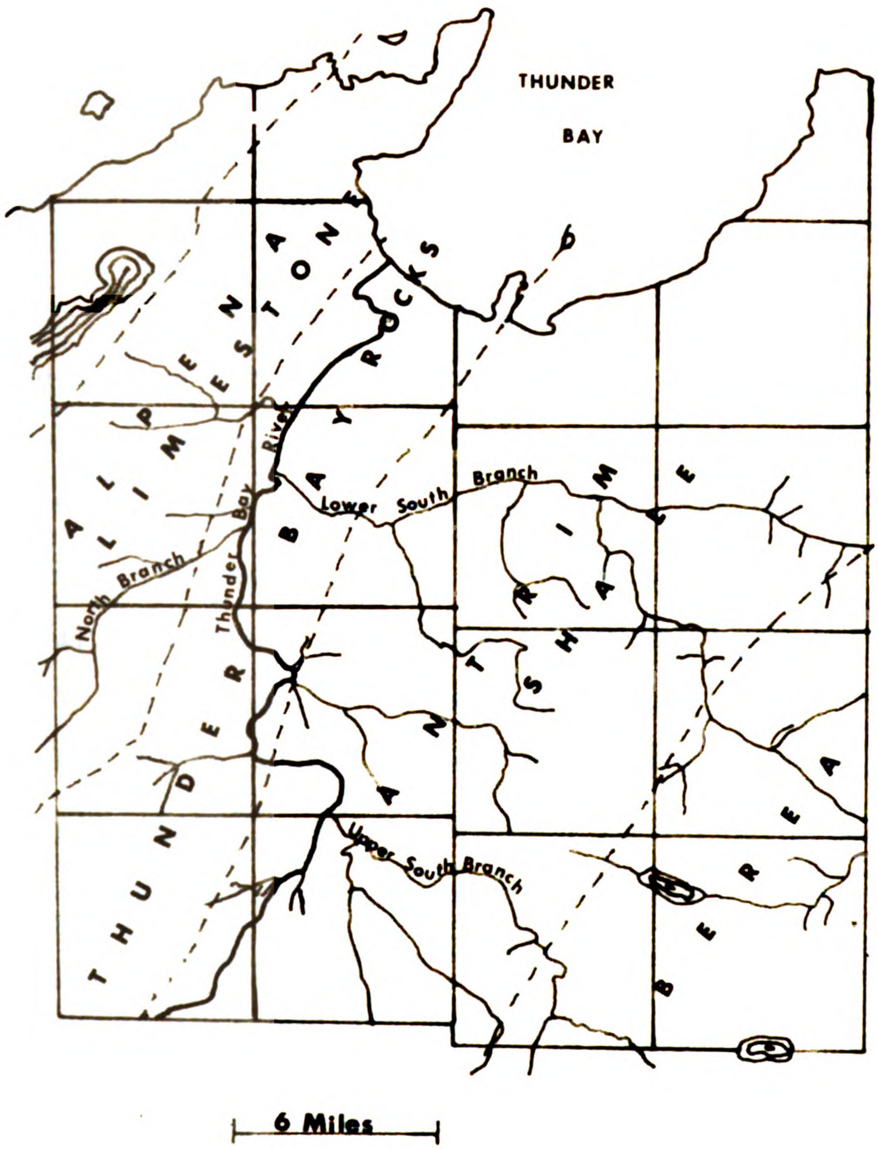


Figure 2- Areal geology of Alpena County Michigan (Ver Wiebe, 1927).

plains, and broad outwash aprons, the latter constituting the great sand plains throughout the Thunder Bay River drainage. Glacial moraines, till plains, and outwash aprons occur with such frequency and are of such magnitude that these formations are obvious even to the most inexperienced observer.

Water Chemistry

The water chemistry of the river system has been studied by Moreau (unpublished). He found the Thunder Bay River water to be relatively hard (250 to 350 mg/l EDTA). Average total hardness values from the North Branch were lowest (250 mg/l), from the main branch highest (343 to 348 mg/l), the upper and lower South Branches being intermediate (307 to 323 mg/l). Total alkalinity (mg/l $CaCO_3$) was lowest in the North Branch (149), highest in the South Branches (168 to 181), and intermediate in the main branch (152). The North Branch had the highest color (2.4 mg/l Tannin), the Main Branch lowest (1.4 to 1.6 mg/l), and the South Branches intermediate (1.9 mg/l).

Total solids followed the same pattern as alkalinity and hardness; North Branch highest (319 mg/l), Main Branch lowest (253 to 264 mg/l), South Branches intermediate (292 to 300 mg/l).

Climate

The United States Department of Commerce Narrative Climatological Summary of Alpena, Michigan states that "the climate along the immediate Lake Huron shore is semi-maritime in nature and lacks most of the temperature extremes shown in many cases only a few miles inland. The early winter temperatures are higher than are common to this latitude but, as the Great Lakes freeze the temperature commonly approaches zero ^{o}F. Thunder Bay and the river are usually free of ice by the first week in April. The average date of the last killing frost is May 12, but frost has occurred as late as June 9. The average date of the first killing frost in autumn is October 4, but frost has occurred as early as September 6."

Precipitation is well distributed throughout the year. Velz and Gannon (1960) state that the most probable annual precipitation for Alpena is 28.8" with 16.8" most probable from May to October, and 8.10" most probable from August to October. "The spring thaw and runoff seldom offer any flood danger" (U.S. Department of Commerce, 1967).

"Prevailing winds are from the northwest with the exception of May and June when southeasterly winds predominate. During July and August, when Lake Huron surface temperatures are near their maximum, southeasterly winds occur during the warmest hours of the day when conditions are favorable for sea breezes. During the summer there is a daily average of more than 15 hours of daylight" (U.S. Department of Commerce, 1967).

DESCRIPTION OF STUDY AREA

The Ninth Street Hydroelectric Dam was completed in 1910 and is now property of the Alpena Power Company. The Ninth Street Dam impedes the flow of the Thunder Bay River creating the 432 acre Ninth Street Impoundment.

In addition to hydroelectric power the Ninth Street Impoundment provides such recreational opportunities as fishing, swimming, boating, water skiing, and turtle hunting (ten to twenty-five pound snapping turtles, *Chelydra serpentina* (Linn) are common). The entire impoundment is a waterfowl sanctuary. Ducks, geese, and swans are year-round residents.

The Ninth Street Impoundment has several sources of water. The discharge of the Thunder Bay River makes by far the largest contribution, so large in fact that all other sources of water are considered minor. There are two tributary creeks. One, unnamed, flowing into Lake Besser, is intermittant, flowing only during periods of high water. The second, Fletcher Creek, flows continually. In addition to the streams there are several springs within the Ninth Street Impoundment (Appendix 1). These springs flowed continuously throughout the summer of 1968.

Peak mean monthly discharge from the Ninth Street Dam (1963 to 1968) occurs in April, the low discharge in August (Figure 3). No apparent relationship exists between mean monthly discharge from the Ninth Street Dam and mean monthly precipitation at the United States Weather Bureau's Alpena office (Figure 3).

The area selected for study included all of the impounded water extending from the Ninth Street Dam westward to the point where the entire discharge of the Thunder Bay River is in a single channel (Appendix 1). For convenience the study area was divided into two units; the area east (downstream) of the Chisolm Street (US-23 North) bridge was referred to as Lake Besser and the area west of the Chisolm Street Bridge referred to as the "Oxbows" (Appendix 1).

An outline map was traced from an enlargement of a U.S. Soil Conservation Service aerial photograph. Soundings were taken through the ice during February, 1969, the points fixed by means of dual compass readings. Depth contours at depths of six and twelve feet were determined by inspection. The resulting hydrographic map (Appendix 1) was used to determine several morphometrical statistics. Shoreline length was measured with a map measurer and area was determined by the planimeter method. Length and breadth were measured from the map with a ruler. Estimates of morphological parameters as defined by Hutchinson (1957) are:

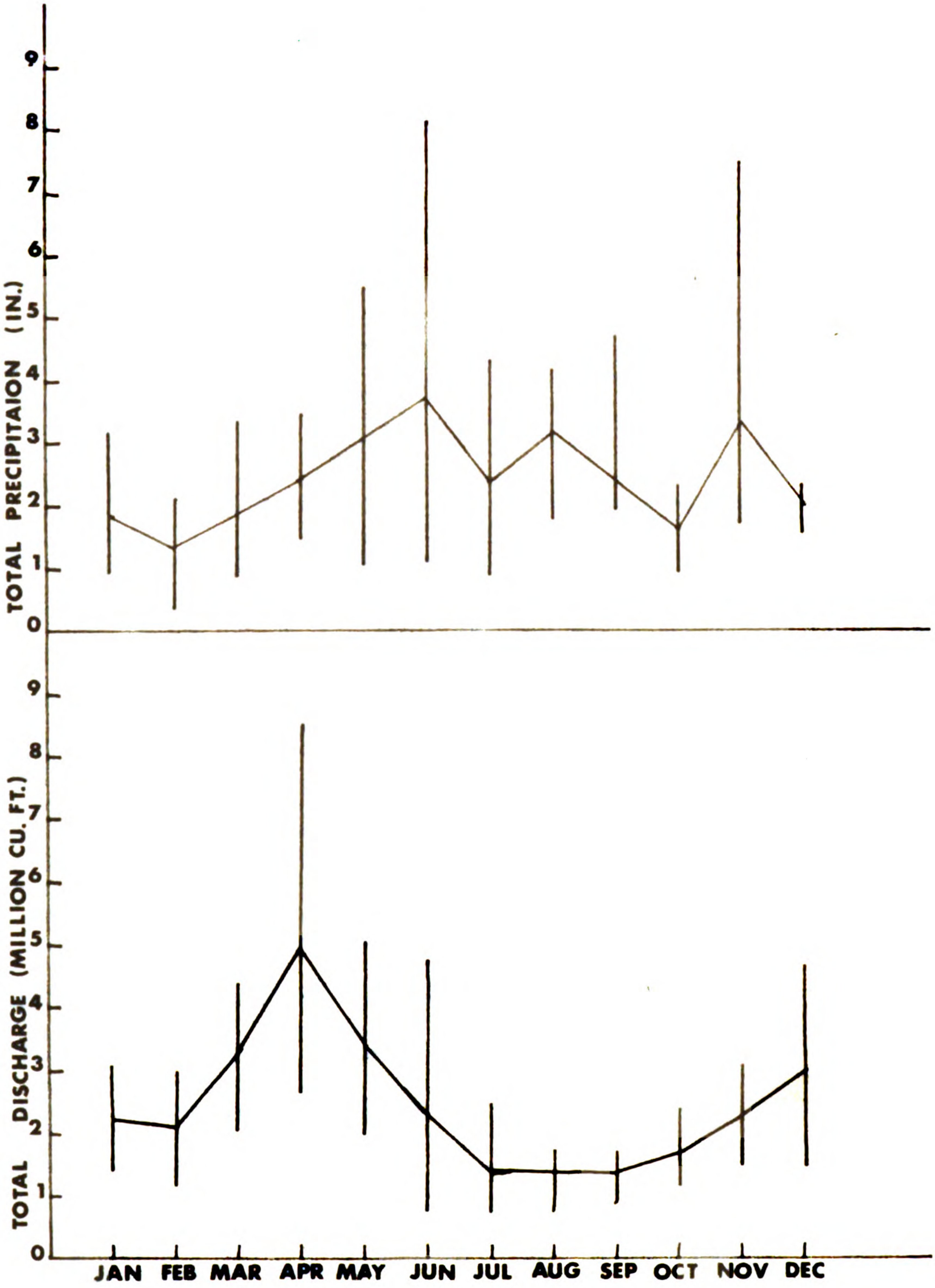


FIGURE 3.- MONTHLY TOTAL DISCHARGE OF THE THUNDER BAY RIVER AT THE NINTH STREET DAM AND MONTHLY PRECIPITATION FOR ALPENA, MICHIGAN, 1963-1968. VERTICAL BARS REPRESENT RANGES, INTERCONNECTING BARS PASS THROUGH MEANS. DISCHARGE DATA COURTESY OF ALPENA POWER CO. PRECIPITATION DATA FROM U.S. DEPT. COMMERCE LOCAL CLIMATOLOGICAL DATA FOR 1968.

Length of the Ninth Street Impoundment - 1.364 miles

Breadth - .980 miles

Maximum Depth - 21 feet

Shoreline - 6.41 miles

Total Area - 432 acres

Area of Lake Besser - 2,602,600 sq. ft.

Shoreline Development - 2.20

Insulosity - 22%

At some point in geologic time the lower stretch of the Thunder Bay River (that section including the area 3 to 4 miles upstream from Lake Huron) reached the limit of its downward cutting and began meandering. The result of this meandering can be readily observed in the number of variously aged meander scars. The Ninth Street Impoundment can be characterized as an area of extremes as far as water depth is concerned. The deeper waters (6 to 12 feet) are remnants of the more recent river channels, the shallower waters are primarily areas inundated subsequent to the impounding of the river by the Ninth Street Dam. Several of the more recent river channels still have currents of water moving through them (Appendix 1).

Insulosity is that percentage of a lakes total area that is occupied by islands. High values for both insulosity and shoreline development indicate that the Ninth Street Impoundment has a relatively large littoral zone.

BENTHIC INVERTEBRATE AND LIMNOLOGICAL SAMPLING STATIONS

Migratory chinook salmon smolts tend to follow the direction of water currents. Presumably, after introduction the smolts followed a fairly direct route through and out of the Ninth Street Impoundment. Most probably the smolts, after leaving Fletcher Creek, moved down the flowing channels either east or west of Sportsman's Park and through the short stretch of the Thunder Bay River that separates the Oxbows area from that of Lake Besser proper. The smolts probably followed one or more of the three current channels through Lake Besser and eventually passed through the turbines of the Ninth Street Dam.

In that this route of migration was thought to be highly probable, it was decided to study the limnological and benthological conditions of this area more thoroughly than in the remainder of the impoundment. Accordingly, the COA (Coho Hall Oxbow Area) stations were established in the channels surrounding Sportsman's Park, TBR (Thunder Bay River) stations were established between the Oxbows and Lake Besser, and LB (Lake Besser) stations were established both in the limnetic (channels) and littoral (shallow) areas of

Lake Besser. Sampling station positions are recorded in Appendix 1. Stations are described in Appendix 2.

LIMNOLOGICAL CHARACTERISTICS

Methods

Water temperature and dissolved oxygen profiles were measured with a Precision Scientific Galvanic Cell Oxygen Analyzer-Thermister Unit. The oxygen probe was calibrated by the Rapid Azide modification of the Iodometric Method. The Rapid Azide modification differs from the Azide modification (Amer. Publ. Health Assoc. et al., 1965) in that twice the quantities of manganese sulfate solution and alkali-iodide-azide reagents are used in the Rapid Azide modification.

Hardness (EDTA) total alkalinity, and pH values were determined for surface samples only. Alkalinity and hardness (EDTA) tests were conducted according to Standard Methods (Amer. Publ. Health Assoc. et al., 1965). pH was measured with a Beckman pH meter.

On both 15 June and 3-4 July single dissolved oxygen and water temperature profiles plus Secchi disc readings were taken at each station sampled. Beginning 08:00 EST, 25 July, water temperature and dissolved oxygen profiles, Secchi disc readings, and surface alkalinity-pH values were determined at four selected stations every two hours for 22 consecutive hours. Total hardness (EDTA) was measured at each of the four stations at 16:00 EST, 25 July.

Results

Temperature

Water temperatures at the stations sampled ranged from 16.0 to 18.7 C on 15 June, 15.1 to 19.5 C on 3-4 July, and 21 to 26 C on 25-26 July. Ranges of temperatures within each temperature profile for TBR and LB stations never exceeded 1 C on any sampling date (Tables 1 to 3). Ranges of temperatures within each COA temperature profile were as wide as 2.5 C. There was never any indication of a thermocline at any sampling station. Station COA-2 was the only station to consistently exhibit thermal stratification. Apparently long term thermal stratification was impossible at the shallower stations because changing air temperatures rapidly affect a large percentage of the profile. The remainder of the deeper stations had some degree of water currents, the mixing action of which kept the water column nearly the same temperature from top to bottom.

Dissolved Oxygen

Dissolved oxygen values at 911 stations generally ranged from 6 to 12 mg/l. Dissolved oxygen values lower than 5.0 mg/l occurred only at station COA-2 on two sampling dates. At 11:00 EST, 15 June, values of 4.0, 3.3, 3.3, and

Table 1. Oxygen (mg/l), Temperature (C), Secchi Disc (ft), and Depth (ft), values for selected stations, Ninth Street Impoundment, 15 June, 1968. (DO = Dissolved Oxygen, T = Temperature)

Station	Time (EST)	Air Temp.	Secchi Disc	Depth to Bottom		Depth of Reading 2	4	6	8	10	12	14	16
COA-1	10:00	20.5	bottom	4.0	T	17.0							
					DO	5.9							
COA-2	11:00	15.0	6.5	9.5	T	18.0	17.0	16.5	16.0				
					DO	4.0	3.3	3.3	3.0				
COA-3	11:30	16.5	6.5	8.0	T	18.0	18.0	17.5					
					DO	6.4	6.2	6.4					
COA-4	13:20	20.0	6.5	6.5	T	16.1	16.4	16.0					
					DO	9.7	12.0	12.0					
TBR-1	12:00	17.0	5.0	11.5	T	17.5	18.0	18.0	18.0	17.5			
					DO	6.5	6.5	6.5	6.7	6.7			
TBR-2	12:15	17.0	4.5	13.0	T	18.5	18.0	18.0	18.0	18.0	18.0		
					DO	6.7	6.9	6.9	6.7	6.7	6.7		
LB-1	12:40	17.0	4.5	11.0	T	18.5	18.5	18.0	18.0	18.2			
					DO	6.8	6.8	6.9	6.9	6.9			
LB-2	13:00	15.0	5.0	16.0	T	18.7	18.5	18.7	18.7	18.5	18.5	18.5	18.5
					DO	7.0	7.0	7.0	7.0	6.8	6.8	6.8	6.7

Table 2. Oxygen (mg/l), Temperature (C), Secchi Disc (ft), and Depth (ft) values for selected stations, Ninth Street Impoundment, 3-4 July, 1968. (DO = Dissolved Oxygen, T = Temperature)

Station	Time (EST)	Air Temp.	Secchi Disc	Depth to Bottom		Depth of Reading 0	2	4	6	8	10	12
COA-1	9:30	17.0	Bottom	5.0	T	16.0	16.0	15.5				
					DO	8.0	8.0	8.0				
COA-2	14:20	21.0	8.0	9.0	T	18.5	18.0	17.5	16.5	16.0		
					DO	11.4	11.5	8.5	9.0	8.1		
COA-3	13:55	23.0	7.0	11.0	T	19.0	18.5	18.0	18.0	16.5	16.5	
					DO	9.7	9.4	9.1	8.4	8.4	8.6	
COA-4	11:00	19.0	to bottom	6.0	T	15.5	15.5	15.4	14.7			
					DO	12.0	12.1	11.7	11.6			
COA-5	14:47	21.5	to bottom	2.0	T	20.5						
					DO	10.5						
COA-6	9:00	14.0	to bottom	3.0	T	16.0	15.1					
					DO	9.8	12.4					
COA-7	11:30	18.0	to bottom	7.0	T	17.5	17.3	16.9	16.6			
					DO	11.6	11.4	11.8	11.6			
COA-8	10:12	22.0	to bottom	2.5	T	17.5	17.3					
					DO	9.5	9.7					
TBR-1	9:55	19.0	6.0	6.5	T	17.0	17.2	17.2	17.2			
					DO	9.7	9.7	9.8	9.8			

Table 2 (Cont'd.)

Station	Time (EST)	Air Temp.	Secchi Disc	Depth to Bottom		Depth of Reading 0	2	4	6	8	10	12
TBR-2	9:47	19.5	6.0	13.0	T	18.5	18.5	18.7	18.6	18.5	18.5	18.5
					DO	9.1	9.1	9.6	9.4	9.4	9.4	9.4
LB-1	8:10	12.0	5.5	12.0	T	18.4	19.5	19.4	19.2	19.0	19.5	19.1
					DO	9.1	9.0	9.2	9.4	9.5	9.2	9.5
LB-2	9:57	18.0	6.5	11.5	T	19.2	19.2	19.2	19.0	19.2	19.3	
					DO	9.3	9.4	9.5	9.7	9.4	9.4	
LB-3	9:15	19.0	too weedy	3.0	T	19.0	19.0					
					DO	10.0	9.9					
LB-4	9:42	16.0	6.5	11.0	T	18.7	19.2	19.2	19.0	19.0	18.4	
					DO	9.1	9.3	9.4	9.4	9.4	8.7	
LB-5	9:45	18.0	to bottom		T	18.6	18.2					
					DO	9.3	9.6					
LB-6	8:30		weedy	4.5	T	19.0	19.2	18.8				
					DO	10.0	10.0	8.0				

Table 3. Oxygen (mg/l), and Temperature (C) Profiles, Secchi Disc (ft), pH, Phenophthalein alkalinity (mg/l $CaCO_3$), Methyl Orange alkalinity (mg/l $CaCO_3$) for the Ninth Street Impoundment during a 22 hour sampling period, 25-26 July, 1968. (DO = Dissolved Oxygen, T = Temperature)

Table 3. Station COA-2

Time (EST)	Air Temp.	Secchi Disc		Depth of Reading 0	2	4	6	8	10	pH	Alkalinity M.O.	Phth.
8:00	21.8	8.5	T	22.8	23.1	22.9	22.6	21.5	21.0	8.50	150	0
			DO	10.1	10.1	10.4	9.4	8.5	6.0			
10:00	24.7	8.5	T	23.4	23.4	23.3	22.5	21.5	21.0	8.35	162	0
			DO	10.4	10.4	10.2	9.6	9.1	6.5			
12:00	27.0	8.0	T	24.4	24.2	23.7	22.3	21.7	21.3	8.40	156	0
			DO	9.5	9.8	9.6	9.1	7.1	5.8			
14:00	26.1	8.5	T	24.8	24.9	23.6	23.0	21.7	21.3	8.50	150	2
			DO	12.1	11.8	11.4	10.3	9.0	8.1			
16:00	15.0	8.5	T	24.4	25.4	24.0	22.6	21.8	21.5	8.55	148	4
			DO	11.1	11.5	10.6	9.8	8.2	7.2			
18:00	21.5	8.5	T	24.2	25.4	24.5	23.3	21.0	21.5	8.60	144	12
			DO	12.2	11.4	11.8	10.9	8.3	5.1			
20:00	20.0	6.5	T	23.6	25.2	25.0	24.5	22.5	21.5	8.60	124	22
			DO	12.6	11.6	12.4	9.7	8.1	6.3			
22:00	22.0	0.0	T	24.0	25.0	25.1	23.1	22.4	22.0	8.65	138	14
			DO	10.7	10.2	9.4	8.5	7.5	6.0			
24:00	21.0	0.0	T	23.3	24.3	24.7	23.2	22.5	21.4	8.65	144	14
			DO	9.2	8.6	8.4	8.0	6.0	5.0			
2:00	20.8	0.0	T	22.9	24.6	24.5	23.6	22.5	22.2	8.60	158	14
			DO	10.9	9.1	9.2	8.7	7.2	4.1			
4:00	18.0	0.0	T	23.5	24.8	25.0	25.0	23.0	23.0	8.55	138	18
			DO	10.9	9.6	9.3	8.7	8.2	4.0			

Table 3 (Cont'd.) Station TBR-2

Time (EST)	Air Temp.	Secchi Disc		Depth of Reading 0	2	4	6	8	10	12	pH	Alkalinity M.O.	Phth.
8:00	20.9	8.5	T	22.6	22.9	22.9	22.8	22.9	22.7	22.9	8.20	172	0
			DO	7.8	7.8	7.7	8.0	8.0	8.0	7.8			
10:00	24.2	7.5	T	23.2	23.2	23.2	23.0	23.1	23.1	23.1	8.30	180	0
			DO	8.8	8.5	8.4	8.4	8.4	8.4	8.2			
12:00	27.0	6.5	T	24.0	23.7	23.6	23.9	23.6	23.5	23.6	8.40	168	0
			DO	8.2	8.3	8.3	8.1	8.3	8.3	8.3			
14:00	25.3	7.0	T	24.0	24.0	23.9	24.0	24.0	24.0	24.0	8.45	176	0
			DO	9.7	9.7	9.9	9.9	9.8	9.8	9.9			
16:00	25.4	6.5	T	24.2	24.1	24.3	24.3	24.3	24.2	24.2	8.50	160	8
			DO	9.4	9.5	9.4	9.4	9.4	9.5	9.5			
18:00	21.7	7.5	T	24.0	24.2	24.2	24.2	24.3	24.3	24.3	8.50	154	14
			DO	10.1	9.9	9.8	9.7	9.7	9.5	9.5			
20:00	20.0	6.5	T	23.5	24.2	24.3	24.2	24.2	24.1	24.2	8.50	180	6
			DO	9.7	9.4	9.3	9.5	9.4	9.5	9.3			
22:00	21.5	0.0	T	22.5	24.0	24.0	24.0	23.8	23.8	23.8	8.45	174	0
			DO	8.2	7.8	7.8	7.8	7.8	7.8	7.7			
24:00	21.0	0.0	T	23.1	23.6	23.9	23.8	23.6	23.9	23.8	8.50	170	0
			DO	7.1	6.7	6.8	6.8	6.9	6.8	6.7			
2:00	20.4	0.0	T	23.1	23.8	24.0	24.0	24.0	23.9	24.1	8.45	170	0
			DO	8.0	7.1	7.4	7.4	7.4	7.4	7.3			
4:00	18.0	0.0	T	22.0	24.1	24.0	24.4	24.3	24.3	24.2	8.35	176	0
			DO	9.2	7.7	7.9	7.6	7.3	7.3	7.3			

Table 3 (Cont'd.) Station COA-5

Time (EST)	Air Temp.	Secchi Disc	Depth of Reading	0	1	pH	Alkalinity M.O.	Alkalinity Phth.
8:00	22.3	bottom	T	22.5	22.5	8.10	152	0
			DO	9.4	10.3			
10:00	25.2	bottom	T	23.5	23.7	8.45	148	0
			DO	12.6	12.2			
12:00	27.0	bottom	T	25.3	25.3	8.70	148	4
			DO	12.3	12.3			
14:00	26.5	bottom	T	25.0	26.0	8.75	134	6
			DO	15.8	13.4			
16:00	26.8	bottom	T	25.6	25.8	8.72	146	14
			DO	12.6	11.6			
18:00	21.0	bottom	T	25.8	25.7	8.85	124	22
			DO	13.4	12.6			
20:00	20.0	bottom	T	24.5	25.5	8.80	120	26
			DO	13.8	14.4			
22:00	22.1	0	T	23.5	24.5	8.75	120	26
			DO	11.0	10.1			
24:00	21.0	0	T	22.5	23.5	8.65	134	8
			DO	8.8	8.1			
2:00	21.0	0	T	22.5	23.2	8.50	138	8
			DO	9.0	8.2			
4:00	18.0	0	T	22.0	23.4	8.30	126	20
			DO	10.3	9.1			

Table 3 (Cont'd.) Station LB-2

Time (EST)	Air Temp.	Secchi Disc		Depth of Reading 0	2	4	6	8	10	12	14	pH	Alkalinity M.O.	Alkalinity Phth.
8:00	19.0	6.5	T	22.8	23.1	23.1	23.3	23.1	22.8	22.8	22.9	8.30	168	0
			DO	8.8	8.9	8.9	8.7	8.7	9.0	8.8	8.9			
10:00	25.9	8.5	T	23.2	22.7	22.7	22.7	23.0	23.0	22.7	22.7	8.30	176	0
			DO	8.2	8.0	7.9	7.6	7.5	7.5	7.6	8.7			
12:00		7.5	T	23.7	23.5	23.5	23.4	23.5	23.5	23.4	23.5	8.40	170	0
			DO	9.4	8.4	8.3	8.2	8.1	8.1	8.1	7.8			
14:00	24.5	7.5	T	24.0	23.5	23.5	23.4	23.5	23.4	23.4	23.4	8.40	166	2
			DO	9.1	9.1	9.0	9.0	8.8	8.9	8.9	9.2			
16:00	25.5	7.5	T	24.5	24.0	24.0	23.8	23.8	24.0	24.0	23.9	8.50	174	8
			DO	8.5	8.5	8.6	8.7	8.6	8.6	8.6	8.8			
18:00	22.0	7.0	T	24.0	24.3	24.2	24.1	24.2	24.1	24.1	24.0	8.50	160	10
			DO	8.6	9.0	9.2	9.3	9.4	9.6	9.5	9.9			
20:00	20.0	7.0	T	23.2	24.2	24.3	24.2	24.4	24.3	24.3	24.1	8.50	160	2
			DO	9.3	9.5	9.6	9.7	9.5	9.6	9.5	9.7			
22:00	20.0	0.0	T	23.5	24.0	23.9	24.3	24.3	24.4	23.9	23.5	8.50	176	0
			DO	8.0	8.1	8.2	8.0	8.0	8.3	8.4	8.8			
24:00	20.0	0.0	T	23.4	24.0	24.4	24.4	24.4	24.5	24.5	24.4	8.50	166	6
			DO	7.0	6.9	7.0	7.1	7.1	7.2	7.2	6.9			
2:00	20.6	0.0	T	23.6	24.1	23.7	23.9	23.7	24.2	24.1	24.0	8.50	166	8
			DO	7.8	7.4	8.2	6.7	7.7	7.5	8.0	8.0			
4:00	22.0	0.0	T	22.6	24.5	24.5	24.3	24.5	24.5	24.5	24.5	8.50	160	8
			DO	9.8	8.3	8.4	8.6	8.4	7.6	7.8	8.3			

3.0 mg/l dissolved oxygen were recorded at the 2,4,6, and 8-ft. levels, respectively (Table 1). On 26 July, values of 4.1 and 4.0 mg/l dissolved oxygen were recorded at the 10-ft. levels at 02:00 and 04:00 EST, respectively (Table 3).

Alkalinity, pH, Hardness (EDTA)

Methyl orange alkalinity varied from 120 to 180 mg/l as $CaCO_3$ (Table 3). Phenolphthalein alkalinities were as high as 26 mg/l as $CaCO_3$, but were not present in all samples (Table 3). pH varied from 8.1 to 8.85 (Table 3). Total hardness (EDTA) ranged from 186 to 242 mg/l as $CaCO_3$ (Table 3).

As would be expected, pH values at each station generally increased during daylight hours and decreased during the night. The time at which highest phenolphthalein alkalinity values occurred at each station, approximately 20:00 EST, was the time at which lowest methyl orange alkalinity values occurred (Tables 1 to 3).

When median pH value, mean phenolphthalein alkalinity, and mean methyl orange alkalinity for each station over the 22-hour sampling period (25-26 July) are coupled with total hardness (EDTA) data (Table 4) the inter-relationships between these four parameters become apparent. Station COA-5 has the highest median pH followed by COA-2, LB-2, and TBR-2. Mean phenolphthalein alkalinity decreases while mean methyl

Table 4. Median pH, Total Hardness (EDTA, mg/l $CaCO_3$), Methyl Orange Alkalinity (mg/l $CaCO_3$), and Phenolphthalein Alkalinity (mg/l $CaCO_3$), values for surface samples during a 22-hour continuous sampling period beginning 16:00 EST, 25 July, 1968, at selected stations in the Ninth Street Impoundment.

Parameter	Station			
	COA-5	COA-2	LB-2	TBR-2
Total Hardness (EDTA)	186	210	222	242
Mean Methyl Orange Alkalinity	135.5	146.5	167.9	170.9
Mean Phenolphthalein Alkalinity	12.2	9.1	3.6	2.5
Median pH	8.70	8.55	8.50	8.45

orange alkalinity and total hardness (EDTA) increase with decreasing median pH values (Table 4).

Phenolphthalein alkalinity values larger than zero for a sample means that metallic bicarbonates are present in solution. Methyl orange alkalinity indicates relative amounts of metallic monocarbonates in solution. Metallic bicarbonates are kept in solution by dissolved free carbon dioxide. Station COA-5 (located in a rooted aquatic plant bed, depth of 2 ft.) has the highest median pH value and mean bicarbonate alkalinity of the four stations because the rooted aquatic plants and associated organisms inhabit the total water column and, therefore, make up a higher theoretical biomass per volume of water. This concentrated biomass yields a high concentration of free carbon dioxide. High levels of free carbon dioxide indicate that higher levels of bicarbonates are also present. Bicarbonates are used by aquatic plants as a carbon source, the chemical reaction giving off hydroxide (Ruttner, 1963). High bicarbonate levels therefore induce high pH. Station COA-2, second highest median pH and mean phenolphthalein alkalinity is in the limnetic zone, but is surrounded by rooted aquatic plant beds. Station LB-2, third highest median pH and mean phenolphthalein alkalinity, is also limnetic, but receives the waters of the river station, TBR-2 (lowest in median pH and mean phenolphthalein alkalinity), after the waters have moved through and around the massive aquatic plant beds of Lake Besser.

Secchi Disc Values

Secchi Disc readings ranged from 4.5 to 8.5 ft. (Tables 1 to 3). On any sampling date Secchi readings were higher for COA stations than for LB or TBR stations.

Secchi Disc readings are proportional to the depth of light penetration. They thereby indicate that the photosynthetic zone in Oxbow area (COA stations) extends to a greater depth than in the Lake Besser area (LB stations plus station TBR-2).

BIOLOGICAL CHARACTERISTICS

Aquatic Plants

Methods

During the summer months of 1968 enough qualitative aquatic plant samples were secured incidental to fishing and bottom sampling that the author learned to recognize many genera on sight. An attempt was made to identify all aquatic plants encountered in the reservoir. Field collections probably included all of the genera of aquatic plants growing in the Ninth Street Impoundment.

Results

A total of nineteen genera of aquatic plants were collected (Table 5). Nearly all areas where the water depths were six feet or less (Appendix 1) were densely crowded with aquatic plants. Relatively pure stands of *Myriophyllum* sp, *Anacharis canadensis*, *Chara* sp, and *Potamogeton pectinatus* were common in both Lake Besser and Oxbows areas. *Myriophyllum* sp was the most abundant rooted aquatic plant. *Chara* sp was also quite abundant. *Chara* sp and *Utricularia* sp were commonly lime encrusted.

Table 5. A list of aquatic plant taxa collected from the Ninth Street Impoundment, June-September, 1968. References used for identification of rooted aquatics and algae were Fassett (1968) and Prescott (1962).

Rooted Aquatics	Algae
Anacharis canadensis (Michx)	*Chara* sp
Cladophora sp	*Oscillatoria* sp
Eleocharis sp	*Spirogyra* sp
Equisetum fluviatile L	
Lemna minor L	
Megalodonta Beckii (Torr)	
Myriophyllum sp	
Nuphar sp	
Potamogeton natans L	
Potamogeton pectinatus L	
Scirpus sp	
Sparganium sp	
Typha latifolia L	
Utricularia sp	
Valisneria americana	

All of the aquatic plants found in the Ninth Street Impoundment are widely distributed throughout North America and many genera are cosmopolitan (Fassett, 1966 and Prescott, 1962). Fifteen of the taxa collected are capable of growth in rather broad ranges of environmental conditions. The remaining four taxa are tolerant of such small ranges of environmental conditions that these taxa are used as indicator organisms for the rather restricted circumstances in which they grow (Prescott, 1962; Fassett, 1966).

Cladophora sp is almost invariably confined to hard or semi-hard water and in general is an indicator of high pH (Prescott, 1962). *Potamogeton pectinatus* and *Chara* sp occur in hard water (Fassett, 1966; Prescott, 1962). *Anacharis canadensis* requires calcareous waters (Fassett, 1966).

Invertebrate Animals

Methods

Invertebrates were collected from the established stations using Eckman and Petersen dredges. An aerial insect net was used to collect adult insects both from shore and from a boat. Many organisms were removed from fish stomachs.

Three separate series of Petersen dredge samples were collected during the summer of 1968. The series were collected on 19 June, 3-4 July, and 1 August. Single samples were secured from each station on each date.

All of the zooplankton were removed from fish stomachs. Surface hauls of the Wisconsin type plankton net were carried out during daylight hours at two-week intervals during June and early July. Stations sampled were the Thunder Bay River at the Ninth Street Bridge, TBR-2, COA-7, COA-2, and the Thunder Bay River immediately above the Ox-bows area. The purpose of this sampling scheme was to determine the effect of the Ninth Street Impoundment on the composition of the zooplankton of the Thunder Bay River. No zooplankters were collected by this method and the plankton hauls were eliminated from the overall sampling routine. Probably the zooplankton sampling project would have been more successful if it had been conducted at night.

No attempt was made to take quantitative samples. Petersen dredge samples and fish stomach analysis were the primary methods by which invertebrates were obtained.

Invertebrate animals were identified by the author using the keys of Edmondson (1959), Pennak (1953), Heard and Burch (1966), and Burks (1953). Organisms were classified to the smallest taxon that the author could confidently assign.

Results

Thirty-four families, thirty-nine genera, and fourteen species of invertebrate animals were collected (Appendix

3). Tendipedidae were the most commonly collected organisms. Coenagrionidae were second in abundance.

Several invertebrate taxa collected (Baetidae, Cladocera, *Polycentropus*, *Stenonema*, *Hexagenia limbata*, *Oectis*) are listed as "intolerant" organisms in the Michigan Water Resources Commission Report of Thunder Bay and the Lower Thunder Bay River (Fetterolf, Robinson, Seeburger, Newton, and Mills, 1968). That report defines intolerant organisms as those "organisms whose growth and development are dependent upon a narrow range of optimum environmental conditions, rarely found in areas of organic enrichment, not adaptable to adverse situations and therefore are replaced by less sensitive organisms if the quality of their environment is degraded."

Fresh water sponge colonies were numerous and large in size. Sponge colonies were found on submersed railroad ties, rocks, and aquatic plants. The sponge *Meyenia mulleri* is characteristic of alkaline waters. Pennak (1953) states that "*M. mulleri* has not been reported from waters with less than 5.6 ppm calcium." He further states that *M. mulleri* requires a minimum of 1.6 ppm silicon dioxide. Mollusc shells were not pitted, another indication of calcareous waters.

The remaining taxa collected have general ecological requirements and therefore cannot be used as indicators of year-round environmental conditions within the Ninth Street Impoundment.

Fish

Methods

Three 100-ft nylon experimental gill nets (four 25-ft sections each, two nets with bar mesh sizes ½"-1"-1½"-2", one net with ½"-1¼"-2"-3" mesh) were set at many sites throughout the entire impoundment, but primarily in the Lake Besser and Coho Hall Oxbow Areas. Effort was concentrated in the lower reaches of the impoundment because of the need to gather information concerning the fate of the introduced chinook salmon smolts. One hoop net with three foot diameter hoops, a 1½" square mesh cod end, and a 50 ft lead was set in shallow areas of the Coho Hall Oxbow. At least two gill nets and the hoop net were fished almost continuously from June 11 to August 28, 1968. Net catches were supplemented by hook and line angling and by one spot poisoning (approximately 2 ppm rotenone).

Fish were identified by the author using the key of Eddy (1957). Common and scientific names used are those approved by the American Fisheries Society (Bailey, 1960).

Total and standard length (Lagler, 1952) was measured to the nearest millimeter. Fish as heavy as 490 g were weighed on a 500 g capacity dietetic spring balance. Fish heavier than 490 g were weighed on a 50 lb capacity spring balance. Scale samples were taken from the left side of the fish, approximately half-way between the insertion of the dorsal fin and the lateral line. Stomach contents of 208 fish were examined under a 10 power dissecting microscope and the numbers of each type of food item counted.

An attempt was made to estimate the total number of several fish species and to acquire some information on the extent of movement of individual fish. Accordingly a great effort was expended to tag as many fish as possible. Fish were marked with a numbered streamer-type tag applied to the dorsal caudal peduncle by the method of Joeris (1953). The following numbers of each species were tagged: 17 yellow perch (Perca flavescens), 36 rockbass (Ambloplites rupestris), 63 pumpkinseed (Lepomis gibbosus), 26 northern pike (Esox lucius), 8 black crappie (Pomoxis nigromaculatus), 25 bluegill (Lepomis macrochirus), 10 redhorse (Moxostoma sp), 11 bowfin (Amia calva), 3 carp (Cyprinus carpio), 4 bullheads (Ictalurus sp), 6 largemouth bass (Micropterus salmoides), and 9 white suckers (Catostomus commersoni). Numbers of fish at large and methods of recapture available were inadequate for a population estimate. Some fish were recaptured and their minimum distance from point of release was noted.

Northern pike, pumpkinseed, bluegill, rockbass, and yellow perch were selected for age and growth analysis because they were the species most commonly caught during this investigation. In addition, these five species are the most important game fish in the impoundment. Northern pike, rockbass, yellow perch, and large bluegills are likely predators on chinook salmon smolts.

Northern pike scales were mounted dry between two microscope slides. Plastic impressions of pumpkinseed, bluegill, rockbass and yellow perch scales were made by the method of Smith (1954). Scale mounts or impressions were placed on a Bausch and Lomb microprojector and examined at 43x. Scale radius (mm x 43) and relative positions of annuli were recorded on scale analysis cards. Scale radius-total length and standard length-total length regressions were calculated for five species. Standard length-weight curves were calculated from the general length-weight relationship $W = cL^n$ (Rounsefell and Everhart, 1953). Condition factors, K, were calculated for all fish using the equation

$$K = \frac{100,000W}{L^3}$$

where W = weight in grams and L = standard length in millimeters. Total lengths at times of annulus formation were back-calculated using the Lee method (Lagler, 1952). All lengths are reported in millimeters; all weights are reported in grams.

Species Diversity

Twenty-five species of fish were collected from the Ninth Street Impoundment (Table 6). Single walleye (*Stizostedion vitreum vitreum*) and burbot (*Lota lota*)

Table 6. Phyletic list of fish collected in the Ninth Street Impoundment.

CLASS OSTEICHTHYES	
Order Amiiformes	
Amiidae	
	Amia calva Linnaeus Bowfin
Order Clupeiformes	
Umbridae	
	Umbra limi (Kirtland) Central Mudminnow
Esocidae	
	Esox lucius Linnaeus Northern pike
Order Cypriniformes	
Cyprinidae	
	Chrosomus eos Cope Northern redbelly dace
	Cyprinus carpio Linnaeus Carp
	Notemigonus crysoleucas (Mitchill) Golden shiner
	Semotilus atromaculatus (Mitchill) Creek chub
Catostomidae	
	Catostomus commersoni (Lacepede) White sucker
	Moxostoma sp Redhorse
Ictaluridae	
	Ictalurus natalis (LeSueur) Yellow bullhead
	Ictalurus nebulosus (LeSueur) Brown bullhead
	Noturus gyrinus (Mitchill) Tadpole madtom
Order Cyprinodontiformes	
Cyprinodontidae	
	Fundulus diaphanus (LeSueur) Banded killifish

Table 6 (Cont'd.)

CLASS OSTEICHTHYES	
Order Gadiformes	
Gadidae	
	Lota lota (Linnaeus) Burbot
Order Gasterosteiformes	
Gasterosteidae	
	Eucalia inconstans (Kirtland) Brook stickleback
Order Perciformes	
Centrarchidae	
	Ambloplites rupestris (Rafinesque) Rock bass
	Lepomis gibbosus (Linaeus) Pumpkinseed
	Lepomis macrochirus (Rafinesque) Bluegill
	Micropterus dolomieui Lacepede Smallmouth bass
	Micropterus salmoides Lacepede Largemouth bass
	Pomoxis nigromaculatus (LeSueur) Black crappie
Percidae	
	Etheostoma nigrum (Rafinesque) Johnny darter
	Perca flavescens (Mitchill) Yellow perch
	Percina caprodes (Rafinesque) Log perch
	Stizostedion vitreum vitreum (Mitchill) Walleye

specimens were collected during the sampling period and both species were regarded as rare in occurrence. Pumpkinseed, yellow perch, bluegill, northern pike, and rockbass were the most abundant species.

Conversions

Total length-standard length conversions, total length-scale radius (mm x 43) regressions (Appendix 4) and standard length-weight regressions (Appendix 5) were calculated for yellow perch, northern pike, bluegill, pumpkinseed, and rockbass. These equations were included for the convenience of those investigators who may wish to transform values reported in this thesis.

Growth

The growth rates of Ninth Street Impoundment northern pike, rockbass, pumpkinseed, bluegill, and yellow perch (Table 7) can be most meaningfully compared with Laarman's (1963) Michigan state average lengths (hereafter referred to simply as "average") for each age of the five species. Pumpkinseed, rockbass, and northern pike have a slower growth rate than average. Yellow perch and bluegill are smaller than average at ages I and II, approximately equal to average at age III, and larger than average at ages IV and V. Age class IV and V yellow perch from the Ninth Street Impoundment were as large as the largest values reported in the

Table 7. Back-calculated total lengths for several fish species collected from the Ninth Street Impoundment.

Age group	Number per group		Mean back-calculated total lengths (mm) at annulus						Standard Error					
Esox lucius			I	II	III	IV	V	VI	I	II	III	IV	V	VI
I	13		218						11.12	--	--	--	--	--
II	27		205	355					4.69	8.54	--	--	--	--
III	7		197	334	447				12.07	11.86	14.17	--	--	--
IV	1		195	318	484	680			--	--	--	--	--	--
		Avg	207	343	452	680								
Ambloplites rupestris														
I	27		52						6.01	--	--	--	--	--
II	6		52	78					1.26	3.70	--	--	--	--
III	27		51	76	104				0.74	1.11	1.40	--	--	--
IV	20		50	74	100	127			0.85	1.39	1.99	2.19	--	--
V	14		50	73	102	129	152		0.46	0.88	2.21	2.37	2.05	--
VI	2		54	83	108	136	167	187	--	--	--	--	--	--
		Avg	51	75	102	128	153	187						

Table 7. (Cont'd.)

Age group	Number per group		Mean back-calculated total lengths (mm) at annulus						Standard Error					
			I	II	III	IV	V	VI	I	II	III	IV	V	VI
Lepomis gibbosus														
I	35		43						0.81	--	--	--	--	--
II	7		45	78					1.98	4.14	--	--	--	--
III	5		47	77	117				3.20	2.42	1.96	--	--	--
IV	11		39	68	102	135			2.01	2.73	3.46	4.45	--	--
V	30		37	61	94	124	153		0.66	1.27	2.15	2.45	2.10	--
VI	4		36	55	87	124	147	167	--	--	--	--	--	--
		Avg	41	65	97	127	152	167						
Lepomis macrochirus														
I	5		29						2.25	--	--	--	--	--
II	9		36	96					4.10	7.92	--	--	--	--
III	5		42	94	156				5.01	5.65	6.98	--	--	--
IV	14		33	83	145	191			3.48	6.13	5.88	3.91	--	--
V	10		26	70	128	176	212		0.72	1.66	4.64	5.08	4.05	--
VI	2		28	74	143	174	204	228	3.00	16.50	0.50	7.50	5.00	7.50
		Avg	45	83	142	184	210	228						

Table 7. (Cont'd.)

Age group	Number per group		Mean back-calculated total lengths (mm) at annulus							Standard Error				
Perca flavescens			I	II	III	IV	V	VI	VII	I	II	III	IV	V
I	37		61							1.52	--	--	--	--
II	5		57	135						3.43	6.79	--	--	--
III	7		54	111	176					3.77	5.86	5.10	--	--
IV	22		55	115	176	219				1.96	3.08	4.10	4.04	--
V	7		47	114	167	203	241			3.26	4.17	3.90	3.31	5.06
VI	--													
VII	1		43	102	161	227	257	184	310					
		Avg	57	118	174	215	242	284	310					

literature: Jobes (1952) from Lake Erie; and Carlander (1950) from Lake of the Woods, Minnesota.

Northern pike and rockbass were each smaller at any given age than the Pennsylvania state averages (Miller and Buss, 1962), while yellow perch, bluegill, and pumpkinseed were larger at each age than the Pennsylvania averages.

Food Studies

Early in the summer, stomachs of young-of-the-year bluegills, pumpkinseed, rockbass, and yellow perch all contained primarily zooplankton with some small Tendipedidae. As the summer progressed and the fish grew in size zooplankton were replaced with small Amphipoda, Odonata, and Trichoptera. Feeding habits of Ninth Street Impoundment young-of-the-year bluegills, pumpkinseed, rockbass, and yellow perch agree with those reported by Keast and Webb (1966), Keast (1968), Pycha and Smith (1955), and Ewers and Boesel (1935).

Age classes I to VI of pumpkinseed and bluegill consumed adult terrestrial insects, Amphipoda, Isopoda, and adult and larval Tendipedidae, Ephemeroptera, and Odonta. Similar consumption patterns were reported by Keast (1968) and Seaburg and Moyle (1964).

Rockbass from ages I to VI contained the same types of food as age I to VI bluegill and pumpkinseed. Keast and Webb (1966) reported that rockbass larger than 77 mm began to vary their insect, amphipod, and isopod diet with fish fry and crayfish, and at 120 mm consumed primarily crayfish, fish, and Anisoptera. Crayfish were apparently quite abundant in the Ninth Street Impoundment. Why so few crayfish were included in the larger rockbass diet remains a mystery.

Yellow perch from 90 to 200 mm total length (one, two, large three, and small four-year-olds) contained primarily Coenagrionidae, Libellulidae, and Hyalella azteca. Yellow perch larger than 200 mm (large three-year-olds and older) contained mostly crayfish and unidentifiable fish remains. Similar trends in yellow perch food habits were observed by Pycha and Smith (1955), Pearse (1918), Moffett and Hunt (1943), Ewers and Boesel (1935), Keast and Welsh (1968), Tharrett (1959), and Keast and Webb (1966).

All of the Northern pike stomachs examined were from fish larger than 100 mm. One-half of the northern pike stomachs examined were empty. Nearly all the stomachs that contained food contained fish remains (usually unidentifiable). An occasional Hexagenia naiad was found in northern pike stomachs. Rawson (1951), Lawler (1965), Franklin and Smith (1963), Frost (1954), Hunt and Carbine (1951), and Nelson and Hasler (1942), concur that northern pike larger than 100 mm eat almost exclusively fish.

Condition

Average condition of each age class of yellow perch for age classes I to V ranged from 1.86 to 2.46 (Table 8). Average condition of each age class of Ninth Street Impoundment yellow perch was much greater than those values reported by Hile and Jobes (1941) for Saginaw Bay, Beckman (1948) for Michigan, and Eschmeyer (1937) for a stunted northern Michigan population. Ninth Street Impoundment yellow perch were in approximately the same condition as the "very plump perch" reported by Carlander (1950) from Lake of the Woods, Minnesota. Indeed, the Ninth Street Impoundment yellow perch were the plumpest ever observed by the author.

Condition factors determined for northern pike from the Ninth Street Impoundment, .91 to 1.01 (Table 8), were very similar to the Michigan "average values" for this size range as reported by Beckman (1948), but were poorer than values reported for northern pike from Houghton Lake, Michigan (Carbine, 1944).

Ninth Street Impoundment bluegill and pumpkinseed were each in much higher condition (Table 8) than Michigan average values reported by Beckman (1948); while rockbass were in approximately the same condition as the state average.

Table 8. Average condition factors (K) at time of capture for each age group of several species of fish from the Ninth Street Impoundment. Numbers of fish in each group appear in parenthesis.

Species	Age Group I	II	III	IV	V	VI	Standard Error I	II	III	IV	V	VI
<u>Esox lucius</u>	0.93 (14)	1.01 (25)	0.91 (7)	0.91 (1)	--	--	0.04	0.07	0.13	0.06	--	--
<u>Ambloplites rupestris</u>	4.21 (27)	3.85 (4)	4.07 (26)	4.04 (21)	4.03 (12)	4.18 (2)	0.26	0.34	0.11	0.11	0.08	0.19
<u>Lepomis gibbosus</u>	2.84 (34)	3.90 (5)	4.85 (5)	4.65 (10)	4.34 (27)	4.82 (3)	0.09	0.41	0.23	0.13	0.11	0.15
<u>Lepomis macrochirus</u>	3.21 (5)	4.13 (9)	4.53 (5)	4.53 (14)	4.96 (9)	4.32 (2)	0.27	0.20	0.22	0.25	0.08	0.26
<u>Perca flavescens</u>	1.86 (37)	2.29 (6)	2.19 (7)	2.34 (22)	2.46 (10)	--	0.06	0.16	0.09	0.04	0.09	--

Tagging and Recovery

Six fish were recaptured. Two rockbass, two pumpkinseed, and one yellow perch were recaptured in the same general areas in which they had been released. One pumpkinseed, captured and released in the Oxbow area 100 yards west of Sportsman's Park, was later recaptured at the railroad bridge that crossed Lake Besser (Appendix 1).

Gear Selectivity

Age classes 0 to III northern pike were commonly caught in the experimental gill nets. Very few northern pike larger than 500 mm were captured. A great deal of time in both summer and winter months was spent by local anglers fishing for northern pike in the Ninth Street Impoundment. The fishery is by Michigan law restricted to fish larger than 500 mm (20 inches). These local anglers probably would not fish in the Ninth Street Impoundment if they did not catch some legal fish. I, therefore, believe that the sample of northern pike was not representative of the Ninth Street Impoundment population.

From personal observation it seems that a high proportion of young northern pike are extremely active and voracious. Older pike, probably III + years old, seem less active and more wary. Gill nets (the main mode of capture for northern pike) being stationary would be selective against younger, smaller, more active northern pike.

DISCUSSION

The Ninth Street Impoundment can be classified under the system of Forel and Whipple (Welch, 1952) as a third order temperate lake. The seasonal surface water temperature varies above and below 4°C while the instantaneous temperature of the bottom water is very similar to that of the surface water; there is constant mixing of surface and subsurface waters.

The hard, alkaline waters of the Thunder Bay River System in general and the Ninth Street Impoundment in particular are usually indicative of high biological productivity. The amounts of monocarbonate and bicarbonate alkalinity present indicate that there is a vast amount of free, bound, and half-bound carbon dioxide available for primary production.

Those organisms collected from the Ninth Street Impoundment that have very limited environmental requirements are in every case index organisms for hard, alkaline waters. These index organisms provide evidence that the high levels of hardness and alkalinity found in the Ninth Street Impoundment are not a random occurrence but are characteristic of long term water quality.

The Ninth Street Impoundment has a high shoreline development index and a high insulosity value. Shoreline development and insulosity are cumulatively an indicator of the potential effects of the littoral zone on the limnology and biology of a lake. Shoreline development, insulosity, and personal observation reveal that the Ninth Street Impoundment is largely if not entirely littoral. The combination of morphometrical and chemical potentials indicates that the Ninth Street Impoundment is biologically a very productive body of water.

The productivity of the Ninth Street Impoundment would probably lead to an oxygen deficiency for aquatic life if it were not for the slow currents of water that branch off from the Thunder Bay River (Appendix 1). The slow currents provide just enough mixing action that oxygen is always present in adequate quantities for life at practically all depths. It appears that deposition of silt and sand is occurring at the head of the Ninth Street Impoundment, the point where the major slow currents originate. If the slow currents cease to flow I believe that the entire Oxbows area (with the exception of the most recent river channel) will become a stagnant swamp. It appears that periodic dredging will probably be necessary to maintain the Oxbow area as a sport fishery.

The unusually slow first year growth of Ninth Street Impoundment perch is most probably explained by competition for food with several other fish species. Yellow perch in their first and early second summers of life, inhabit "heavily to moderately vegetated areas in association with young largemouth bass, bluegill, pumpkinseed, black crappie, and black bullhead (Ictalurus melas)" (Ridenhour, 1960). Johnny darter (Etheostoma nigrum) and banded killifish (Fundulus diaphanus) are littoral (Lux, 1960). All of these small fish consume the same type and size arthropods that young perch eat. There is probably direct competition for the available food resources of the littoral zone between young yellow perch and the small largemouth bass, bluegill, pumpkinseed, black crappie, bullheads, johnny darter, and killifish. In addition, adult largemouth bass, black crappie, rockbass, and bluegill inhabit the littoral zone for at least part of the summer (Cady, 1945) and while in the littoral zone undoubtedly consume some of the food available to young yellow perch.

Most yellow perch probably abandon inshore areas prior to the time of formation of the third annulus (Parsons, 1950). Yellow perch leave the littoral areas to forage in the relatively uninhabited waters deeper than six feet. The very fast growth rate of Ninth Street Impoundment (annulus III and IV yellow perch) probably reflects the relatively higher food concentration at depths greater than those at which dense weedbeds occur.

Adult yellow perch are an active, probably constantly moving, fish (Hasler and Bardach, 1949; Hergenrader and Hasler, 1967). The faster growing perch should be the most active and the most vulnerable to gill nets (the main gear fished). However, I believe that the yellow perch sample is not particularly biased because it is only within the last 10 years that perch have been captured in the Ninth Street Impoundment by sport fishermen (personal communication with several local fishermen). The growth rate exhibited by the larger perch sampled corresponds to the growth rate of a rapidly expanding population that has not yet filled its niche.

The pumpkinseed, bluegill, and rockbass populations of the Ninth Street Impoundment are almost unexploited by sports fishermen. It is not surprising that the average size of these species caught by hook and line is large and their growth rate slow. I have no explanation why age III bluegill suddenly begin to grow very rapidly.

The fish populations of the Ninth Street Impoundment would be more efficiently cropped if anglers would shift some of their fishing pressure from northern pike to yellow perch, pumpkinseed, bluegill, or rockbass. Cropping the larger panfish would yield higher growth rates for all the species in the lake. Higher growth rates would make possible a larger potential harvest of all species; increasing the value of the Ninth Street Impoundment as a recreational fishery.

The motive for introducing chinook salmon into the Thunder Bay River system is to establish a fishery for returning adults.

The migration rate of chinook salmon smolts in the Snake River System is greatly slowed by impoundments (Raymond, 1968). While impoundments on the Snake River are much larger than the Ninth Street Impoundment and present somewhat different problems to the chinook smolts, this author believes that the Ninth Street Dam and Impoundment probably retard downstream migration. Any retardation of smolt migration leads to increased mortality due to predation by the numerous piscatorial residents of the impoundment thereby decreasing numbers of chinook smolts reaching Thunder Bay. The number of smolts entering Thunder Bay should be proportional to the number of these fish that will return as adults. I believe that the probability of establishing an adult chinook salmon run in the Thunder Bay River large enough to serve as an egg source for future plantings is substantially reduced by planting the smolts above the Ninth Street Dam. I recommend that future chinook salmon smolt plants be made at the base of the Ninth Street Dam, downstream from the Ninth Street Impoundment.

SUMMARY

1. This study is a summarization of previous limnological and biological studies done on the Thunder Bay River system and a description of the physical, chemical, and biological characteristics of the Ninth Street Impoundment of the Thunder Bay River at Alpena, Michigan.

2. The Thunder Bay River drains a basin of approximately 1,118 square miles. The northern third of the basin is underlain by limestone; the southern third is underlain by shale; and the central third is underlain by a mixture of limestone and shale. Glacial moraines, till plains and outwash aprons are abundant throughout the basin. Precipitation is well distributed throughout the year with 28.8 inches annual precipitation most probable.

3. The 432 acre Impoundment was created in 1910 by the completion of the Ninth Street Hydroelectric Dam. From that time the reservoir has provided such recreational opportunities as fishing, swimming, boating, water skiing, and turtle hunting.

4. A hydrographic map was constructed and was used to determine several morphometrical statistics. Shoreline development was 2.20 and insulosity was 22%.

5. The Ninth Street Dam impounds waters over an area where extensive river meandering had taken place. Deeper areas (6 to 12 feet) of the reservoir are remnants of the more recent river channels. Several of the more recent channels still have currents of water moving through them.

6. Water temperatures recorded ranged from 15.1 to 26 C. There was never any indications of a thermocline at any station. Dissolved oxygen concentrations lower than 5.0 ppm were rarely encountered. Methyl orange alkalinity varied from 120 to 180 mg/l as $CaCO_3$. Phenolphthalein alkalinities were as high as 26 mg/l as $CaCO_3$. pH ranged from 8.1 to 8.85. Total hardness varied from 186 to 242 mg/l as $CaCO_3$.

7. Four of nineteen aquatic plant genera collected were indicators of hard, alkaline waters.

8. Invertebrates were collected primarily from Petersen dredge samples and fish stomach analysis. Thirty-four families, thirty-nine genera, and fourteen species of invertebrates were collected. Baetidae, Cladocera, *Polycentropus* sp, *Stenonema* sp, *Hexagenia limbata*, and *Oectis* sp are organisms present in the reservoir that are intolerant of organic enrichment of their environment. Fresh water sponges were abundant.

9. Fish species composition was typical for a warmwater lake. Yellow perch, northern pike, rockbass, large bluegill, black crappie, bowfin, and largemouth bass were potential predators on the introduced chinook salmon smolts.

10. Northern pike, rockbass, and pumpkinseed had growth rates less than the Michigan state averages. Yellow perch and bluegill younger than age III were smaller than average while fish older than III were larger than average.

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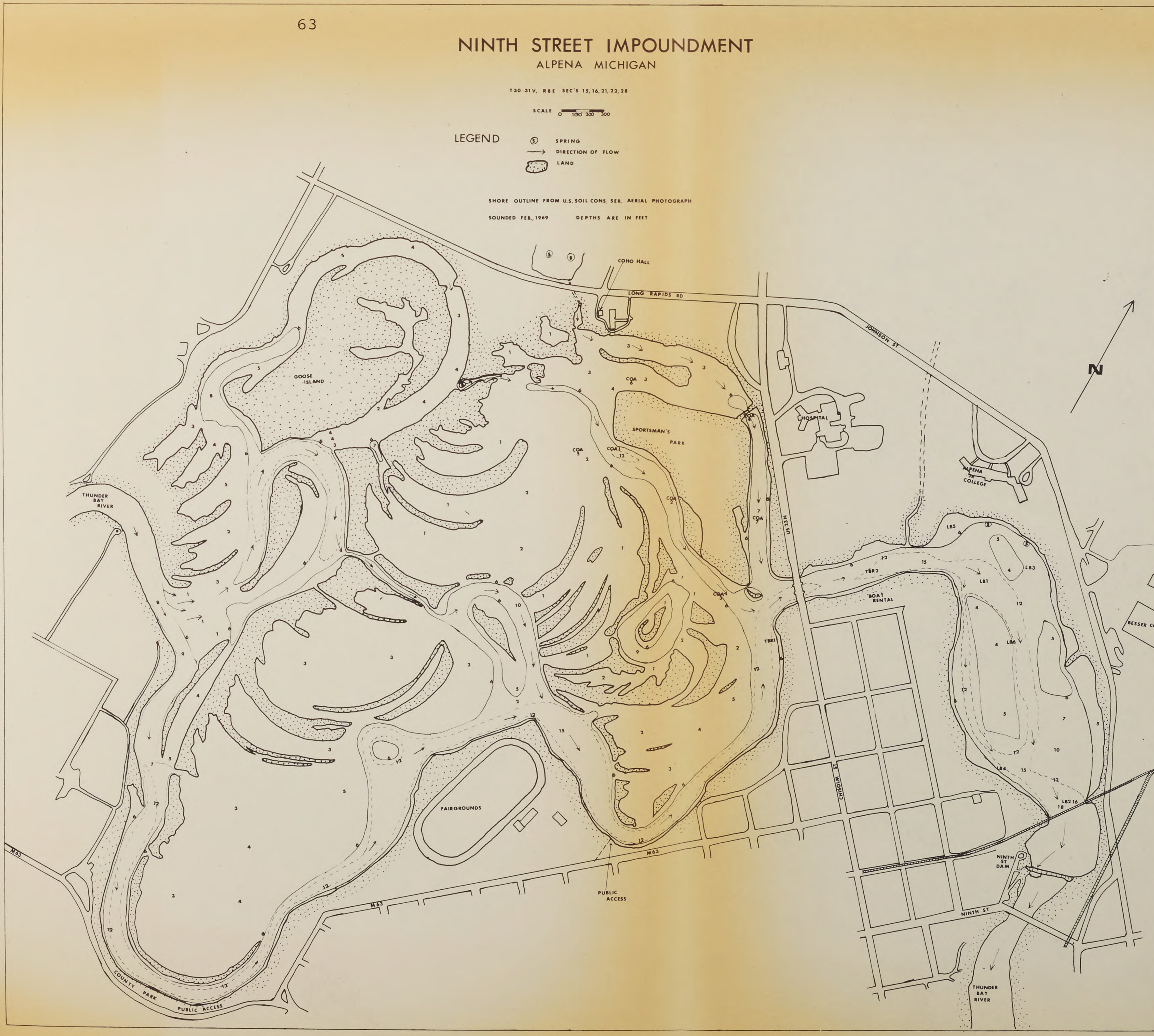
APPENDICES

Appendix 1. The Ninth Street Impoundment, Alpena, Michigan.


NINTH STREET IMPOUNDMENT
ALPENA MICHIGAN
T30-31V, R8E SEC'S 15, 16, 21, 22, 28
SCALE 0 100 200 300
LEGEND
SPRING
DIRECTION OF FLOW
LAND
SHORE OUTLINE FROM U.S. SOIL CONS. SER. AERIAL PHOTOGRAPH
SOUNDED FEB., 1969
DEPTHS ARE IN FEET
COHO HALL
LONG RAPIDS RD
JOHNSON ST
N
GOOSE ISLAND
SPORTSMAN'S PARK
HOSPITAL
ALPENA COLLEGE
THUNDER BAY RIVER
US 23 N
BOAT RENTAL
BESSER CO
CHISOLM ST
FAIRGROUNDS
M63
PUBLIC ACCESS
NINTH ST DAM
NINTH ST
COUNTY PARK
PUBLIC ACCESS
THUNDER BAY RIVER

Appendix 2. Description of limnological sampling stations in the Ninth Street Impoundment.

Station	Depth (ft)	
COA-1	4	Bottom type: Soft gray marl with gray and black organic debris. Vegetation: Myriophyllum sp, Utricularia sp Invertebrates: Hyalella azteca, Polycentropus sp, Physa sp, Lymnaea sp, Planorbidae, Sphaerium sp
COA-2	8	Bottom type: Soft gray marl Vegetation: None Invertebrates: Caenis sp, Hexagenia limbata, Hyalella azteca, Sialis sp, Planorbidae, Lymnaea sp, Physa sp, Sphaerium sp, Polycentropus sp, Asellus sp
COA-3	11	Bottom type: Soft gray marl Vegetation: None Invertebrates: Tendipedidae, Leptocerus sp, Sphaerium sp, Helisoma sp, Lymnaea sp, Caenis sp, Planorbidae
COA-4	6	Bottom type: Rock, large rubble, cement blocks Vegetation: Myriophyllum sp Invertebrates: Sphaerium sp, Leptocerus sp, Enallagma sp, Lymnaea sp, Physa sp, Planorbidae, Nehalennia sp, Tendipedidae, Dugesia sp, Campeloma sp, Meyenia mulleri
COA-5	2	Bottom type: Soft gray marl Vegetation: Chara sp, Utricularia sp, Valisneria americana Invertebrates: Asellus sp, Dugesia sp, Hyalella azteca, Enallagma sp, Banksiola solina, Sphaerium sp, Lymnaea sp, Physa sp, Polycentropus sp, Oecetis sp
COA-6	3	Bottom type: Soft gray marl with black gray organic debris Vegetation: Myriophyllum sp

Appendix 2 (Continued)

Station	Depth (ft)	
COA-6	3 (cont)	Invertebrates: Physa sp, Lymnaea sp, Planorbidae, Sphaerium sp, Asellus sp, Ischnura sp, Hyalella azteca
COA-7	7	Bottom type: Soft gray marl with plant remains Vegetation: Myriophyllum sp Invertebrates: Caenis sp, Tendipedidae, Campeloma sp, Planorbidae, Physa sp, Lymnaea sp, Sphaerium sp, Tetragoneuria sp
COA-8	3	Bottom type: Hard-packed sand Vegetation: Potomogeton pectinatus, Myriophyllum sp Invertebrates: Hyalella azteca, Caenis sp, Physa sp, Campeloma sp, Sphaerium sp, Dugesia sp, Polycentropus sp
TBR-1	8	Bottom type: Rubble Vegetation: None Invertebrates: Lymnaea sp, Sphaerium sp, Elliptio sp, Villosa sp
TBR-2	13	Bottom type: Rubble Vegetation: None Invertebrates: None
LB-1	12	Bottom type: Rubble Vegetation: None Invertebrates: Spongilla lacustris, Campeloma sp, Sphaerium sp
LB-2	12	Bottom type: Rubble Vegetation: None Invertebrates: Spongilla lacustris, Sphaerium sp, Hexagenia limbata
LB-3		Bottom type: Soft gray marl Vegetation: Potamogeton pectinatus, Megalodonta Beckii, Myriophyllum sp Invertebrates: None collected

Appendix 2 (Continued)

Station	Depth (ft)	
LB-4	11	Bottom type: Firm gray marl Vegetation: *Valisneria americana* Invertebrates: *Sialis* sp, *Sphaerium* sp, *Lymnaea* sp, Planorbidae
LB-5	4	Bottom type: Soft dark gray marl with much organic debris Vegetation: *Anacharis canadensis*, *Megalodonta Beckii*, *Myriophyllum* sp Invertebrates: *Campeloma* sp, *Lymnaea* sp, Planorbidae, *Sphaerium* sp, *Hyalella azteca*, *Enallagma* sp, *Tetragoneuria* sp, *Hexagenia limbata*
LB-6	5	Bottom type: Soft gray marl Vegetation: *Potamogeton pectinatus*, *Myriophyllum* sp Invertebrates: *Physa* sp, *Lymnaea* sp, Planorbidae, *Enallagma* sp, *Tetragoneuria* sp, *Polycentropus* sp

Appendix 3. A phyletic list of invertebrate animals collected from the Ninth Street Impoundment June, 1968 to February, 1969

Phylum	Order	Family	Genus	Species	Describer
Porifera		Spongillidae	Meyenia	mulleri	(Lieberkuhn)
			Spongilla	lacustris	(Linnaeus)
Platyhelminthes	Tricladida	Planariidae	Dugesia	sp	Girard
Annelida					
Arthropoda	Cladocera	Bosminidae	Bosmina	longirostris	(O.F. Muller)
		Daphnidae	Ceriodaphnia	megalops	Sars
		Chydoridae	Eurycercus	lamellatus	(O.F. Muller)
		Polyphemidae	Polyphemus	pediculus	(L.)
	Copepoda	Cyclopidae	Cyclops	vernalis	Fischer
	Isopoda	Asellidae	Asellus	sp	Geoffrey St. Hillaire
	Amphipoda	Talitridae	Hyalella	azteca	(Saussure)
	Decapoda	Astacidae	Orconectis	virillis	(Hagen)
	Ephemeroptera	Ephemeridae	Hexagenia	limbata	(Serville)
		Baetidae	Baetis	sp	Leach
		Caenidae	Caenis	sp	Stephens

Appendix 3. (continued)

Phylum	Order	Family	Genus	Species	Describer
		Heptageniidae	Stenonema	tripunctatum	Banks
	Odonata	Coenagrionidae	Enallagma	sp	Charpentier
			Ischnura	sp	Charpentier
			Nehalennia	sp	Selys
Arthropoda	Odonata	Aeshnidae	Aeshna	sp	Fabricus
			Anax	sp	Leach
		Libellulidae	Libellula	sp	Linne'
			Tetragoneuria	sp	Hagen
	Hemiptera	Notonectidae	Notonecta	sp	Linne'
		Pleidae	Plea	striola	Fieber
		Nepidae	Ranatra	sp	Fabricus
		Belostomatidae	Belostoma	sp	Latreille
			Lethocercus	americanus	(Leidy)
		Corixidae			
	Megaloptera	Sialidae	Sialis	sp	Latreille
	Trichoptera	Leptoceridae	Leptocerus	sp	Leach

Appendix 3. (continued)

Phylum	Order	Family	Genus	Species	Describer
			Oecetis	sp	McLachlan
		Phryganeidae	*Banksiola*	*selina*	Betten
		Psychomyiidae	*Polycentropus*	sp	Curtis
	Lepidoptera	Nymphulidae	*Nymphula*	sp	Schrank
	Diptera	Tendipedidae			
Mollusca	Basommatophora	Lymnaeidae	*Lymnaea*	sp	Lamarck
		Physidae	*Physa*	sp	Draparnaud
		Planorbidae			
	Mesogastropoda	Viviparidae	*Campeloma*	sp	Rafinesque
	Eulamellibranchia	Unionidae	*Elliptio*	sp	Rafinesque
			Villosa	sp	Frierson
	Heterodonta	Sphaeriidae	*Sphaerium*	sp	Scopoli

Appendix 4. Total length-standard length conversions and scale radius-total length regressions for five species of fish from the Ninth Street Impoundment. (TL = total length, SL = standard length, SR = scale radius).

Species	Number of fish	Range of total length (mm)	Scale radius (mm x 43) total length (mm) regression	Total length-standard length conversions (mm)
Esox lucius	77	170-750	TL = 40 + 2.60 SR	SL = 0.87 TL - 5.52
Ambloplites rupestris	113	62-246	TL = 43 + 0.80 SR	SL = 1.69 + 0.7912 TL
Lepomis gibbosus	146	33-223	TL = 34 + 0.85 SR	SL = 0.52 + 0.7976 TL
Lepomis macrochirus	71	67-256	TL = 41 + 1.08 SR	SL = 0.81 TL - 2.60
Perca flavescens	80	55-320	TL = 37 + 1.50 SR	SL = 0.84 TL - 2.21

Appendix 5. Length-weight relationships for five species of fish collected from the Ninth Street Impoundment. L = standard length in millimeters, W = weight in grams.

Species	Number of fish	Size range (total length mm)	Length-weight relationship
Esox lucius	77	170-750	LogW = 0.63269 + 1.2073 LogL
Ambloplites rupestris	113	62-246	LogW = 4.34776 + 2.9762 LogL
Lepomis gibbosus	146	33-223	LogW = 4.960 + 3.2830 LogL
Lepomis macrochirus	71	67-256	LogW = 5.03358 + 3.3131 LogL
Perca flavescens	80	55-320	LogW = 5.2934 + 3.2840 LogL