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STUDIES OF TROUT PRODUCING LAKES AND PONDS

BY

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(FROM THE DEPARTMENT OF BIOLOGY

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CONTENTS

STUDIES OF TROUT PRODUCING LAKES AND PONDS

Abstract

Speckled trout occur naturally in a large number of static waters of the Province of Ontario.

Previous studies of Lake Nipigon and other waters have shown that, while speckled trout grow to a large size in a few very large lakes, in such situations they occupy a subordinate position, being much less common than several other food and game fish.

Smaller trout lakes may be divided into two classes on a basis of the lime content of their water: hard-water lakes and soft-water lakes.

Soft-water lakes are characteristic of the Laurentian country of northern Ontario. Speckled trout occur only in those which afford cool water with adequate oxygen throughout the year—conditions whose occurrence is sporadic and not fully understood. The food of adults is principally of minnows; plankton is an important item, insects are less so. Lake trout are sometimes associated with speckled trout in these lakes.

Hard-water lakes are characteristic of the sedimentary region of south-western Ontario, and are usually more restricted in area and depth than the above. By virtue of the high concentration of calcium bicarbonate in their waters, they commonly support a luxuriant growth of *Chara*, which in turn affords shelter for an abundance of aquatic insects. Speckled trout occur abundantly only in such waters as remain cool throughout the summer, springs and spring creeks being the usual refrigerating agents. As a rule, they are associated with very few other fish and no other game fish, but in some warmer ponds they exist in comparatively small numbers alongside of abundant suckers and minnows. Aquatic insects are the predominant food of trout in the cold ponds, the caddis larva *Limnephilus* being the most important single item.

Introduction

Brook trout is considered by some to be the vernacular name of *Salvelinus fontinalis*, yet this species is by no means confined to running waters. Within the boundaries of Ontario, it occurs in a great variety of static waters, from the smallest mill ponds to the great Lake Superior; and along the northern and eastern coasts of Canada, "brook" trout are often found in salt water. But of the many lakes which have been subjected to biological examination in North America, only a few have been found to contain speckled trout.

REVIEW OF LITERATURE

Lake Nipigon, Ontario, was studied systematically for a number of years by the Ontario Fisheries Research Laboratory. The results of these studies are presented in a number of papers in the present series.

Lake Nipigon is a large lake, 1,530 square miles (3,978 square kilometres) in extent exclusive of islands, with a bold, rocky coast line; the bottom falls away rapidly from the shore to a maximum depth of 402 feet (122 metres). Its water is cool, and exhibits a sharp thermocline in summer, which increases in depth as the season advances until it is destroyed by the autumn storms. A high oxygen content prevails throughout the summer at all depths; the carbon dioxide is low, bicarbonate fairly high (100 parts per million expressed as $Ca\ CO_3$), and hydrogen-ion concentration is near pH 8.0. Off the main lake are several large, shallow bays, possessing considerable quantity of the larger aquatic vegetation. The speckled trout is not an abundant fish in this lake. It has been taken occasionally in pound nets at moderate depths, but apparently does not invade the deep waters where lake trout (*Cristivomer namaycush*) is abundant. Its food, as tabulated by Clemens *et al* (1924, p. 123), varies with the size of the fish. Nineteen trout, eight to twenty-one inches long, had taken a few insects, chiefly terrestrial flies, bugs, and beetles, but the bulk of their food was of fish. The species found were, in order of abundance: *Percopsis omisco-maycus*, *Pungitius pungitius*, *Cottus cognatus*, and *Leucichthys* sp. The accompanying chart (figure 1) of the food chains which culminate in the speckled trout is compiled from the food studies of these four fish and from the picture of the circulation of food materials in a lake, prepared by Rawson (1930, p. 122). With what other workers have found in view, it is noteworthy that none of the Lake Nipigon trout contained any trace of plankton organisms.

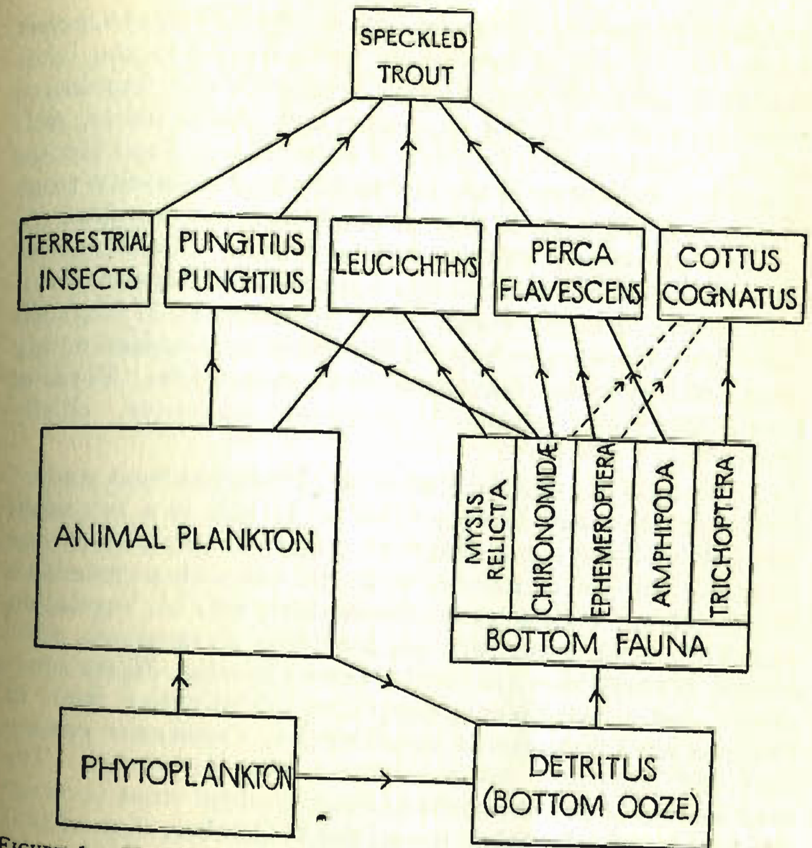

FIGURE 1. Chart showing food chain of speckled trout from Lake Nipigon

Juday (1906) has published a description of Twin Lakes, Colorado. These are high mountain lakes, 475 and 1,440 acres in extent (192 and 583 hectares), and of moderate depth (maximum 79 feet, or 24 metres). Thermal stratification of the water is only fairly well developed; the bottom temperature in summer is 6.5°C. Four species of *Potamogeton*: *P. nuttali*, *P. perfoliatus*, *P. richardsonii*, and *P. praelongus* are the principal vascular plants, and they occur only in scattered areas. Phytoplankton was present in "a comparatively small amount", and zooplankton was probably also deficient.

Fishes include *Catostomus commersonii*, *Rhinichthys atronasus dulcis*, two forms of cut-throat trout native to the lake: *Salmo clarkii macdonaldi* and *S. c. stomias*, and four introduced salmonids: *Salmo salar sebago*, *S. irideus shasta*, *Salvelinus fontinalis*, and *Cristivomer namaycush*. Food studies of most of these species showed that one of the native trout (*S. stomias*) ate a great deal of plankton; the rainbows (*S. irideus*), salmon (*S. sebago*), and lake trout (*C. namaycush*) preferred fish, while both groups consumed aquatic and terrestrial insects to some extent. Ten specimens of *S. fontinalis* from the lakes were examined, but these have unfortunately been grouped with a large number of stream fish. Three of them, however, contained plankton organisms, chiefly *Daphnia*.

The food of trout in Fish Lake, Utah, has been studied by Hildebrand and Towers (1927). It also is a mountain lake, about 7,500 acres (3,000 hectares) in extent, up to one hundred feet (thirty metres) in depth, but with an extensive shallow area. Its waters are "moderately soft". Vegetation is abundant at lesser depths, including *Potamogeton praelongus*, *Myriophyllum spicatum*, *Lemna trisulca*, *Elodea canadensis*, and *Ceratophyllum demersum*. The native trout in this lake are *Salmo irideus* and *S. clarkii*; *Cristivomer namaycush* and *Salvelinus fontinalis* have been introduced. The examination of 142 stomachs of large speckled trout (average weight 1¼ pounds) taken from June to October, showed that they feed on *Daphnia*, Chironomidae, *Gammarus limnaeus*, aquatic insects other than Chironomidae, fish eggs, *Potamogeton*, *Nostoc*, fish, snails, and leeches, in order of decreasing importance. The stomach contents of the other species were very similar. The authors have also considered the food of the invertebrates, from references in published accounts.

Needham (1901, p. 389 and 1903, pp. 204-217) has presented a sketch of the biological relationships in Bone Pond, N.Y. This body of water is about sixteen acres in extent (6.5 hectares), and resembles the acid lakes of northern Ontario. Hidden in deep woods, it lacks an outlet, and its shore is lined with *Sphagnum*, *Kalmia*, and other bog plants.

Since it is situated in a region of granitic rocks, its water is almost certainly poor in lime. Its flora included a *Sparganium* with floating leaves, *Nymphaea*, and the calciphobous *Eriocaulon*. It was not, however, a typical boggy lake, since the bottom was of white sand rather than mud. In its natural state this pond was apparently barren of fish life, but it had been systematically stocked with speckled trout from a hatchery near by. The stomachs of twenty-five "adult" specimens, taken in August, were examined. They contained chiefly chironomid larvae and pupae, a much smaller proportion of *Corethra* and caddis larvae, occasional nymphs of *Aeshna constricta*, and in one case a large number of *Daphnia*.

CLASSIFIED LIST OF ONTARIO LAKES AND PONDS STUDIED

During the summers of 1928 and 1929, the author, in cooperation with Mr. F. P. Ide, was able to make biological examinations of a number of lakes and ponds in Ontario. This work was under the auspices of the Ontario Fisheries Research Laboratory; much assistance has been received from Professor W. J. K. Harkness and other members of the staff of the Department of Biology, University of Toronto.

The speckled trout producing lakes and ponds which have been studied in Ontario may be classified as follows:

Large Lakes

Area greater than 1,500 square miles (390,000 hectares); bicarbonate content about 100 parts per million (expressed as $CaCO_3$). Only three examples occur: Lake Nipigon, Lake Superior, and the north shore of Lake Huron.

Acid or Soft-water Lakes

Area not greater than five square miles (1,300 hectares), often much less; bicarbonate content less than twenty-five parts per million; pH, except near surface, less than 7.0; typical aquatic plant *Eriocaulon*. Examples: Wolf Lake, Crown Lake. Lakes of this type are found in the Laurentian region of Ontario, where granitic rocks prevail. They grade into the next group.

Bog Lakes

Area not greater than 100 acres (40 hectares); shores a quaking bog, which is gradually encroaching upon and filling in the lake; water always dark brown, acid; bottom of loose silt. Lakes of this type also are common in Laurentian country, but only rarely contain speckled trout.

Hard-water Lakes

Usually less than 100 acres (40 hectares) in extent, sometimes quite small; bicarbonate content greater than 100 parts per million; pH greater than 7.0; typical aquatic plant *Chara*; bottom temperature less than 20°C. in summer. In this class belong all the cooler lakes and ponds in southern Ontario, where bed-rock is of sedimentary origin and usually calcareous. Examples: Little Wonder Pond, Waylington Lake, the Glen Major Ponds, Mulmur Lake, the Caledon Club Ponds, and many others. A few of the warmer hard-water lakes support speckled trout, but are more typically occupied by centrarchids.

DESCRIPTIVE ACCOUNTS OF ONTARIO LAKES AND PONDS STUDIED

Large Lakes

This type has been discussed above. Only three examples occur in Ontario: Lake Nipigon, Lake Superior, and the north shore of Lake Huron. In these speckled trout are not of first-rate importance. They do not frequent the deep water, but remain along shore, off rocky reefs, receiving locally the name of "coasters".

Acid or Soft-water Lakes

In this class—that of typical Laurentian lakes—belong most of the trout lakes of northern Ontario. In August, 1929, a study was made of two examples: Ragged Lake and Wolf Lake, both near the south-western border of Algonquin Park, long. 78°40'W., lat. 45°30'N., and 1,400 to 1,500 feet above sea-level.

Wolf Lake

Wolf Lake (figure 2) has a total area of about 300 acres (120 hectares). It is a mile and a half long and averages one-quarter of a mile in width. On the north-west is a bay separated from the remainder by a shallow area grown up with *Scirpus*. Into this flows a small stream from Luck Lake to the north. The outlet is into Crown Lake on the east, so that there is very little flow of water through the main body. The shores are all covered with a forest, consisting in most places of mixed hardwoods and conifers, although on the northern side there is a black spruce and tamarack swamp. Several small islands in the lake consist of pillars of bed-rock projecting up from a considerable depth.

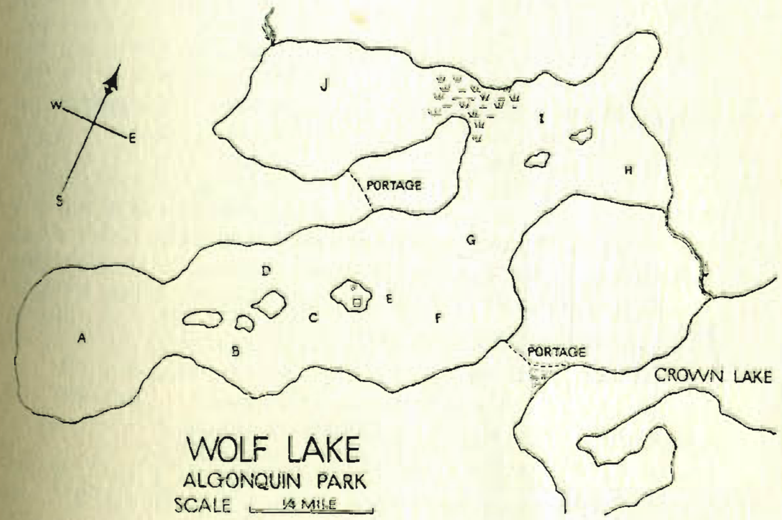

FIGURE 2. Map of Wolf Lake, Ontario

The maximum depth found in the lake was sixty-six feet, in the south-eastern or central part of the lake. It was fairly deep in the middle, even close to the islands, but shallow at both the western and the north-eastern ends. Depths at the stations shown on the map in figure 2 are given in table 1. The bottom was of small or large stones in shallow water, and mud with poorly decomposed organic debris at greater depths.

No complete survey was made of aquatic vegetation in the lake. The several acres of shallow, sedge-covered marsh have already been mentioned. Growing in water up to five feet deep elsewhere, were the long scapes and basal leaf rosettes of *Eriocaulon articulatum*; *Lobelia dortmanna* was less common.

TABLE 1. Temperature, pH and oxygen content, Wolf Lake

Station	Depth		Level		Date	Time	Temperature		pH	Oxygen		
	Metres	Ft	Metres	Ft			C.	F.		cc/1	p.p.m	% sat.
A......	4.6	15	0	0	Aug. 22	9.30 a.m.	18.3	65	7.2	6.3	9.0	102
			4.6	15	"	" "	17.4	63	6.8	5.4	7.7	86
B......	8.8	29	0	0	"	10 "	18.7	66	7.3	6.5	9.3	106
			3.0	10	"	" "	18.4	65	7.2	6.3	9.0	93
			6.1	20	"	" "	16.2	61	6.4	3.1	4.5	48
			7.6	25	"	" "	12.6	54.5	6.2	1.2	1.8	17
			8.8	29	"	" "	12.4	54.5	6.2	0.0	0.0	0
C......	6.7	22	6.7	22	"	11.00 a.m.	15.3	59.5	6.1	1.0	1.4	15
E......	9.1	30	0	0	"	12.30 p.m.	19.3	66.5	7.3	6.3	9.0	104
			3.0	10	"	" "	18.6	65.5	7.2	6.3	9.0	103
			6.1	20	"	" "	15.5	60	6.2	4.2	6.0	64
							16.5	61.5	6.1	4.3	6.1	67
			9.1	30	"	" "	10.5	51	6.3	5.6	8.1	77
							9.0	48	...	5.8	8.4	77
F......	20.2	66	0	0	"	2.30 p.m.	19.2	66.5	7.3	....	.....	....
			3.0	10	"	" "	19.2	66.5	7.3	....	.....	....
			6.1	20	"	" "	14.8	58.5	6.2	4.0	5.8	60
			9.1	30	"	" "	10.8	51.5	6.3	6.1	8.7	84
			15.2	50	"	" "	8.2	47	6.2	5.6	8.1	73
			20.2	66	"	" "	7.4	45.5	6.2	2.2	3.2	28
D......	5.5	18	......	...	....	....	....	....	...	....	.....	....
G......	15.2	50	......	...	....	....	....	....	...	....	.....	....
H......	7.0	23	......	...	....	....	....	....	...	....	.....	....
I......	4.6	15	......	...	....	....	....	....	...	....	.....	....

The water of Wolf Lake was quite transparent and not noticeably coloured. Soundings and chemical tests were

made on August 22, 1929, and are presented in table 1. It was a windy day, with waves on the surface, so that the surface water was warm and saturated or slightly supersaturated with oxygen. The distribution of oxygen with depth was very unusual. At station B it decreased steadily below the epilimnion to zero at the bottom in twenty-nine feet of water. At station E, which was of the same depth, it had decreased at a depth of twenty feet, but rose again to 5.7 cc. per litre at the bottom. At the deep station F, the same stratification was evident down to thirty feet as at E; at lower levels it retained this high oxygen content as far as fifty feet, but at the bottom, sixty-six feet, it had again dropped to 2.2 cc. per litre. This anomalous distribution of oxygen in the lake was paralleled to some extent by the hydrogen-ion concentration; in the epilimnion the pH was 7.2-7.3, below the epilimnion it was 6.1-6.4, the higher figures usually being coincident with the high oxygen content.

Although the cause of this peculiar stratification is unknown to the author, it is a factor of prime importance in the distribution of speckled trout in the lake. Most of the specimens were caught near station E; a few were taken at F, although not necessarily at a greater depth. None at all were taken at B, where bottom oxygen content was zero, nor in the warm, shallow parts such as at A. Trout were also captured in the north-west arm (J), but no soundings were taken there.

In addition to the speckled trout the following fish occur in the lake: *Semotilus atromaculatus*, *Ameiurus nebulosus*, and *Perca flavescens*. The list is probably incomplete. All of these were readily caught by angling off an island in the middle of the lake. The stomachs of several, taken September 10, were examined: seven *Ameiurus*, six to seven inches long, had empty stomachs; one *Perca* 5.4 inches in length, had eaten a chironomid pupa and a mayfly nymph (*Caenis*); of seven *Semotilus*, 3.9-7.0 inches long, four were empty and three contained the remains of crayfish (*Cambarus*) and insects.

Speckled trout grow to a rather large size in the lake, the largest seen by the author being 14.8 inches long and weighing

16.2 ounces. The average length of twenty-five specimens was twelve inches. Small specimens are rarely seen; only two were taken less than ten inches long. The contents of twenty-nine stomachs are presented in table 2. It is evident that fish are the principal food of these large trout. Insects commonly taken were nymphs of *Hexagenia* and larvae of *Corethra* and Chironomidae—all deep-water forms. The most interesting organism, however, is the large Cladoceran

TABLE 2. Stomach contents of *Salvelinus* and *Cristivomer* from northern lakes[1]

	Salvelinus	*Cristivomer*	*Cristivomer*
	Wolf Lake	Ragged Lake	Porcupine Lake
Length of trout in inches	10.0–14.5	12.4–22.5	14.1–22
No. of stomachs examined	29	11	5
Av. vol. of contents in cu. mm.	2150	?	?
Av. no. of Nematoda	+	?	?
Leptodora	5	–	54
Cambarus	1	–	–
Hydrachnida	+	+	–
Aquatic Insecta:			
Ephemeroptera: *Hexagenia*	1	–	–
Trichoptera: Polycentropidae	+	–	–
Chironomidae	2	+	1
Corethra	1	–	–
Coleoptera: Gyrinidae	+	–	–
Heteroptera: Gerridae	+	–	–
Terrestrial Insecta:			
Orthoptera	+	–	–
Homoptera: Cercopidae	+	–	–
Diptera: Muscoidea	+	–	–
Coleoptera: Elateridae	+	–	–
Hymenoptera: Formicidae	+	–	–
Fish:			
Semotilus atromaculatus	48	–	–
Perca flavescens	11	58	–
Unidentified fish	31	42	45

[1]In this and all succeeding tables of stomach contents, unless otherwise stated, figures indicate what percentage of the total food, by volume, is made up of the item in question; a cross (+) indicates that it occurred in a quantity which was less than one-half of one per cent.; a dash (–) that it was entirely absent.

Leptodora, which was present in great numbers. In Crown Lake, which is adjacent to Wolf Lake and very similar in appearance, a trout 13.2 inches long, had eaten large numbers of *Daphnia* as well as *Leptodora*. It may well be that at certain times of year plankton organisms form a large part of the food of these fish.

Ragged Lake

Ragged Lake is larger than Wolf Lake, comprising about a thousand acres (400 hectares) of water surface (figure 3). The main or eastern part contains a large island eccentrically placed; from a small northern bay flows the outlet; to the west is a long, narrow, and rather shallow bay, terminating in an expansion, the western arm, in which the trout are found. The western arm is the deepest part of the lake, the greatest depth found being 102 feet (31 metres); the northern bay is nearly as deep. Most of the lake does not exceed thirty feet (9 metres) in depth.

Two inlet creeks feed Ragged Lake, both coming from the south, from Porcupine and Crown Lakes. The volume of flow of the outlet was not greater than twenty cubic feet

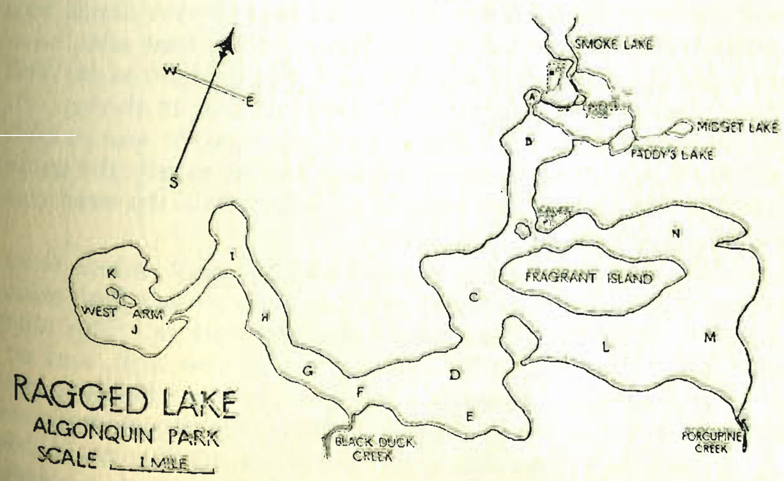

FIGURE 3. Map of Ragged Lake, Ontario

per second in August and September, 1929. The level of the water is maintained several feet above normal by a logging dam at the outlet; the resultant flooding of the banks has killed many bordering trees.

As at Wolf Lake, the shores are high, often rocky, and covered by a mixed growth of yellow birch, maple, and hemlock. Only to the south, at the mouth of Crown Lake Creek, is there a large boggy area, covered by the tangled remains of drowned cedars and tamarack.

Large aquatic plants do not grow extensively throughout the lake. However, on muddy bottoms in shallow water there are often found *Nymphaea advena*, *Castalia odorata*, *Potamogeton* spp., and *Nitella* sp. No *Eriocaulon* was noted but it may occur in some places; its absence may be due to the scarcity of suitable sandy or stony shores. In the shore areas the bottom usually fell away steeply, or was of soft mud.

The water of Ragged Lake was of a dark, tea-brown colour throughout. Soundings and chemical tests made in August, 1929, are recorded in table 3. At this season a thermocline was evident throughout the lake between the depths of fifteen and twenty-five feet. The surface temperatures were all near 19°C., those of the bottom near 10°C. In most parts of the lake the oxygen decreased with depth to a bottom value of about 3 cc. per litre. In the west arm, however, the same peculiar stratification was evident as in Wolf Lake: decrease at twenty feet, then increase at thirty. At station J in 102 feet of water the oxygen content was as high as 5.6 cc. per litre; in the northern bay at nearly the same depth, it was only 2.0 cc. per litre. It is only in the west arm that trout are caught in summer.

The only fish which the author has seen taken from Ragged Lake are *Cristivomer namaycush*, *Salvelinus fontinalis*, and *Perca flavescens*, but others doubtless occur. The lake trout are readily taken by trolling in the west arm, and an occasional speckled trout is caught in the same fashion, but the latter is a rare fish in the lake. Perch are very numerous. Many were seen along shore, and the stomachs of some of the lake trout were full of these fish from one to one and a half

TABLE 3. Temperature, pH, and oxygen content, Ragged Lake

Station	Depth		Level		Date	Time	Temperature		pH	Oxygen		
	Metres	Ft	Metres	Ft			C.	F.		cc/1	p.p.m	% sat.
A......	3.3	11	0	0	Aug. 12	5.00 p.m.	21.8	71	7.2	6.0	8.6	104
			3.3	11	"	" "	19.4	67	6.5	5.1	7.3	85
B......	29.0	95	0	0	Aug. 20	11.30 a.m.	19.0	66	7.1	6.1	8.7	99
			29.0	95	"	" "	7.4	45	6.1	2.0	2.9	25
C......	17.4	57	0	0	"	2.30 p.m.	19.7	67.5	7.0	6.3	9.0	104
			9.2	30	"	" "	11.6	53	6.2	3.6	5.1	50
			17.4	57	"	" "	9.5	49	6.1	3.0	4.3	40
D.....	4.6	15	0	0	"	3.00 p.m.	19.5	67	7.0	6.4	9.2	105
			4.6	15	"	" "	18.5	65.5	6.9	5.8	8.4	93
E......	4.6	15	......	...	....	....	....	....	...	....	.....	....
F......	1.2	4	......	...	....	....	....	....	...	....	.....	....
G.....	7.3	24	......	...	....	....	....	....	...	....	.....	....
H.....	2.4	8	......	...	....	....	....	....	...	....	.....	....
I......	4.6	15	0	0	"	7.00 p.m.	19.6	67.5	7.1	6.5	9.3	106
			4.6	15	"	" "	18.0	64.5	6.8	6.2	8.9	98
J......	31.1	102	31.1	102	"	6.00 p.m.	9.4	49	...	5.6	8.1	74
K.....	12.8	42	0	0	"	4.30 p.m.	20.0	68	7.3	6.3	9.0	104
			3.0	10	"	" "	18.2	65	7.2	6.4	9.2	102
			4.6	15	"	" "	17.4	63.5	...	....	.....	....
			6.1	20	"	" "	14.4	58	6.4	5.2	7.4	77
							12.4	54.4	6.4	5.2	7.4	72
			7.6	25	"	" "	10.2	50.5	...	....	.....	....
			9.2	30	"	" "	9.7	49.5	6.4	6.1	8.7	81
							10.2	50.5	6.4	6.3	9.0	85
			12.8	42	"	" "	9.5	49	6.4	5.5	7.9	73
L......	9.2	30	0	0	Aug. 27	10.30 a.m.	19.6	67.4	7.2	6.2	8.9	102
			3.0	10	"	" "	18.7	65.5	7.1	6.1	8.7	100
			4.6	15	"	" "	18.4	65	6.9	5.6	8.1	91
			6.1	20	"	" "	15.6	60	6.2	2.9	4.2	44
			9.2	30	"	" "	10.5	51	6.2	2.7	3.9	37
M.....	3.0	10	......	...	....	....	....	....	...	....	.....	....
N.....	13.1	43	13.1	43	"	12 noon	7.0	44.5	6.0	3.4	4.8	43

inches long. They were, in fact, almost the only recognizable food item found in the eleven stomachs examined (table 2). Ten of the perch taken from these stomachs had eaten large numbers of *Daphnia* and nothing else. Lake trout are not, however, exclusively piscivorous, as shown by five stomachs taken from Porcupine Lake, which is smaller than Ragged Lake but of a similar appearance. Three of these had eaten *Leptodora* almost exclusively; only one contained a fish (table 2).

It is interesting to speculate upon the factors determining the distribution of speckled and lake trout in these lakes. The two fish are very closely related phylogenetically, both being "charr" rather than true trout. They are very similar in appearance, are capable of eating much the same food, and both spawn on shoals in the autumn. The lake trout grows to the larger size, four-pound specimens being not uncommon, while individuals several times as large are on record. Four-pound speckled trout are exceptional. In lakes where both species occur abundantly, such as Eagle Lake, Algonquin Park, the speckled trout are commonest off rocky shores, and near islands at moderate depths, while the lake trout prefer more open and deeper water. Lakes in which only *Salvelinus* occurs are, as a rule, small, and in the author's experience are usually found near the top of a local height of land. Lakes in which *Cristivomer* is the only trout are larger, contain a larger expanse of deep water, and may be situated anywhere along a river system. These facts suggest that of the two, the lake trout are better adapted to lake conditions. The reason that speckled trout are in sole possession of certain lakes may be that they alone were present when the lake became isolated, or because they are able to surmount existing barriers to migration (such as small, warm streams, low falls, *etc.*) which the lake trout find impassable.

Bog Lakes

Bog lakes are dotted over the Pre-Cambrian area of North America, but do not usually contain speckled trout. The author knows of only one example containing trout: Lasseter Lake near Huntsville, Ontario. Bog lakes are usually smaller than lakes of the type just described, but grade insensibly into them, *i.e.*, a lake may have part of its shore boggy, and part sandy or stony. The fish fauna and general ecology of a bog

lake has been discussed by Jewell and Brown (1924) and Brown and Jewell (1926). More recently, Trembley (1931) has briefly described bog lakes of the Adirondacks, and divided them into four types, one of which commonly contains speckled trout.

Hard-water Lakes

The hard-water lakes of southern Ontario vary considerably in size, depth, temperature, flora, and fauna, but those which support speckled trout have enough characteristics in common to warrant their being grouped together. A discussion of these similarities will be withheld until some typical examples have been considered.

Little Wonder Pond

PHYSIOGRAPHY

This is a mill pond, formed by the damming of one of the headwaters of the Pine River, at Horning's Mills, Dufferin County, Ontario; in latitude 44°10'N. and longitude 80°13'W. Its shape is that of a broad V (figure 4), and comprises about two acres (0.8 hectares) of water surface. The banks for the most part slope fairly steeply to the water's edge, and at one point there is a small outcrop of Lockport dolomite, the basal rock of the region. On the east side and at the northern ends, the banks are wooded with young cedars; elsewhere it borders on open fields.

The pond is a shallow one, the greatest depth found being seven feet, and the average about three and a half. The approximate position of the three-and five-foot contours is indicated in figure 4. Since the amount of water withdrawn through the mill race is often greater than that supplied by the inlets, the level was subject to daily fluctuations. The greatest depression noted in 1928 was during September, when the water on one occasion fell three feet below the spillway of the dam.

WATER SUPPLY

The pond is supplied with water by two spring creeks, designated B and F, which flow into the north-western and

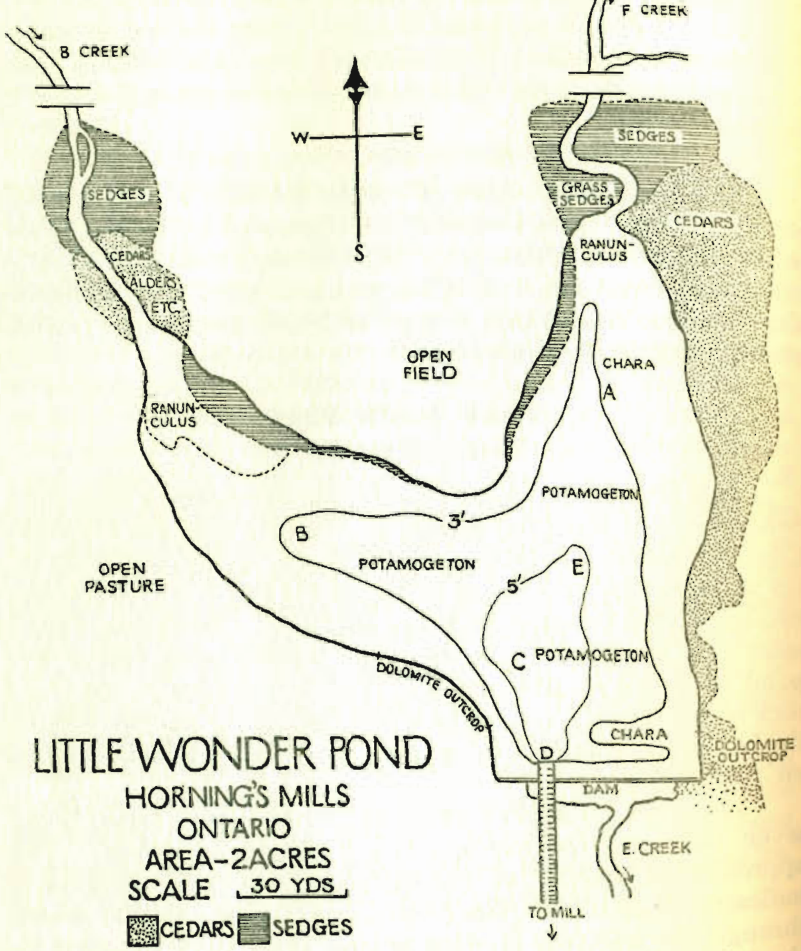

FIGURE 4. Map of Little Wonder Pond, Horning's Mills, Ontario

northern angles of the pond respectively. B creek is the larger, having a normal volume of flow of seven cubic feet per second in summer. It is also of greater length than F creek, and flows through more open country; consequently its temperature is higher. An analysis of its water, made July 14, 1928, at 4 p.m., was as follows: Temperature, 15.8°C. (60°

F.); pH 8.2; oxygen content, 5.6 cc. per litre. F creek is shorter, flows through swampy wood, and as a result has a low temperature: 12.9° at 3 p.m., July 9. In addition to these sources of water, a small spring was found in the north-west arm, and others may be present.

The water of the pond is clear and colourless in summer, except after heavy storms, when it is slightly turbid. It was sounded on August 3 from 3.30 to 4.30 p.m., using a minimum thermometer accurate to one-half degree Fahrenheit; the results are presented in table 4. Water at the bottom remained at nearly the same temperature as when it entered the pond. That near the outlet, which had entered during the night or early morning, was coldest—10°C.—while that in the arms was much warmer.

TABLE 4. Water temperatures of Little Wonder Pond

Station	Depth in feet	Temperature Centigrade		Temperature Fahrenheit	
		Surface	Bottom	Surface	Bottom
A.	2.5	19.7	14.4	67.5	58
B.	3	14.2	12.2	57.5	54
E.	5	17.8	11.1	64	52
C.	6	15.5	10.0	60	50
D.	7	15.3	10.0	59.5	50

VEGETATION

Emergent littoral plants:—The borders of the pond were in some places grown up with sedges, as shown in figure 4. *Scirpus atrovirens* and six species of *Carex* were most numerous. At the extreme end of the pond a tall grass, *Calamagrostis canadensis*, was abundant, and two species of *Juncus* occurred sporadically among the sedges. These semi-aquatic plants were fairly abundant along the banks of the central peninsula, and formed a small marsh around each of the inlet creeks. The eastern and western shores were barren.

Aquatic plants:—Most of the bottom of the pond was covered by aquatic plants. The only bare areas were near shore where plants had been killed by exposure to the air when the level was low. In the deepest water also, plants were scattered sparsely over the naked mud.

Potamogeton pusillus? was the most abundant plant in the pond, covering perhaps two-thirds of the bottom. It grew at all depths from one foot down, but was rather scarce in the deepest water. In early June its stems were low and spreading, but it grew rapidly so that at the end of July it almost reached the surface. By September 1 it formed a thick mat covering most of the surface of the pond, and sending its flower stalks up out of the water. The owner of the pond was of the opinion that it had greatly increased in abundance within the last few years.

Chara sp. The "stinking pond weed" covered perhaps a quarter of the bottom area of the pond, being most abundant in the south-east corner and in the northern arm. It grew at depths of two to four feet, often adjacent to, but never mixing with, the *Potamogeton*. Early in the season it stood taller than that plant, but later on the *Potamogeton* greatly exceeded the *Chara*, and shaded its margin quite extensively.

Ranunculus sp. White water-crowfoot was a conspicuous and beautiful pond plant. From July 10 to the end of the month its fragrant blossoms covered the shallow water near the two inlets, and extended in scattered clumps to a depth of five feet.

Green algae:—No adequate collections were made of either the macroscopic algae or the phytoplankton. *Spirogyra* was found abundantly in all shallow parts of the pond, particularly on the otherwise bare mud of the littoral region.

AQUATIC INVERTEBRATES

In the following list of species, numerical abundance is expressed by one of four words: rare—one or fewer per square foot; occasional—two to five per square foot; frequent—six to fifteen per square foot; abundant—more than fifteen per square foot.

Oligochaeta

Tubificidae. Frequent to abundant on bare mud, especially in the deeper water.

Hirudinea. Occasional or rare among weeds.

Helobdella stagnalis. Frequent among stones near shore; elsewhere rare.

Glossiphonia complanta. Frequent along a stony shore.

Haemopis grandis. Rare under sticks, *etc.*, in the littoral region.

Haemopis plumbeus. Rare among the *Chara* stems.

Nephelopsis obscura. Occasional in mud or among stones.

Crustacea

Hyalella knickerbockeri. Occasional.

Cladocera, Copepoda, and Ostracoda were abundant.

Ephemeroptera. Ide (1930) has recorded the following species:

Callibaetis americana Bks. Abundant.

Callibaetis skokiana. Rare; imagos taken 3. viii. 28.

Arthroplea bipunctata. Rare; a single nymph was found.

Odonata. Nymphs were rarely taken, but imagos of Zygoptera were common about the pond. Dr. E. M. Walker has identified nymphs and imagos.

Ischnura verticalis. Imagos not uncommon. 19-26. vii. 28.

Enallagma borealis. Imago. 15.vii.28.

E. ebrium or *hageni*. Nymph taken rarely; ♂ imago 25.vii.28.

E. cyathigerum ? Imagos. 20.vi.28 and 15.vii.28.

Lestes unguiculatus. Imagos. 19.vii.28.

Agrion maculatum. Imagos. 15.vii.28.

Aeshna canadensis. Imagos. 24.vii.28.

Ae. umbrosa. Imagos. 7-31.vii, 4.viii.28. Nymphs were rare, but were the only dragonfly nymphs taken.

Libellula quadrimaculata. Imagos. 1.vii.28.

Sympetrum obtrusum. Imagos. 18.vii.28.

Trichoptera. Imagos have been identified by Dr. Cornelius Betten.

Hydroptilidae. A single larva was taken in deep water.

Phryganea interrupta. Imago taken 26.vii.28.

Anabolia bimaculata. Imago. 26.vii.28.

Limnephilus indivisus. Imago. 19.vii.28.

Limnephilus larvae were very common in the *Chara.*

Larvae of two other Limnephilds occurred more rarely.

Neuroptera

Sialis infumata. Several imagos taken. One larva was found in a trout stomach.

Heteroptera. Corixidae have been determined by Mr. G. Stuart Walley.

Arctocorixa modesta Abb. Abundant. 7.ix.28.

A. alternata Say. Rare. 7.ix.28.

Corixids were occasional during the early part of the summer, and frequent or abundant later.

Diptera

Chironomidae. Larvae were examined by Dr. O. A. Johannsen, imagos by Mr. Stuart Walley.

Imagos

Metriocnemus par Joh. 27.vi.28.

Tanytarsus nigripilus Joh. 16.vii.28.

Larvae

Culicoides. Occasional.

Procladius (*adumbratus* group). Frequent at moderate depths.

Procladius sp.? Occasional.

Chironomus (*sensu stricto*). Frequent on bare mud at moderate depths.

Chironomus (*Limnochironomus*). Frequent on bare mud at moderate depths.

Chironomus (*Cryptochironomus*). Rare.

Larvae of several other species of Chironomidae were collected but not determined.

Tabanidae. Imagos were determined by Mr. C. H. Curran.

Chrysops carbonarius Walker. 13.vi.28, 16.vi.28, 14.vii.28.

C. indus O.S. 16.vii.28, 24.vii.28.

Larvae of *Chrysops* were occasionally collected in water up to one foot deep.

Coleoptera. Determined by Mr. William Brown.

Dytiscidae

Hydroporus depressus Fab. 16.vi.28, 7.ix.28. Occasional.

H. solitarius Sharp. 21.vii.28. Occasional.

H. niger Say. 26.vi.28. Rare.

H. tristis Payk. 4.vi.28. Rare.

Larvae of *Hydroporus* were occasional.

Haliplidae

Haliplus immaculicollis Harr. 3.vi.28. Rare.

H. subguttatus Robts. 3.vi.28. Rare.

Hydrachnida. Collected occasionally.

Pelecypoda. A few of the Sphaeriidae collected have been examined by Dr. V. Sterki.

Pisidium overi Sterki

Pisidium sp.? cf. *milium* Held.

Pisidia were occasional to frequent in the dredgings.

Gastropoda. Most of the snails were determined by the Hon. F. R. Latchford.

Lymnaea stagnalis L. Rare.

Stagnicola caperata? Frequent in shallow water near the inlets.

Gyraulus parvus. Occasional.

Physella gyrina Say. Determined by Dr. Clench. Frequent on the bottom near shore, and on the weeds over greater depths, especially on *Potamogeton.*

Distribution:—The collections made were not sufficient to permit a very complete survey of the bottom fauna of the pond, but do show that it may be divided roughly into three different areas.

Shore area (depth up to one foot)

Animal life was frequent in this area. Where the bottom was covered with sticks and vegetable debris, larvae of *Limnephilus* and others of the family were the most conspicuous inhabitants. The aquatic beetles, corixids, *Physella* and *Stagnicola*? were commonest in this region. Under logs or boards the large leech *Haemopis grandis* was occasionally found, while under the stones of a rocky shore the smaller *Nephelopsis*, *Glossiphonia*, and *Helobdella* were frequent. In late summer this area was exposed to the air at times.

Area of moderate depth (1 to 4 feet)

In this region chironomid larvae were the most important forms; most of those collected were of three species, which belong to the genera *Chironomus* (s.s.), *Limnochironomus* and *Procladius* respectively. There was, however, a great emergence of midges about May, before any collections were made, so that certain other forms may be just as abundant. Some organisms found in the shore area also occur here in lesser numbers, being found especially among the stems of the weeds when they rise near the surface. Examples are *Limnephilus* larvae, *Physella*, *Hydroporus*, and *Arctocorixa*.

Deep water (5 to 7 feet)

A collection taken in the deepest water in July contained a large number of Oligochaeta, but little else. The almost complete absence of Chironomidae is noteworthy, but they may have been present earlier in the season. There can be no doubt, however, that the deep water is much less productive than the shallow.

FISH

The fish occurring in the pond were the speckled trout (*Salvelinus fontinalis*), the five-spined stickleback (*Eucalia inconstans*), and the sculpin (*Cottus cognatus*). The sculpin were quite rare, only one specimen having been taken, on June 4. Sticklebacks appeared to be rare in spring, but by late summer were fairly common. One nest was found on July 21; the young were common in September, and were occasionally found in trout stomachs. The sticklebacks fed principally on Entomostraca.

Speckled trout were abundant. Those occurring in the pond were for the most part over five inches long, that is, in their second year or older, though a few fingerlings were taken in a seine on June 18, 1927. Many small fish doubtless descend to the pond from the streams above. The largest trout seen by the author were 13.9 and 14.3 inches long, but they were exceptional; the largest one ever caught was reported to have been eighteen inches long. The average length of fifty-eight specimens over seven inches long caught by anglers during 1928 was 8.4 inches.

The stomachs of 140 specimens were examined. The food of nine fingerlings 1.5 to 2.2 inches long is presented in table 5. They were eating chironomid pupae almost exclusively at this time, with a small proportion of other insects and ostracods.

TABLE 5. Stomach contents of nine fingerling speckled trout, 1.5-2.2 inches long, taken June 18, 1927, in Little Wonder Pond

Av. volume of contents in cu. mm.	63
Av. no. of Nematoda	0.5
Ostracoda	1
Trichoptera larvae	1
Chironomidae	91
Other aquatic Diptera	2
Hymenoptera	+
Terrestrial Coleoptera	2
Insect remains	3

The food of 131 larger specimens, taken from May to July, is shown in table 6. The table is arranged to show both seasonal variation in the organisms consumed and variation with increase in size of the fish.

On May 1 chironomid pupae occurred in large numbers in the five specimens examined, but during the rest of the year they were of minor importance. In June *Physella* and *Limnephilus* larvae were the principal foods; in July the caddis were predominant. In September and probably throughout

TABLE 6. Stomach contents of speckled trout, five to twelve inches long, from Little Wonder Pond

	May	June				July			September	
No. of stomachs	5	16	30	6	2	29	24	3	11	5
Length in inches	9–12	5–7	7–10	10–12	14	5–7	7–10	10–12	5–7	7–10
Av. vol. of stomach cont. in cu. mm.	3000	550	610	670	8500	360	680	4350	270	150
Av. no. of Nematoda	?	4	2	0	+	1	2	+	9	2
Vegetable matter	–	1	2	–	+	4	+	–	14	8
Hirudinea and Oligochaeta	–	–	4	–	–	–	–	–	–	–
Gastropoda	6	18	21	67	4	5	7	35	58	7
Amphipoda and Hydrachnida	–	1	1	–	–	1	+	+	+	2
Odonata nymphs	–	2	+	–	–	1	4	–	–	–
Trichoptera:										
Larvae and imagos	1	40	39	3	4	27	44	30	1	–
Larval cases	1	8	16	6	2	22	29	26	+	–
Heteroptera: Corixidae	–	3	5	9	–	6	2	2	12	29
Diptera: Chironomidae	86	20	8	6	–	20	8	+	2	5
Others	–	–	1	–	–	–	+	–	1	–
Coleoptera: Dytiscidae	–	2	1	1	–	8	6	7	10	18
Terrestrial Hemiptera	–	+	+	–	–	1	+	–	+	–
" Diptera	–	3	–	–	–	–	+	–	+	–
" Coleoptera	–	2	1	–	–	1	+	+	1	26
" Hymenoptera	–	2	+	–	–	1	+	–	2	6
Fish	6	–	2	7	90	–	–	–	–	–
Total surface food	–	7	2	1	–	3	1	+	4	25
Total submersed food	100	93	98	100	99	97	99	100	96	75

most of August, the *Limnephilus* larvae had retired to pupate, so the trout turned once more to snails, and to corixids, *Hydroporus* larvae, and terrestrial insects.

Glen Major Ponds

The four ponds at Glen Major are very similar in most respects, and may be considered as a unit.

PHYSIOGRAPHY AND VEGETATION

All the ponds, numbered 1, 2, 3, and 4, lie in a wooded valley among moraine hills, fifteen miles north of Lake Ontario, latitude 44°1′N. and longitude 79°3′W. They are in a linear series, number 4 being uppermost. Their size and arrangement are shown in figure 5. All are held back by long earthen dams, and number 2 at least was originally a mill pond.

Number 4:—The "Nursery Pond" is about a quarter of an acre (1,000 square metres) in extent, mostly less than a foot in depth, and with a bottom of loose mud, except for a small patch of *Chara* on the south-west side. The shores are swampy, grown up with willows and *Typha*, and contain small springs which seep into the pond.

Number 3:—This is the smallest of the fishing ponds, 1.3 acres (0.5 hectares) in extent. Its upper end is quite shallow and carries a thick growth of *Equisetum fluviatile*, through which the course of the deeper channel is marked by a profusion of watercress. The main part of the pond is mostly shallow, reaching a maximum of seven feet near the dam. *Chara* covers the bottom; except for several bare lanes artificially cleared, it forms a mat three feet in thickness over the mud bottom.

Number 2:—The second pond is 3.3 acres (1.3 hectares) in extent, and reaches a greater depth than the first (11 feet); the transition from shallow to deep water is characteristically abrupt. At the upper end of the pond there is considerable watercress, although the channel is mostly bare. Elsewhere, *Chara* abounds, rising to the surface in shallow water; in places it is covered by a mat of tangled filaments of *Spirogyra*.

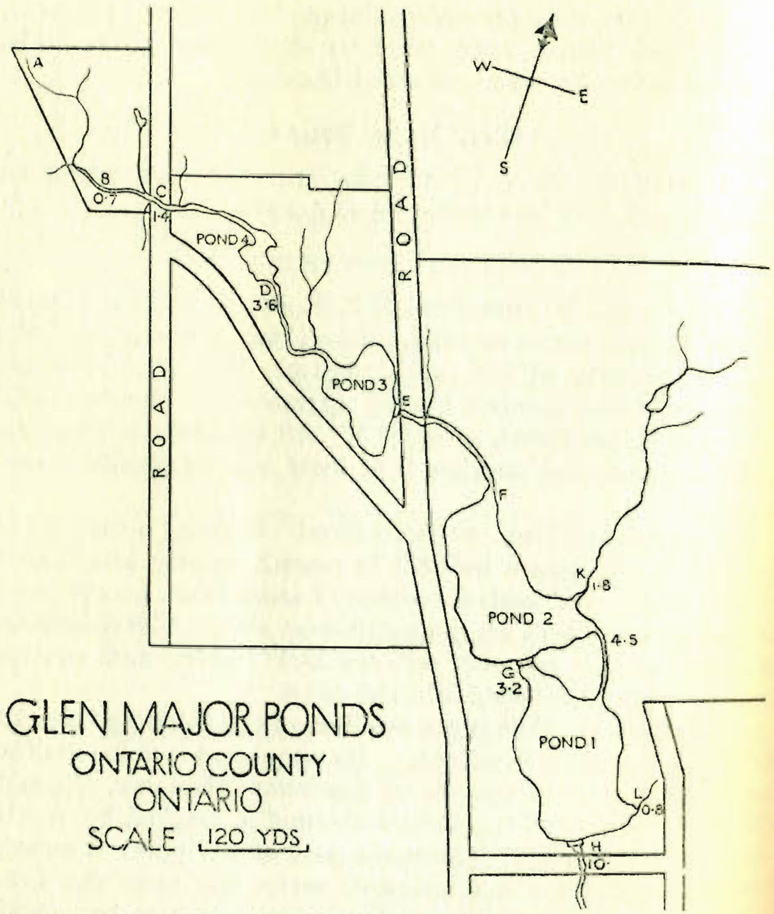

FIGURE 5. Map of Glen Major Ponds, Ontario County, Ontario. The numbers indicate volume of flow in cubic feet per second, August 11 to 13, 1928

Number 1:—The lowermost pond resembles the preceding one in size, but the deep water is of greater extent, being found over half the total area. Nine feet is the greatest depth found. Except for two long, clear lanes in deep water and a strip along the shore, the bottom is covered with *Chara*. Near the eastern inlet a small patch of *Potamogeton*, apparently a recent arrival, has successfully established itself.

WATER SUPPLY

Almost all the water entering these ponds in summer is from the numerous springs of the region. Figure 5 shows the more important creeks and rivulets. In table 7 their volume of flow, temperature, pH, and oxygen content are recorded. Some of the springs are low in oxygen (3.1 cc. per litre), and all have a relatively high hydrogen-ion concentration (pH 7.4-7.6). The water quickly gains oxygen and loses carbon dioxide upon exposure to the air in the creeks, so that when the latter enter the ponds the oxygen content is about 6.5 cc. per litre and pH 7.8. Photosynthesis in the ponds was proceeding at a rapid rate on the clear days on which these analyses were made. On such occasions the oxygen released more than saturates the water, and bubbles which form among loose bits of *Chara* and *Spirogyra* cause great masses of these plants to float to the surface during the day, only to sink again at night. The concentration of oxygen in the water leaving the ponds is nearly 130 per cent. of saturation in each of the cases presented in table 7. On another occasion, at 5.00 p.m., the water leaving pond 1 was 156 per cent. saturated with oxygen. The single fall at the foot of each pond is not sufficient to reduce the water to saturation; it remains at about 110 per cent. in each case; but in the case of pond 3 outlet, its subsequent flow of several hundred feet over a gravel bed is sufficient to bring the value down to 100 per cent. The concentration of hydrogen-ion in the water becomes less as it passes through the series of ponds, reaching a pH value of 8.1 or 8.2 at the outlet of pond 1. It does not change when the water goes over a fall. The high pH values prevailing throughout the series is the result of a low carbon dioxide and high bicarbonate content.

The bottom temperature of the ponds was taken on August 10, by means of a minimum thermometer. The deep water of pond 3 averaged 11°C. (52°F.) at 4 p.m., pond 2, 10°C. (50°F.) at 2 p.m., pond 1, 13°C. (56°F.) at 11 a.m. Several springs are found in the upper part of pond 2, which account for its low temperature. Smaller springs are found in pond 1 as well.

TABLE 7. Temperature, pH, and oxygen content, Glen Major waters

Position on map	Description	Date Aug., 1928	Time	Vol. of flow in cu. ft. per sec.	Temp. C.	Temp. F.	pH.	Dissolved oxygen cc/1	Dissolved oxygen p.p.m.	Dissolved oxygen Per cent. sat.
A.....	A spring hole at the source..............	11	10.50 a.m.	....	7.3	45	7.6	3.1	4.6	40
B.....	West branch of main feeder..............	7	2.30 p.m.	0.7	11.1	52	7.7	....	....	....
C.....	Below junct. of E. & W. branches.........	11	11.20 a.m.	1.4	9.7	49	7.8	6.2	8.9	82
D.....	Outlet of pond 4, above fall..............	"	11.30 a.m.	3.6	13.2	56	7.8	7.1	10.2	101
D.....	Outlet of pond 4, below fall..............	"	2.15 p.m.	....	13.0	55	7.8	6.7?	9.5?	94?
E.....	Outlet of pond 3, above fall..............	"	4.00 p.m.	....	18.6	66	8.0	8.4	12.0	133
E.....	Outlet of pond 3, below fall..............	"	4.10 p.m.	....	18.2	65	8.0	7.1	10.2	113
F......	Head of pond 2..........................	"	4.15 p.m.	....	17.4	63	7.9	6.4	9.2	100
G.....	Outlet of pond 2, above fall..............	13	2.00 p.m.	[1]3.2	15.3	59	7.9	8.9	12.7	131
G.....	Outlet of pond 2, below fall..............	"	2.00 p.m.	....	15.8	60	7.9	7.4	10.5	110
H.....	Outlet of pond 1, above fall..............	"	10.45 a.m.	10.0	16.5	62	8.1	8.9	12.8	136
H.....	Outlet of pond 1, below fall..............	"	" "	....	16.3	61	8.1	7.2	10.4	109
K.....	Eastern feeder of pond 2.................	11	4.20 p.m.	1.8	8.3	47	7.8	6.6	9.4	84
L......	Eastern feeder of pond 1.................	13	10.30 a.m.	0.8	8.5	47	7.6	7.0	10.0	90

[1] Western outlet only. Volume of flow of eastern outlet is 4.5 cu. ft. per second.

It is clear that in each of the ponds cold water, rich in oxygen, is available at all times.

AQUATIC INVERTEBRATES

Hydrozoa

Hydra sp. A single specimen was dredged from eight feet.

Turbellaria

Planaria sp. Occasional.

Oligochaeta

Tubificidae. Occasional.

Hirudinea

Helobdella stagnalis. Occasional.

Glossiphonia complanata. Occasional.

Nephelopsis obscura. Occasional.

Crustacea. Cladocera, Copepoda, and Ostracoda were doubtless represented by a variety of species. The only Entomostracan taken in the net was the abundant *Simocephalus*.

Hyalella knickerbockeri. Frequent.

Ephemeroptera

Callibaetis americanus. Ide (1930) records the occurrence of large numbers of nymphs and imagos of this species at Glen Major, 7-15.viii.28. They were common again, June 9, 1931. Nymphs were abundant in dredgings from the shallower areas of all three ponds.

C. skokiana. Imagos recorded by Ide, 14-16.viii.28. Rare.

Odonata. Identified by Dr. E. M. Walker. All the imagos collected in the neighbourhood of the ponds are listed here, though it is probable that some of them are not pond inhabitants.

Ischnura verticalis. 8-19.viii.28.

Enallagma carunculatum. 7.viii.28.

E. exsulans. 7.viii.28.

Lestes congener. 17.viii.28.

Agrion maculatum. 7-17.viii.28.

Nymphs of Zygoptera were rarely taken in dredgings.
Aeshna canadensis. 11-14.viii.28.
Ae. interrupta interrupta. 11-13.viii.28.
Ae. constricta. 7-11.viii.28.
Ae. umbrosa. 9-14.viii.28.
Anax junius. 9.vi.31.
Somatochlora walshii. 11-14.viii.28.
S. tenebrosa. 11.viii.28.
Libellula quadrimaculata. 9.vi.31.
L. lydia. 15.viii.28.
Sympetrum danae. 14.viii.28.
S. semicinctum. 13-17.viii.28.
S. obtrusum. 7-21.viii.28.
S. vicinum. 11-17.viii.28.
The only anisopteran nymphs taken in the ponds were of *Aeshna umbrosa*. For dragonflies, they were quite common, appearing rarely or occasionally in the dredgings.

Trichoptera
Limnephilus larvae were frequent. A few had entered the pupal state by August 20.

Heteroptera
Arctocorixa modesta. Determined by Walley. Nymphs and adults were frequently collected.
Notonecta. Rare.
Gerridae. Rare.

Diptera
Tipula. A large larva was taken.
Chironomidae. Larvae were abundant.
Culicoides. Occasional.
Chrysops. Occasional.

Coleoptera
Haliplus sp. near *subguttatus* Rbts. Determined by Brown. Adults. 13.viii.28.
Haliplus. Larvae were occasionally taken.
Berosus. Larvae rare.
Hydroporus depressus. Fab. Determined by Brown. Adults. 13.viii.28.

Hydroporus. Larvae abundant, especially in pond 3.
Dytiscus. Rare.
Helmis. Rare.

Hydrachnida. Occasionally collected.

Pelecypoda. Sphaeriidae identified by Dr. V. Sterki.
Pisidium compressum. Say. Abundant.
P. variabile Prime. Abundant.
Musculium ryckholti Normand? Frequent in pond 1.
Sphaerium rhomboideum Say. Occasional.

Gastropoda
Lymnaea stagnalis. Rare.
Stagnicola sp. Occasional.
Gyraulus parvus. Occasional.
Helisoma antrosus unicarinatus. Determined by Latchford. Rare.
Physella gyrina Say. Determined by Clench. Frequent to occasional.

Distribution:—As in other ponds of a similar nature, so in these ponds, invertebrate life was much more abundant at depths of less than three or four feet than in the deeper areas. The thick masses of *Chara* and *Spirogyra* overlying a soft mud in shallow water were teeming with organisms of many sorts, the most conspicuous of which were various leeches, *Limnephilus*, *Callibaetis*, *Hydroporus*, Chironomidae, *Physa*, and *Musculium*. The rather limited areas of bare mud bottom near shore were the favoured home of *Helisoma antrosus unicarinatus* and of *Pisidium*, but they also contained many of the organisms of the *Chara* beds, in lesser numbers.

At depths greater than four feet, chironomid larvae were the only important inhabitants; they occurred there more abundantly than in the shore region. This was true both on the *Chara* beds and in the bare lanes. A few representatives of the shore fauna, such as *Physa*, *Gyraulus*, and Hydrachnida, occur at depths as great as six feet. The total weight of the bottom fauna in deep water is less than one-tenth of that occurring in shallow water.

FISH

Cottus sp. A small specimen was taken from each of ponds 1 and 2, but sculpins are rare in the Glen Major waters.

Salvelinus fontinalis. Speckled trout are abundant in the three larger Glen Major Ponds. Fingerlings are to be seen around the borders of the ponds and in the connecting creeks. Larger fish commonly remain in deep water by day. The stock of trout in the ponds is maintained by natural propagation and by the introduction of 8,000 fingerlings per year. The number caught out by club members has varied between 912 and 1,465 per year during the period 1922-1931,[1] averaging 1,112, or fourteen per cent., of those planted. If it be assumed that the rate of growth is similar to that in Little Wonder Pond, then the catch in August, 1928, is distributed as follows: four per cent. in their second year, eighty-six per cent. in their third year, ten per cent. in their fourth year. This may be taken as typical of recent years. Pond 3 yielded fewer trout than the others, but its catch included two-thirds of those 9.5 inches long and over. Factors which may account for the disappearance of the remaining eighty-six per cent. of planted fingerlings, and those hatched naturally are: poaching, escape of trout over the dam of pond 1, cannibalism, destruction by piscivorous birds and mammals, and death from disease or senility.

The result of the analysis of the stomach contents of 104 specimens is presented in table 8. In August, larvae of *Limnephilus* are the most important food item, particularly in pond 3. *Physella* is common in stomachs of fish from pond 1, but other molluscs are rare. Because of their large size, the few nymphs of *Aeshna umbrosa* found, bulk rather large in some of the percentages. On the other hand, larvae of *Hydroporus* and of Chironomidae were very common, but on account of their small size do not usually form more than ten per cent. of the total volume. Terrestrial insects, taken at the surface of the water, were not important. The only fish identified was a trout two or three inches long; the other vertebrate may have been a tadpole.

[1] I am indebted to Mr. Garnet Bell for this information.

TABLE 8. Stomach contents of speckled trout from Glen Major Ponds

	August 4-18, 1928						May 2, 1927
Length of trout in inches	4.5-7.0		7.0-9.5			10-11	7.0-9.2
Place taken	Pond 1	Pond 2	Pond 1	Pond 2	Pond 3	Pond 3	?
No. of stomachs examined	11	12	34	21	11	8	7
Av. vol. of contents in cu.mm.	260	300	370	530	490	2000	1160
Av. no. of Nematoda	0	0	0	0	+	+	0
Vegetable matter	11	12	1	8	–	3	–
Oligochaeta and Hirudinea	–	–	10	–	8	–	2
Gastropoda: *Physella, etc.*	33	–	21	8	–	1	3
Crustacea and Hydrachnida	+	2	1	+	6	+	–
Ephemeroptera: *Callibaetis*	3	4	5	3	1	+	3
Odonata: *Ae. umbrosa*	10	–	9	23	1	+	1
Trichoptera: larvae	10	26	16	13	32	41	8
larval cases	5	28	16	14	25	28	1
Heteroptera: Corixidae	3	1	4	6	3	2	2
Diptera: Chironomidae	7	9	4	7	11	3	73
Coleoptera: *Hydroporus* and *Haliplus*	13	9	7	6	10	22	3
Terrestrial Diptera	–	–	+	–	1	–	–
Terrestrial Coleoptera	1	1	–	1	+	–	–
Terrestrial Hymenoptera	–	8	+	5	2	–	–
Fish	–	–	5	7	–	–	–
Total surface food	2	9	1	7	4	+	1
Total submersed food	98	91	99	93	96	100	99

The analysis of seven stomachs taken on May 2, indicates that chironomid pupae are the principal food of the trout at that time of year.

The trout taken from pond 3 are commonly of a much larger size than those from the other two. The average size of those over seven inches long, taken in August, 1928, was in pond 1, 7.9 inches, in pond 2, 8.0 inches, in pond 3, 9.4 inches. It is possible that this may be correlated with a greater abundance of large *Limnephilus* larvae which thrive on the broad areas of shallow water found in pond 3.

Caledon Club Ponds

The Caledon Club near Inglewood, in Peel County, Ontario, possesses a number of artificial ponds of various sizes, which are in two series. The first of these includes nine ponds, which are designated C, A, B, 4, 5, 6, 7, 8, and 3, from the top downward. Of this group, numbers 4 and 3 are about 1 and 2 acres in extent, respectively; the others are much smaller—only a few square rods. The water flowing through the system all comes from springs at its head, and amounted to 0.3 cubic feet per second late in August, 1928. At the foot of each pond is a spillway over which the water drops to the pond below, its fall being usually broken into two stages. An investigation of the properties and composition of the water at points along the system was made on August 27-28, 1928 (table 9). The variations in oxygen content shown in this table are particularly interesting. At the spring the water is only forty-five per cent. saturated with oxygen, but by the time it reaches the uppermost pond it has reached equilibrium in this respect. Pond C contains no fish, and pond A small fingerlings, which lower the oxygen content only slightly. Pond B contains large yearlings, whose respiration apparently reduces the oxygen content to eighty-four per cent. of saturation, and the rather gentle fall below increases this value very little. Pond 4 contains two-year-old fish, but is much larger, and holds an abundant growth of aquatic vegetation, which all the preceding ponds lack. Water leaving it is supersaturated with respect to oxygen, and two falls in its outlet are not sufficient to reduce the content to saturation value. Ponds 5 to 8 are rather small and shallow, contain no fish, and the bottom of each is covered by *Chara*. Water leaving them is supersaturated in every case, the highest content recorded being 167 per cent. of saturation. At this time the pH rose to 8.6.

The other series consists of only two ponds, numbered 1 and 2, which are the fishing ponds. Pond 1 receives its water from cold spring creeks, and drains into pond 2, over a fall of two stages. The water leaving 1 is 120 per cent. saturated with respect to oxygen; the first fall reduces this to 109 per

TABLE 9. Temperature, pH, and oxygen content, Caledon Club waters

Place	Height of fall	Date, Aug., 1928	Time	Temperature C.	Temperature F.	pH.	Dissolved oxygen cc/1	Dissolved oxygen p.p.m.	Dissolved oxygen Per cent. sat.
Spring		27	2.45 p.m.	8.0	46	7.5	3.6	5.1	45
Artesian well		"	2.50 "	7.9	46	7.5	6.1	8.7	77
Spillway of dam		"	3.00 "	9.1	48	7.7	7.2	10.3	94
Top of pond C	4 ft. in 2 stages	"	3.10 "	9.2	49	7.7	7.6	10.8	99
Foot of pond C		28	10.15 a.m.	9.7	50	7.8	7.2	10.3	96
Top of pond A	3.5 ft. in 2 stages	"	10.15 "	10.0	50	7.8	7.4	10.5	98
Foot of pond A		"	10.30 "	10.4	51	7.8	7.1	10.2	97
Top of pond B	3 ft. in 1 stage	"	10.30 "	10.7	51	7.8	7.2	10.3	98
Foot of pond B		"	11.55 "	11.2	52	7.7	6.2	8.9	84
Top of pond 4	3 ft. in 1 stage	"	11.55 "	11.4	52	7.7	6.3	9.0	85
Foot of pond 4		"	12.05 p.m.	21.	70	7.9	8.5	12.2	144
Top of pond 5	7 ft. in 2 stages	"	12.05 "	20.8	70	7.8	6.4	9.2	105
Foot of pond 5		"	1.00 "	21.4	71	8.1	9.0	12.8	152
Top of pond 6	5 ft. in 2 stages	"	1.00 "	21.3	71	8.1	6.7	9.5	113
Foot of pond 6		"	1.10 "	22.	72	8.4	9.2	13.1	156
Top of pond 7	8 ft. in 2 stages	"	1.10 "	22.2	72	8.4	7.9	11.3	137
Foot of pond 7		"	2.10 "	22.	72	8.4	8.1	11.5	139
Top of pond 8	7 ft. in 2 stages	"	2.10 "	21.7	72	8.3	6.8	9.7	116

TABLE 9—*Continued*

Place	Height of fall	Date Aug., 1928	Time	Temperature C.	Temperature F.	pH.	Dissolved oxygen cc/1	Dissolved oxygen p.p.m.	Dissolved oxygen Per cent. sat.
Foot of pond 8	15 ft. in 2 stages, and	27	2.20 p.m.	22.	72	8.6	9.7	13.8	167
Inlet of pond 3	run of 200 ft.	"	2.25 "	22.4	72	8.2	5.9	8.4	101
Overflow of pond 3	6 ft. in one stage	"	3.15 "	24.5	76	8.1	6.4	9.2	115
Below dam of pond 3		"	3.15 "	23.6	74	7.9	5.3	7.6	93
Main inlet of pond 1	Small spring enters	"	5.10 "	12.8	55	7.8	6.7	9.5	94
Creek		"	5.20 "	12.1	54	8.0	7.1	10.2	99
Creek		"	5.25 "	13.7	57	7.9	7.0	10.0	101
Outlet of 1, at dam	3 ft. in 1 stage	"	4.15 "	21.5	71	8.1	7.0	10.0	120
Outlet of 1, below first fall		"	4.15 "	21.6	71	8.1	6.4	9.2	109
Outlet of 1 below 2nd fall	7 ft. in 1 stage	"	4.15 "	21.7	72	8.1	6.0	8.5	102
Outlet of 2 above fall	9 ft. in 2 stages, with	"	3.25 "	22.7	74	8.1	6.8	9.7	117
Outlet of 2 below fall	rapids	"	3.25 "	22.9	74	8.1	5.8	8.2	100

cent., and the second brings it practically to saturation value (table 9). In general it may be said that in summer, during daylight hours, falls at the foot of weedy ponds do not aerate the water which flows over them, but rather *reduce* its supply of dissolved oxygen. At night, or in winter, the reverse is probably true.

PHYSIOGRAPHY OF POND 1

The uppermost fishing pond was dug out and dammed prior to 1900. Its shores are mostly wooded with cedars or deciduous trees. In area it is about three acres (1.2 hectares). The bottom is of sand and small stones in the south-eastern part, elsewhere of black silt. Near the outlet in the south-western arm the depth of the water is ten feet (3 metres); over much of the central part of the pond it exceeds six feet, but there is a considerable area of shallow water near shore.

VEGETATION OF POND 1

In 1928 vegetation was sparse in the pond. At the ends of the shallow bays there were stands of the emergent *Typha latifolia*, but true aquatics were almost absent. In one place only a small bed of *Chara* was found, but the abundance of dead stems indicated that it had formerly been of much wider distribution in the pond. In some places the mud was covered with a mass of tangled filamentous algae, *Spirogyra*.

In the autumn of 1930, the author again visited the pond, and found an extensive growth of *Chara* in all the shallow water. In the interim a large number of suckers had been removed; they had probably hindered the growth of the weed by their grubbing in the mud.

WATER SUPPLY OF POND 1

The pond is supplied with cold, hard water from a large feeder and two smaller ones, with a total flow of three cubic feet per second (table 9). It is approximately saturated with oxygen when it enters, and considerably supersaturated when it leaves, owing to its higher temperature.

INVERTEBRATE LIFE

In 1928, invertebrate life was quite scarce in the pond. On the bare mud bottom chironomid larvae were the only common animals of macroscopic size. A few other dipterous larvae and *Hyalella* were rare; on some of the logs large sponges flourished. A great number of dead shells of *Physa*, *Lymnaea*, *Helisoma*, *Gyraulus*, *Pisidium*, and *Sphaerium* attested the abundance of molluscs in former years. In the small *Chara* bed a few of these molluscs were still alive. Here, too, nymphs of Baetine mayflies, damselflies, and dragonflies, caddis larvae of the families Hydroptilidae and Phryganeidae, tabanid larvae, Hydrachnida, and Oligochaeta were rarely or occasionally taken. Among the *Typha* stems, odonate nymphs and aquatic Coleoptera were not uncommon. Most of the pond was, however, quite unproductive. Following the removal of the suckers and the re-establishment of the *Chara* along the borders of the pond, there can be no doubt that invertebrate life will increase until it is again sufficient to support a large population of trout.

FISH OF POND 1

Cottus bairdii. One sculpin was taken in the pond.

Catostomus commersonii. In 1928 suckers were abundant in the pond. They reached a length of fifteen inches. The digestive tracts of thirteen specimens, 11.8 to 14.5 inches long, taken on August 25-26, 1928, contained the following:

	Per cent. by volume
Filamentous algae (Isokontae)	29
Diatoms: *Navicula*	3
Cladocera: *Daphnia longispina*	30
Ceriodaphnia reticulata	1
Bosmina	+
Copepoda: *Cyclops*	2
Diaptomus	2
Epischura	+
Chironomidae, larvae and pupae	17
Unidentified matter, possibly *Spongilla*	16

Salvelinus fontinalis. Speckled trout are also abundant in the pond. Each spring a large number are planted, over nine inches long, and by the autumn a good proportion of these have been caught out. During their stay in the pond, the trout were not well fed, as shown by their stomach contents, analysed in table 10. The stomachs contained less than one-tenth as much food as did trout of the same size in other ponds. The principal organisms found were in the autumn, chironomid pupae and in the spring, bumble bees. The suckers, which inhabited the pond in 1928, competed directly with the trout to some extent, but were of much greater harm as destroyers of the *Chara* beds. Since these have been re-established, the trout will be able to feed on the many invertebrates which thrive with this plant.

TABLE 10. Stomach contents of speckled trout, 8.5-12.3 inches long, taken in pond 1, Caledon Club

	May 29-30	Sept. 1
No. of stomachs examined	22	11
Av. vol. of contents in cu. mm.	110	180
Av. no. of Nematoda	0	0
Vegetable matter: *Spirogyra*	–	1
Arachnida: Spiders	+	–
Hydrachnids	+	+
Ephemeroptera: Baetidae	+	9
Odonata: Aeshnidae (imago)	–	17
Plecoptera	+	–
Trichoptera: Limnephilidae	7	–
larval cases	3	–
Heteroptera: Corixidae	+	–
Diptera: Chironomidae	–	72
Terrestrial Diptera	9	–
" Coleoptera	2	–
" Hymenoptera: Bombidae	79	–
Total surface food	90	17
Total submersed food	10	83

Waylington Lake

PHYSIOGRAPHY

Originally, Waylington Lake consisted of two separate bodies of water, lying in a bowl-shaped valley at the head of the Pine River, Dufferin County, Ontario, latitude 44°10′N., longitude 80°13′W. A dam built at the outlet many years ago, has raised the water level several feet, and flooded the land between the two, forming one large lake with a total area of about twelve acres (5 hectares). The maximum depth found in the eastern end was thirteen feet (4 metres), and in the western end twenty-four feet (7.3 metres). Contour lines are very roughly shown on the map in figure 6.

The sides of the valley in which the lake lies are for the most part wooded with cedars and deciduous trees, which extend right to the water's edge. At the eastern end is a small swamp.

AQUATIC VEGETATION

The approximate areas covered by the principal aquatic plants in the lake are indicated in figure 6. In the following list, the species found are in order of decreasing importance:

Chara sp. Covers several times more area than any other plant in the pond. It is the only one which extends into the deepest water.

Hippuris vulgaris. Found sparingly at the western end in patches among the *Chara*, and abundantly in the shallow central area. Late in summer it thrusts its spikes of leaves well above the water's surface.

Ranunculus sp. White water-crowfoot, though found chiefly in shallow water, extended in one place to a depth of nine feet. It was commonest at the western end of the lake.

Nymphaea advena. Grows in colonies, principally along the southern shore.

Radicula Nasturtium-aquaticum. Watercress occurred rarely near the inlet creeks. In the creeks themselves it was the abundant plant.

Phalaris arundinacea. Reed grass grew in a few places along the southern shore.

Equisetum fluviatile. Occurs sparingly along the north shore.

Carex spp. Found along shore.

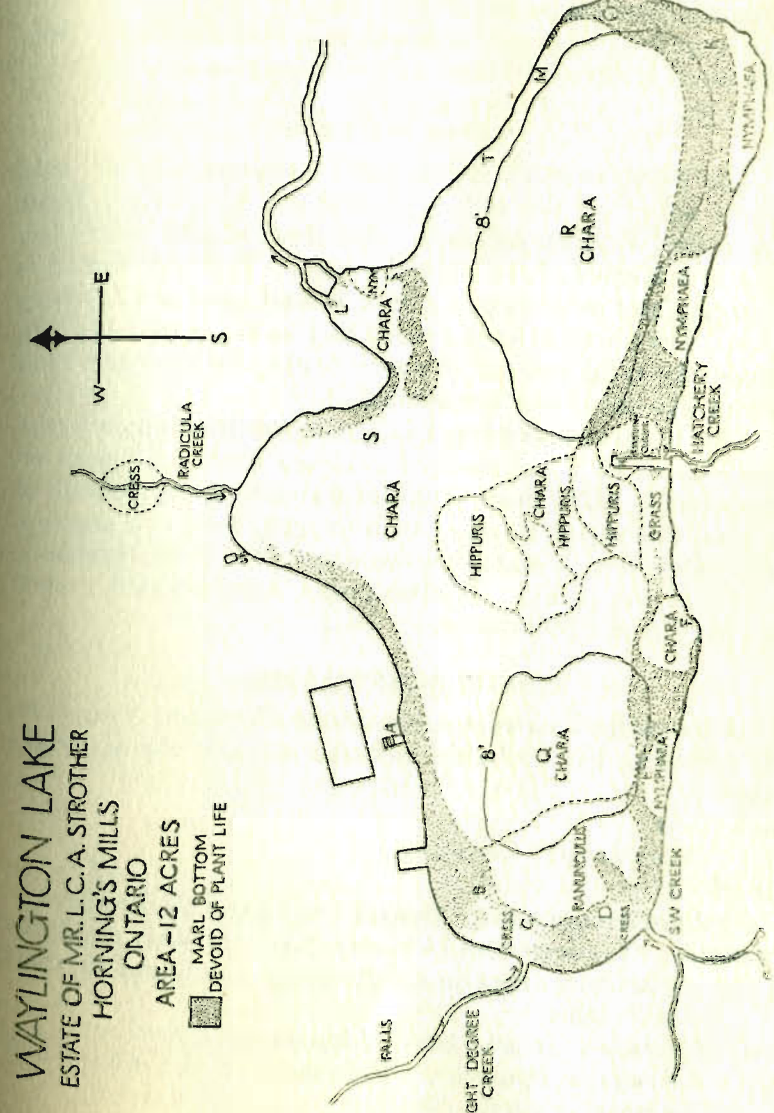

FIGURE 6. Map of Waylington Lake, Horning's Mills, Ontario

Fissidens sp. This and other aquatic mosses grew sparingly on the lime-encrusted logs.

Except for these weedbeds, a large part of the shallow area of the pond is devoid of macroscopic vegetation.

WATER SUPPLY

The pond receives its water from several small, cold streams noted on the map as Hatchery, Southwest, Eight Degree, and Radicula Creeks. All these creeks have their origin in springs not far from the lake. The first named is the largest, and receives water from a small pond and hatchery above. The outlet is from a small bay on the north-east. In summer the total volume of water flowing through the pond is about five cubic feet per second.

The temperature of the inlet creeks in summer varies from 7°C. to 12°C. Chemical analyses made at 5 p.m. on September 8, 1928, show that the water near the bottom of the pond was supersaturated with oxygen, even at a depth of twenty-four feet, presumably because of the photo-synthetic activity of the plants. Hydrogen-ion concentration ranged from pH 7.6 to 7.8.

AQUATIC INVERTEBRATES

A few collections were made among *Chara* and *Nymphaea*. The following list probably includes most of the abundant species:

Turbellaria

Planaria sp. Occasional.

Hirudinea

Haemopis grandis. Found among the *Chara* stems.

Crustacea. Cladocera and Copepoda are probably abundant plankton organisms. *Daphnia* was found in trout stomachs.

Hyalella knickerbockeri. Abundant everywhere.

Gammarus limnaeus. Frequent in the *Chara* and among shore debris.

Ephemeroptera

Blasturus nebulosus. Nymphs occasional.

Odonata

Imagos of Zygoptera were commonly seen; Anisoptera doubtless occur as well.

Trichoptera

Limnephilus sp. Larvae occasional or frequent in shallow water.

Phryganea sp. Taken from a trout stomach.

Heteroptera

Artocorixa atopodonta. Determined by Walley. Rare.

Artocorixa sp. A smaller and commoner species than the last.

Notonecta sp. Rare.

Diptera

Culicoides sp. Occasional.

Chironomidae larvae. Frequent.

Coleoptera

Hydroporus sp. Occasional.

Hydrachnida. Occur.

Pelecypoda

Pisidium spp. Frequent.

Sphaerium sp. Rare or occasional.

Gastropoda

Lymnaea stagnalis. Rare.

Helisoma sp. Rare.

Gyraulus sp. Rare.

Physa sp. Occasional or frequent.

FISH

Cottus sp. One specimen was found in a trout stomach.

Eucalia inconstans. Present in fairly good numbers.

Salvelinus fontinalis. Speckled trout are numerous. The average length of twenty-six specimens examined by the author was about 9.0 inches, the largest was 11.5 inches. The supply is maintained partly by natural spawning in the pond and its inlet creeks, but chiefly by the introduction of fingerlings from the hatchery above. A number of stomachs were examined; their contents are set forth in table 11. Trichoptera larvae, chiefly *Limnephilus*, are important but not predominant; *Physa* also has been met elsewhere. *Gammarus* formed eight per cent. of the volume of food in June, but was absent in September; it did not bulk as large as the smaller but much more numerous *Hyalella*. The presence of plankton organisms in one trout suggests one change which accompanies increase in size and depth of a pond: increase in importance of plankton as compared with bottom fauna.

TABLE 11. Stomach contents of speckled trout from Waylington Lake, 1928

	June 26	Sept. 8-10	Sept. 8
Length of trout in inches	8.0–9.5	8.3–11.0	7.0
No. of stomachs examined	7	14	1
Av. vol. of contents in cu. mm.	1030	460	200
Av. no. of Nematoda	+	0	0
Vegetable matter	+	1	–
Hirudinea	13	–	–
Pelecypoda: *Pisidium*	2	–	–
Gastropoda: *Physa, etc.*	16	13	–
Crustacea: *Gammarus*	8	–	–
Hyalella	13	15	–
Daphnia	–	–	100
Trichoptera: larvae	30	+	–
larval cases	17	4	–
Heteroptera: Corixidae	–	12	–
Diptera: Chironomidae	1	1	–
Coleoptera: *Hydroporus*	+	1	–
Terrestrial Diptera	–	1	–
Terrestrial Hymenoptera	1	1	–
Fish: *Cottus*	–	50	–
Total surface food	1	2	0
Total bottom food	99	98	100

Mulmur Lake

PHYSIOGRAPHY

This beautiful little lake is situated in Dufferin County, Ontario, only a few miles from Waylington. It is in the form of a crescent, surrounded by high hills on the north and west, and blocked off from the valley to the south-east by a gravel moraine (figure 7). Most of the immediate shore line is cov-

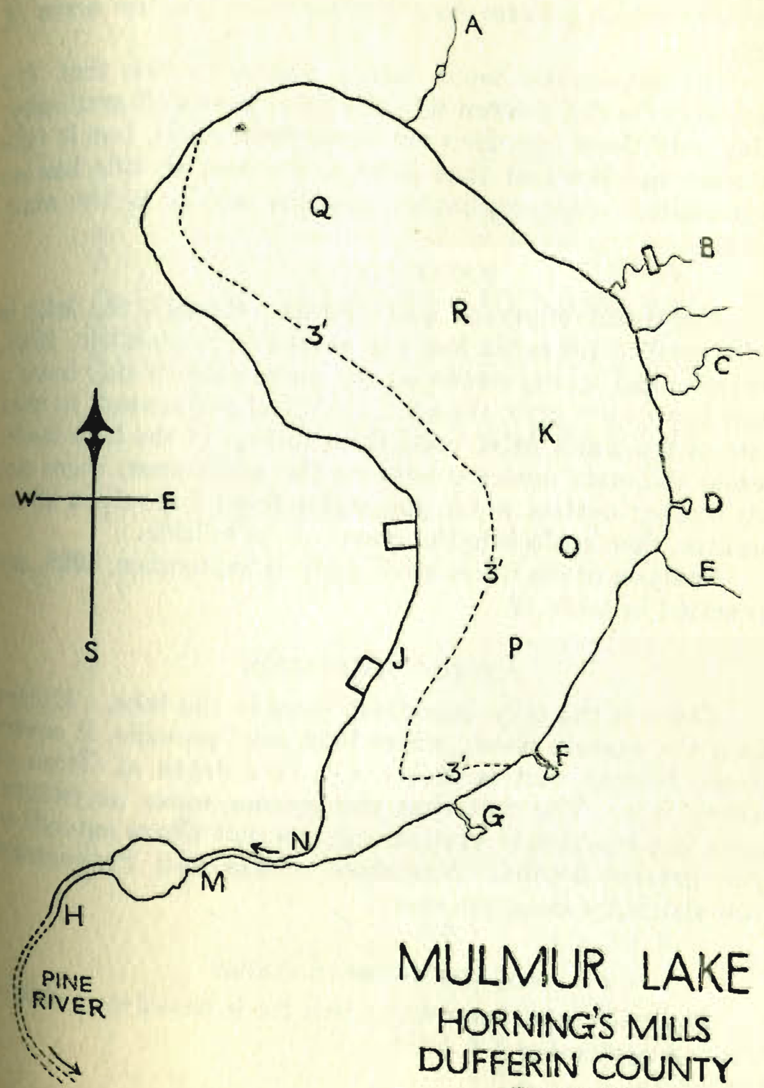

FIGURE 7. Map of Mulmur Lake, Ontario

ered with hardwoods, but fields stand close by, except on the southern side. Its area has been estimated at ten acres (4 hectares).

The maximum depth taken was forty-two feet (13 metres). On the western side the water shoals off gradually, being only three feet deep ten yards from shore, but it falls off more quickly past that point. The eastern side has no such shallow zone; its bottom deepens rapidly to the maximum.

WATER SUPPLY

The total volume of water flowing through the lake is quite small: 1.6 cubic feet per second in September, 1928. Several small spring creeks on the north-eastern side have a total flow of not more than 0.1 cubic feet per second, so that most of the water must come from springs in the lake itself. Beside the main outlet stream on the south-west, there are two smaller outlets where the water flows for only a short distance, then soaks into the gravel of the hillside.

Analyses of the water made early in September, 1928, are presented in table 12.

AQUATIC VEGETATION

Chara is the only important weed in the lake. Except along the western shore, where bare marl prevails, it covers all the bottom that is visible, *i.e.*, to a depth of fifteen or twenty feet. The fact that the bottom water at twenty-seven feet was rich in oxygen suggests that *Chara* extends to even greater depths. *Nymphaea advena* and *Potamogeton* grow sparingly along the shore.

AQUATIC INVERTEBRATES

The collections upon which this list is based were chiefly made on September 5-8, 1928.

Turbellaria

Planaria sp. Occasional.

Oligochaeta

Tubificidae. Occasional.

TABLE 12. Temperature, pH, and oxygen content, Mulmur Lake

Position on map	Description	Date 1928	Time	Temperature C.	Temperature F.	pH.	Dissolved oxygen cc/l	Dissolved oxygen p.p.m.	Dissolved oxygen Per cent. sat.
A	Spring from gravel	Sept. 5	2.00 p.m.	7.3	45	7.4	7.6	10.8	95
A	Below a barrel	"	2.00 "	8.0	46	7.7	8.2	11.7	104
B	At wooden trough	"	1.30 "	8.8	48	7.4	7.0	10.0	92
B	Near mouth of creek	"	1.30 "	9.3	49	7.7	7.9	11.3	104
D	Spring hole	"	3.20 "	8.2	47	7.5	8.3	11.8	106
F	Small outlet creek	"	4.00 "	19.2	67	8.0	8.2	11.7	133
N	Main outlet creek	July 19	3.00 "	23.2	74	...	...	...	...
M	Main outlet creek	Sept. 5	4.40 "	18.5	65	8.2	8.6	12.3	138
H	Same, below pool	"	4.55 "	18.6	66	8.2	8.5	12.2	137
Q	Depth 26 ft.; at bottom	Sept. 6	9.50 a.m.	13.9	57	7.7	8.8	12.6	129
R	Depth 27 ft.; at bottom	"	10.00 "	13.9	57	7.8	8.7	12.5	128
K	Depth 42 ft.; at surface	Sept. 5	5.50 p.m.	16.3	61	8.0	8.5	12.2	125
K	Depth 42 ft.; at bottom	"	5.50 "	13.3	56	...	...	...	...
O	Depth 42 ft.; at bottom	Sept. 6	10.30 a.m.	12.8	55	7.4	4.6	6.6	65
P	Depth 28 ft.; at bottom	"	10.30 "	14.1	57.5	...	...	...	...

Hirudinea

Helobdella stagnalis. Frequent.
Glossiphonia complanata. Occasional.
Haemopis grandis. Rare.
Erpobdella punctata. Occasional.
Nephelopsis obscura. Rare.

Crustacea. Entomostraca were not collected.

Hyalella knickerbockeri. Frequent.
Gammarus limnaeus. Occasional; abundant in a few dredgings.

Ephemeroptera

Callibaetis sp. Rare.
Ecdyurus tripunctata. Rare; among sticks along shore.
E. canadensis. Rare.

Odonata

Ischnura verticalis. Frequent; imagos. 19.vii.28.
Enallagma spp. Frequent.
Argia violacea. Imagos. 19.vii.28.
Lestes sp. Frequent; nymphs very common in some places.
Aeshna umbrosa. Nymphs occasional; imagos. 6.ix.28.
Ae. interrupta interrupta. Imago. 6.ix.28.
Anax junius. Imago. 5.ix.28.
Gomphus sp. Rare.

Neuroptera

Sialis. Frequent.

Trichoptera

Polycentropidae. Rare.
Limnephilus sp. 34 of Dr. Betten's manuscript. Larval cases occasional; imagos. 6.ix.28; determined by Betten.
Phryganeidae. Rare.

Heteroptera

Arctocorixa. Occasional.
Notonecta. Rare.
Gerridae. Rare.

Diptera

Tipula. Rare; several large larvae taken near the outlet.
Culicoides. Occasional.
Chironomidae. Frequent.
Chrysops. Rare.

Coleoptera

Hydroporus. Occasional.
Other Dytiscidae. Rare.
Haliplus. Occasional.
Hydrophilidae. Rare.
Gyrinidae. Rare.

Pelecypoda

Pisidium. Frequent.
Musculium. Occasional.
Sphaerium. Rare.

Gastropoda

Stagnicola? Rare.
Gyraulus. Occasional.
Physella. Occasional; two specimens were determined by Dr. Clench as *P. sayi* Topp.

Discussion:—All collections were made in shallow water. By comparison with other lakes, the fauna of the deep water should consist chiefly of chironomid larvae.

The shallow water fauna bears a very close resemblance to that of the Glen Major Ponds. Distinctive features are the presence of *Gammarus* and *Sialis*, the scarcity of *Callibaetis*, and the abundance of Odonata, particularly of damselflies. The *Limnephilus* imagos, which were emerging in large numbers on September 5-8, are probably of the same species as the larvae common in most of these hard-water lakes.

The bare marl of the western shore was much less productive than the *Chara* beds; it was, however, the favoured home of the alder-fly, *Sialis*.

In a lake of this size and depth, plankton organisms are undoubtedly of first-rate importance. Unfortunately no study of them has been made.

TABLE 13. Stomach contents of speckled trout from Mulmur Lake

	Sept. 6, 1928
Length of trout in inches	5.8–10.0
No. of stomachs examined	15
Av. vol. of contents in cu. mm.	1420
Av. no. of Nematoda	0
Gastropoda: *Physella*	2
Crustacea: *Hyalella*	+
Hydrachnida	+
Aquatic Insecta	
Ephemeroptera	+
Odonata	
Zygoptera—imagos	1
Anisoptera—nymphs	2
Anisoptera—imagos	5
Trichoptera: *Limnephilus* pupae and imagos	63
Heteroptera: Corixidae and Notonectidae	+
Diptera: Chironomidae	+
Coleoptera: Dytiscidae and Gyrinidae	7
Terrestrial Insecta:	
Orthoptera	2
Hemiptera	1
Diptera	1
Coleoptera	2
Hymenoptera	14
Total surface food	70
Total submersed food	30

FISH

Rhinichthys atronasus. Common in shallow water.

Chrosomus erythrogaster. Equally common.

Cottus cognatus. One specimen taken.

Cristivomer namaycush. Apparently introduced into the lake; several large specimens were caught in 1928.

Salvelinus fontinalis. Common; speckled trout occur naturally, and recent fingerlings have been planted as well. Only fifteen stomachs were secured for examination, on September 6, 1928 (table 13). The emerging caddis flies were the principal food of the trout at this time. The large numbers of terrestrial insects indicate that many were feeding

near shore. In spite of their abundance in the lake, damselfly nymphs were not found in the stomachs; *Gammarus* were likewise absent. Adult dragonflies are unusual in trout stomachs, but several specimens of *Aeshna* and *Sympetrum* were found in this lot. No trace was found of plankton, but further study would probably show that it formed some part of the trout food.

Huxtable's Lake

A large earthen dam across the Pine River, in Dufferin County, Ontario, has formed a lake or pond of twenty-five acres (10 hectares) in extent. The maximum depth found was twenty-one feet (6.5 metres); most of the water is more than twelve feet (3.5 metres), but a broad, shallow area is found at the upper end.

Water weeds grow over most of this shallow expanse, the principal species being a narrow-leaved *Potamogeton*, but *P. natans*, *Chara*, and *Nymphaea advena* also occur in some abundance. At greater depths the bottom is apparently bare.

The water supply of the lake is chiefly from the Pine River, which had a volume of flow of thirty cubic feet per second on July 4, 1928, and temperature of 20.8°C. at 4 p.m. In addition a small amount of water is received from cold creeks, and, it is said, from springs in the lake itself. Water taken in the outlet at 5 p.m., July 25, had a temperature of 18.8°C., oxygen content 6.8 cc. per litre (110 per cent. of saturation) and pH 8.2.

The following fish have been taken from the lake: *Cottus cognatus*, *Catostomus commersonii*, *Semotilus atromaculatus*, *Notropis cornutus*, *Salmo irideus*, *Salvelinus fontinalis*. Stomachs of a few trout were examined (table 14). From such evidence as is at hand, it would seem that trout of all sizes over seven inches feed more on fish than on insects, which is the reverse of the condition obtaining in smaller and colder ponds. On the other hand, a plentiful supply of fish food favours the growth of large trout, and specimens twelve to sixteen inches long are taken not infrequently.

TABLE 14. Stomach contents of trout in Huxtable's Pond

	Speckled trout	Speckled trout	Rainbow trout
No. of trout stomachs examined	6	6	1
Length in inches	7.5–8.0	11.5–16.0	12.5
Av. vol. of contents in cu. mm	490	5000	2700
Av. no. of Nematoda	5	?	0
Vegetable matter	+	1	+
Ephemeroptera	1	–	–
Trichoptera	–	+	–
Heteroptera: Corixidae	1	+	–
Diptera: Chironomidae	3	+	1
Coleoptera	7	–	+
Fish: *Cottus*	25	41	–
Semotilus	–	55	–
Unidentified	60	3	90
Trash	–	–	8
Total surface food	0	+	+
Total submersed food	100	100	100

Discussion of Hard-water Lakes

There are a number of features common to most of the ponds and lakes just described, which may briefly be enumerated:

- Small size, and proportionately large area of shallow water.
- Cold water, with much calcium carbonate in solution, rich in oxygen, coming from springs or spring-fed creeks.
- Presence of *Chara* in large quantities on the bottom.
- Abundance of typical invertebrates such as *Physella*, *Callibaetis*, *Limnephilus*, *Artocorixa*, and *Hydroporus*.
- Presence of *Cottus*, though not usually in abundance.
- Abundance of speckled trout, and scarcity of other fish.

In any particular pond, each of these features may depart in greater or lesser degree from the typical condition, and some variations are to be correlated:

As the water becomes warmer, there is a tendency toward a greater diversity of aquatic vegetation until *Chara* may occupy a subordinate position. Various species of *Potomogeton*, *Ranunculus circonatus*? *Hippuris vulgaris*, and *Nymphaea advena* are the principal substitutes. The presence of fish other than speckled trout in greater numbers and variety is also to be associated with higher temperatures. Either *Cottus cognatus* or *C. bairdii* was present in every lake examined; *Eucalia inconstans* was found in most; *Rhinichthys atronasus* and *Chrosomus erythrogaster* were common along the warm borders of Mulmur Lake; *Pimephales promelas* was the principal minnow of pond 2, Caledon Club. *Catostomus commersonii* was found in one cold pond and was probably kept out of the others by geographical rather than ecological barriers. It regularly occurs in warm ponds, along with *Semotilus atromaculatus*, *Notropis cornutus*, and other minnows, and in such water trout are much less common. When really high temperatures prevail, predaceous fish such as *Esox lucius* or *Micropterus dolomieu* take the place of the trout.

These various fish play rather different rôles in the ecology of the lake. The sculpins, sticklebacks, and smaller minnows are apparently not important. Information on their food habits is lacking. They are occasionally eaten by the trout, but not to as great an extent as in certain streams, for example the Mad River. The large minnow, *Semotilus atromaculatus*, was taken by the big trout in Huxtable's Lake, much as it is in the northern soft-water lakes. The presence of suckers, *Catostomus commersonii*, in a small pond is apparently inimical to the growth of *Chara* and other weeds; hence their presence greatly reduces the supply of food for other fish.

Although definite data are lacking, increase in area and depth of cold lakes is probably accompanied by an increasing importance of plankton as compared with bottom fauna. The presence of *Daphnia* in trout from Waylington Lake is a suggestion of this change. Really large lakes of this type have not been studied in Ontario, but the studies of western lakes, reviewed above, indicate that the trout turn to plankton to an increasing extent as the rich life of the shoal water becomes relatively less important.

SUMMARY

Size, temperature, and lime content of the water appear to be the factors most fundamental in classifying lakes and ponds of Ontario as habitats for the speckled trout (*Salvelinus fontinalis*).

In very large lakes, speckled trout occupy a subordinate position, being much less common than the lake trout (*Cristivomer namaycush*). The former attain to a large size, and are chiefly piscivorous.

In soft-water lakes of the Pre-Cambrian shield, speckled trout are frequently abundant, sometimes in association with the lake trout, more often alone. In the case of the two examples studied, they were able to live in only a restricted part of the lake, where oxygen, in August, showed a peculiar and unexplained vertical distribution, and was sufficient for respiration at some depth. In such lakes minnows were their chief food, though plankton was frequently taken, and insects were not neglected.

The cold hard-water lakes and ponds, which lie on the calcareous sediments of southern Ontario, are of quite a different sort. They are usually small and support an abundant growth of aquatic plants, among which *Chara* is outstanding. Their trout are smaller in size than those of either preceding class, and feed on the rich invertebrate fauna of the shallow borders. Other fish are scarce and of little interest to the trout.

Warmer hard-water lakes are more varied in type. They are usually expansions of fairly large streams, and hence their biota is not dissimilar to the slow stretches of larger rivers. Turbidity of the water, the presence of suckers, or some other factor prevents the even growth of aquatic plants found in the preceding type, so that a large part of the bottom is bare. Speckled trout occur only in the cooler of these, and there not in large numbers; but, being piscivorous, their size more nearly approaches that of the trout in the acid lakes.

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