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AN ECOLOGICAL STUDY OF THE MAYFLY *CHIROTENETES*

BY

WILBERT AMIE CLEMENS, M.A.

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AN ECOLOGICAL STUDY OF THE MAY-FLY *CHIROTENETES*

Introduction

Notwithstanding the numerous investigations which have been made upon the life phases of various *Ephemeridae*, our knowledge concerning the physical factors and their co-operation in relation to individual species is singularly small. It was for this reason that the writer, on the suggestion of Professor James G. Needham, undertook and carried out during the years 1913-1915 the detailed study of a single species in a very restricted area, the results of which are described below. The species chosen for study was *Chirotenetes albomanicatus* Needham, the nymph of which is common in and characteristic of the riffles and rapids of the streams of the Cayuga basin. The various stages of the insect are described by Needham ('05). The description is illustrated by two plates and is accompanied by some data on the habits of the nymph and subimago and the food of the nymph. Morgan ('11) gives some brief observations made on this species in Fall Creek, and again ('13) gives further biological data with illustrations of gills and egg.

The writer is greatly indebted to Professor Needham for invaluable advice and for many helpful suggestions freely given during the course of the investigation.

The Nymph

General Habitat.—The nymph of *Chirotenetes albomanicatus* inhabits all the larger streams in the vicinity of Ithaca, New York, but this study has been mainly confined to one stream, Cascadilla Creek. (Contour map, Fig. 1.) It was chosen chiefly because its smaller size made it much more accessible for observation and experimental work. The creek has an approximate length of eight miles. It arises in an upland alder swamp and flows in a westerly direction, emptying into Cayuga Lake Inlet. The stream may be divided into three regions: (1) an upland portion approximately six miles in length where the stream occupies a preglacial drift-filled valley; (2) a gorge portion one mile in length where the stream flows through a gorge which has been cut back in the Devonian shale from the edge of Cayuga valley; (3) a flats portion one mile in length where the stream flows through the sediment deposited at the head of Cayuga Lake by the tributary streams. At its source the stream winds among the alders, flowing over a bed of dark brown vegetable débris, and then, emerging into meadow land, it takes a winding course in the open, its banks bordered with shrubs and scattered trees. The average width is 18 feet. The descent averages 36 feet per mile, producing a moderate current over a bed of gravel and stones, with accumulations of stones and rubble* forming numerous riffles and rapids. Tributaries arising from springs in the surrounding hills increase the volume of the water. The nymphs of *Chirotenetes* occur very abundantly in the riffles and rapids of this upland portion. The creek has a much swifter current in the gorge, spreading out in broad sheets over the smooth rock bottom and tumbling over ledges. *Chirotenetes* nymphs are found under stones and rubble and occasionally on the rock bottom. After descending into Cayuga valley the stream takes a straight north-westerly course, passing over a bed formed of materials brought down from the heights. These materials form an intergrading series. The larger stones and pieces of rock occur at the base of the hill, and then follow in succession smaller stones and rubble, gravel, sand, silt. For the last 250 yards of its course the stream broadens out and becomes deep and sluggish because of the backing up of the water from the lake. The nymphs of *Chirotenetes* are abundant at the base of the hill but gradually decrease in

*The term rubble is used to designate the flat fragments of shale and limestone as distinguished from the stones with rounded edges tending toward a spherical form.

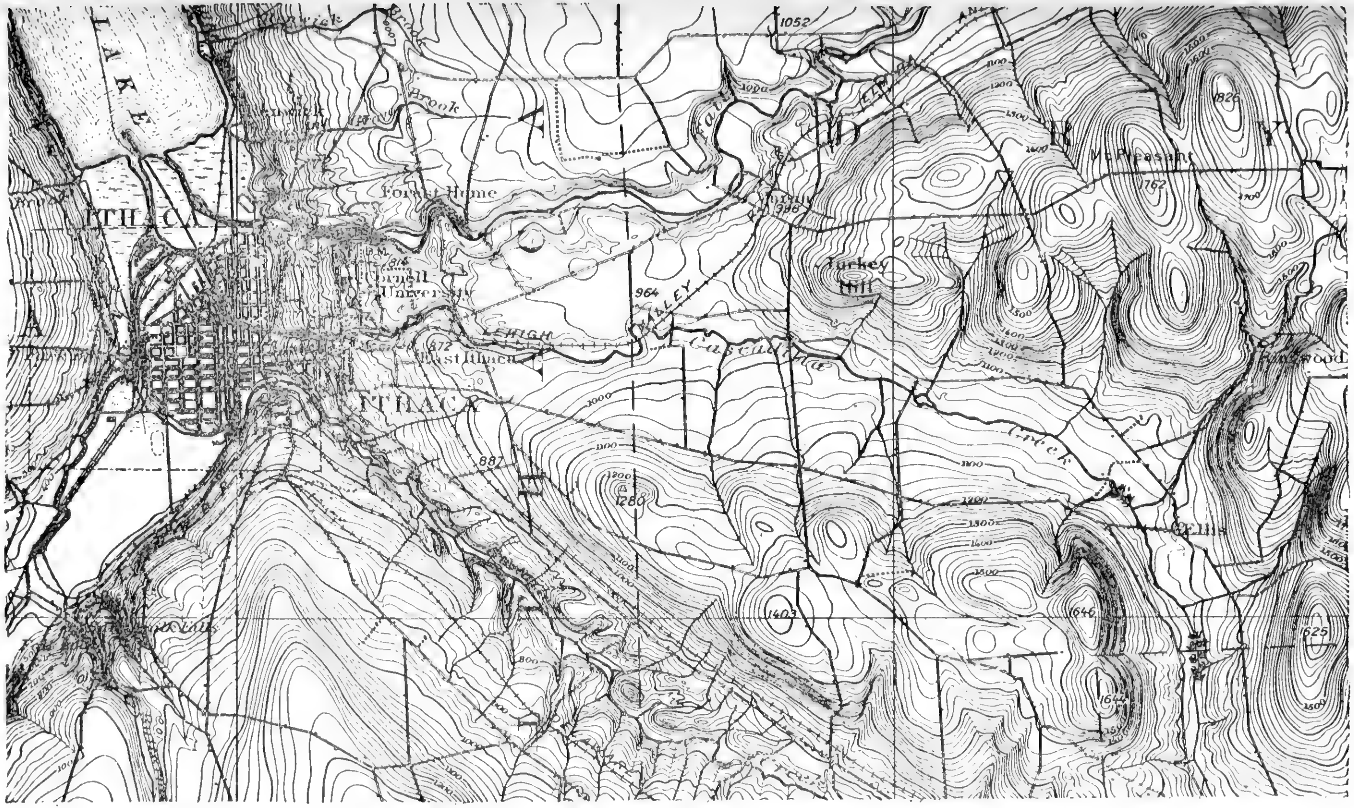


Fig. 1.—Contour map from topographic sheets of the United States Geological Survey.

CHEMICAL ANALYSES OF THE WATER OF CASCADILLA CREEK

All results in parts per million

Date	Temp.	Oxygen	Free CO_2	Normal Car-bonates	Biscar-bonates	Free NH_3	Alb. NH_3	Oxygen Con-sumed	Nit-rites	Nit-rates	Chlo-rine	Alka-linity	Phos-phates	Sul-phates	Iron
1914															
Dec. 1	10°	9.4	3.0	0					.001			108			
" 8	3°	12.1	2.0	0		.01	.08		.006		2.8	119			
" 15	3°	12.1	1.5	0						.3		120			
" 22	3°	12.2	2.0	0	53.4										
1915															
Jan. 12	3°	12.5	.0	0	29.9	.07	.021	4.05	.001		3.0	64			
" 19	0°	12.4	2.0	0	15.2			6.6		.5	2.5	33			
Feb. 16			3.0	0	16.6			1.0				36			
" 23	1.7°	11.6	2.5	0	22.5	.035	.125	3.95				46			
Mar. 5	0°	13.0	2.0	0	17.6										
" 19	0°	13.6	2.5	0	37.7	.01	.047	1.1		.5	2.5	75			
Apr. 13	5°	12.8	2.0	0	21.0	.011	.142	1.45	.001	.1	3.5	60			
" 20	4°	12.7										80	trace	31.8	
May 12	14°	9.7	1.0	0	40.6	.037	.118	1.9	.001	trace	2.5	71			
" 18	8°	11.2	.7	0	38.7							96		34.8	
June 17	22°	8.0	1.5	0	52.9	.058	.101	4.25		.025	2.0	116	trace	33.3	.42
July 14	20.5°	8.7	.0	7.8	32.3			2.8			1.5	74			
" 15	20.5°	8.7	.0	9.8	31.8										
" 21	17°	9.8	.0	9.8	44.6							120			
" 30	23.2°	10.0	.0	13.7	48.5						3.0				
Aug. 10	19°	8.8	.0	15.6	38.7	.04	.04	3.8		.1	2.0	103			

numbers toward the mouth, disappearing when the slack water is reached.

Chemical Analyses of the Water.—In order to obtain definite knowledge concerning the medium in which the nymphs live, chemical analyses were made at various times from December 1, 1914, to August 10, 1915. The results are given in tabular form. Comparison with analyses of the water of the neighbouring Fall Creek shows a very close correspondence. The amount of pollution is not excessive as indicated by the nitrogen determinations as free and albuminoid ammonia, nitrites, nitrates, oxygen consumed, chlorine and alkalinity. The oxygen content is high throughout the year,

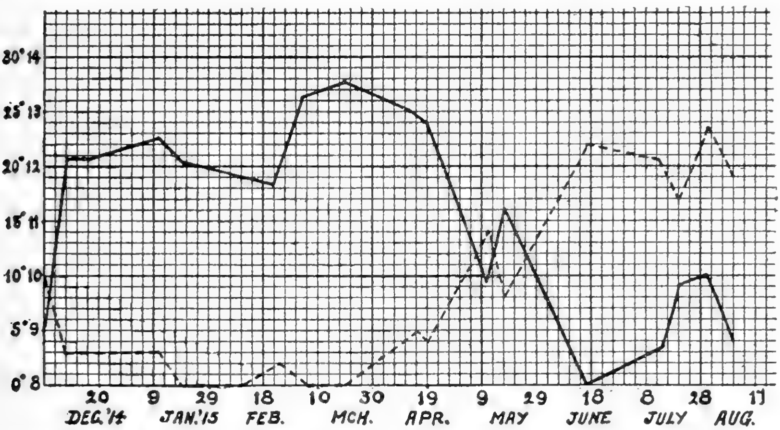


Fig. 2.—Relation of the oxygen content to temperatures of Cascadilla Creek.
——— = oxygen in parts per million at 760 mm. pressure.
- - - - - - = temperature.

doubtless as a result of the turbulent nature of the creek. Figure 5 shows the amounts of oxygen present reduced to 760 mm. pressure as compared with the amounts of saturation at the same temperatures and pressures. The carbon dioxide content is low, probably for the same reason that the oxygen content is high.

Temperatures.—Records of the temperatures of the water in Cascadilla Creek were taken almost daily for over a year for the purpose of obtaining information regarding the fluctuation in temperature from day to day, the maximum summer temperature, the length of the zero period, and the relation between the temperature and the oxygen content in a swiftly flowing stream. The records show that the water temperature fluctuates with the air temperature but never reaches the extremes of the latter. The highest temperature recorded during this period was 28° C. on June 25, 1914. The maximum air temperature on this day, as recorded by the Weather Bureau branch of the United States Department of Agriculture at Ithaca, New York, was 29.9° C. and the day before 32.2° C. The temperature remained at 0° C. from November 8, 1914, to March 28, 1915, except for a rise to 3° C. during four days in February, 1915. The relation of the oxygen content during the year to the temperature of the water is shown in Fig. 2.

Relation to Materials Forming the Creek Bed.—Field observations show that the nymphs of *Chirotenetes* occur in greatest numbers in those parts of the stream where there are deposits of rubble and stones in moderate to swift current. They occur most abundantly in the upland portion of the creek and so numerous at times are they in places that as many as sixteen nymphs of various sizes have been found beneath a stone of 3 x 4 inches, which would mean a nymph to each three-quarters of a square inch. Forty nymphs have been found beneath a piece of rock about one foot square. Frequently a flat shelving piece of rock may be lifted slightly and the nymphs observed clinging to the under surface in company with other may-fly nymphs such as *Epeorus*, *Heptagenia*, *Ecdyurus* and *Baetis*, stonefly nymphs, caddis worms and the water-penny. Needham ('05) reports some observations which he made in Fall Creek gorge. "I have observed the nymph, especially in those places where the creek bed is flat shelving rock over which the water streams in a thin sheet. In such places the flat, rocky floor of the stream is covered with a thin filmy growth of algae, with abundant nets of the caddis seine-maker, *Hydropsyche;* and the broken edges of the floor ledges are fringed with black masses of blackfly larvae, *Simulium*. *Simulium* and *Hydro-*

psyche are fixed in their places, but *Chirotenetes* wanders about freely over the ledges, clinging securely even in the swiftest water, keeping of necessity head up stream, moving by short quick dashes effected by sharp strokes of its powerful tail fin and gill covers, moved synchronously. It is found in the stiller pools at the sides of the current, in which dwell other may-flies of the genera *Caenis* and *Baetis*; and also among the rocks in the current under which cling other nymphs of *Heptagenia*, *Blasturus* and *Choroterpes*."

Field observations appeared to indicate that the lower sides of stones and rubble contribute the preferred habitat of *Chirotenetes*. In order to test the matter, however, certain experiments were devised. These were based on the assumption that the nymphs would not remain in a situation which did not suit them if a more suitable situation were available. A wooden trough three feet long, one foot wide and ten inches deep was constructed and provided with wire netting at both ends, so as to allow water to flow through freely but preventing anything in the trough from escaping. In the upper end of the trough was put a flat stone a foot square. The small crevices between the stone and the sides of the trough were filled in with fine gravel. Behind the stone for the remaining length of the trough course gravel was placed for a depth just equal to the thickness of the stone. In the middle of the trough there was placed a pile of rubble each piece about 3½ inches square. At the lower end was put a pile of small stones, each stone about 1½ inches in diameter. Just enough space was left between these groups of materials to allow a wire screen to be pushed down between them. The trough was then placed in the stream and arranged so that there was a current through the trough of 1 to 2 $^{3}/_{10}$ feet per second according to the depth of the water. Then twenty-four almost mature *Chirotenetes* nymphs were put in the trough at the lower end. At the end of twenty-four hours the screens were carefully put in position between the groups of materials, the trough taken from the stream, the materials carefully removed and the nymphs in each section counted. Nineteen were found among the small stones, four in the rubble, and none on the rock. A series of such experiments was tried; the arrangement and results of a typical set are given as follows:

1		2		3	
Rock 0		Rock 0		Rubble 5	29.4%
Rubble 4	17.4%	Stones 1	4.8%	Stones 12	70.6%
Stones 19	82.6%	Rubble 20	95.2%	Rock 0	

4		5		6	
Stones 3	23%	Stones 0		Rubble 0	
Rubble 10	77%	Rock 0		Rock 0	
Rock 0		Rubble 16	100%	Stones 15	100%

In all cases the nymphs were put into the trough at the lower end. In conducting the fifth test a blocking of the screen at the lower end of the trough one day caused an almost complete cessation of current, and when the trough was examined it was found that all the nymphs except one had migrated to the upper end, close to the screen where there was a slight movement of water. This appeared to indicate that current was a more important factor than material in the selection of a habitat. The results of these experiments indicate that the nymphs have a decided aversion to open rock and a slight preference for rubble as against small stones.

Relation to Light.—It was thought that light might be an important factor in the choice of habitat. Wodsedalek ('11) has shown by experiments that the nymphs of *Heptagenia interpunctata* Say are to a strong degree negatively phototactic. An experiment was devised to determine the reactions of *Chirotenetes* nymphs to light. A trough $51 \times 4 \times 3\frac{1}{8}$ inches, with wire screens at the ends, was divided into three equal compartments by means of cross pieces reaching from the upper edge to within an inch of the bottom. A similar cross piece was put at the lower end against the screen. At the upper end was a small intake area where the water entered before flowing into the three remaining compartments. The trough was then put out in the stream under a small ledge where a current of water could easily be sent through the trough and where conditions of light were normal. The amount of water was then regulated so that the surface just reached the lower edges of the partitions. The bottom of the trough was rough, offering a foothold for the nymphs. Thirteen *Chirotenetes* nymphs were put in the lower compartment over which a close-fitting cover was immediately placed. At the end of two and one-half hours not a single nymph had left the compartment. Then the cover was taken off and placed over the upper compartment. Immediately the nymphs began to migrate up the trough. In four minutes all but four had disappeared into the upper compartment and seven minutes later the remaining four had disappeared also. Not one ventured beyond into the small open intake area. After waiting ten minutes the cover was removed and all the nymphs were driven back into the lower compartment again and the cover replaced. At the end of ten minutes all the nymphs were still in this part. Then the cover was removed and quickly placed over the middle compartment. At once the nymphs began to migrate and in two minutes all

Fig. 3. Diagram of trough used in experiments to determine relation of nymphs to light factor.

except one had disappeared into the darkened chamber, the last one following in forty-five seconds. The trough was left in this condition for seventeen hours and at the end of this time every nymph except one still remained in the middle darkened compartment. When the cover was removed the nymphs scattered. The cover was placed over the lower compartment again and when the trough was examined six and a half hours later all the nymphs were down in the covered area. These experiments were repeated many times. The nymphs thus show very strong negatively phototactic tendencies.

The trough used in the experiment for habitat preference was then used to determine whether or not the nymphs would remain on the bottom of the trough if the empty area were darkened, in preference to moving where the stones and rubble were. Since the nymphs appeared to show no very decided preference as between stones and pieces of rock, the trough was divided into two areas only, one with stones and pieces of rock, the other without any materials, leaving the rough bottom of the trough as a surface to which the nymphs might cling. The empty portion of the trough was closely covered and the trough put out in the current, with the stones and rubble up stream. Eighteen *Chirotenetes* nymphs were put into the lower darkened compartment. When the trough was examined twenty-four hours later, all the nymphs were found in the upper area. The trough was then reversed and the nymphs put in at the lower end among the stones and rubble. Twenty-four hours later all the nymphs were still in this area.

Judging from the results of these experiments and field observations it appears that current is the more important factor in determining the habitat of the nymph with light and materials as secondary but closely linked factors.

Relation to Current.—Since the nymphs of *Chirotenetes* are current dwellers it appeared to be desirable to obtain more accurate data in regard to the velocity of the water in which the nymphs live. For use in a stream such as Cascadilla Creek where the water is turbulent, swift, and comparatively shallow, it was necessary to have some instrument for current measurement which could be used in narrow places and give measurements at slight differences in vertical and horizontal ranges. Upon consultation with Professor E. W. Schoder of the Department of Hydraulics, Cornell University, a Pitot tube was suggested and an apparatus as shown in Figure 4 was constructed. This consists of two copper tubes 24 inches long and $^{3}/_{26}$ inch in diameter, fastened together and having the lower ends bent at right angles so that the openings extend in opposite directions. The copper tubes are connected by means of rubber tubing sixty inches in length and a quarter inch in diameter to two glass tubes each twenty-four inches in length and $^{15}/_{26}$ inch in diameter. The glass tubes are connected at the top and may be opened to the air by means of a stopcock. The glass tubes are attached to a board and between them is placed a scale. This instrument was rated in the canal of the Hydraulic Laboratory of Cornell University.

With the Pitot tube a large number of measurements were made in Cascadilla Creek. The first measurement taken was in the middle of a small stream twenty-two inches wide and five inches deep flowing in a channel in the rock in the gorge. It was found that near the surface there was a velocity of 1.7 feet per second, while on the bottom the velocity was 1.0 foot per second. A stone with dimensions of about 12×10×2½ inches was placed in the middle of the channel. Midway between the surface of the stone and the surface of the water the velocity was 1.9 feet per second. On the surface of the stone the velocity was 1.5 feet per second; three-quarters of an inch behind the stone and one inch above the bottom there was no perceptible current; on the stream bottom behind the stone there was a slight current of not over 0.5 foot per second. A measurement in swifter water

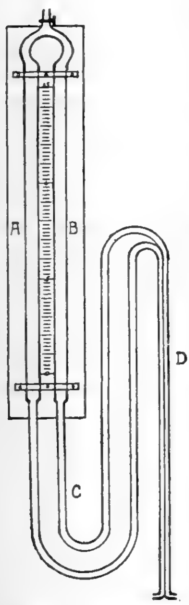
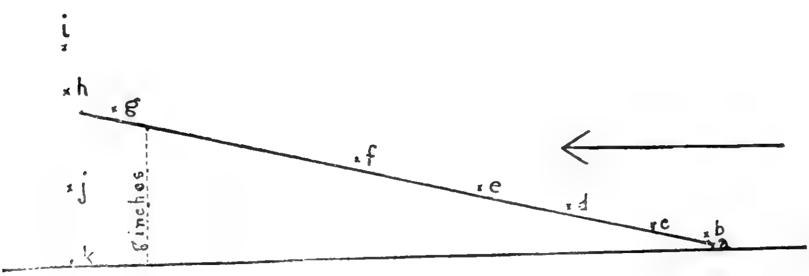


Fig. 4.—Diagram of Pitot-tube. A and B= glass tubes of gage with scale between them. C=rubber tubing. D =copper tubes.

showed a velocity near the surface of 4.3 feet per second while on the bottom only 2.1 feet per second. Many measurements were taken round stones in the creek, particularly round shelving stones, and a few results are here given.

At	a	velocity	1.6	to	2.1	feet	per	second.	
"	b	"	2.0	"	2.6	"	"	"	
"	c	"	very low and indications of slight eddy.						

At	a	velocity	2.9	feet	per	second.
"	b	"	2.6	"	"	"
"	c	"	3.6	"	"	"
"	d	"	.0	"	"	"

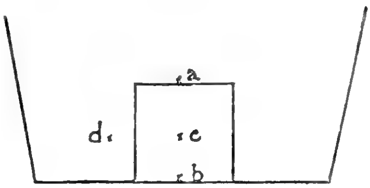


Size of stone = 12 × 22 inches.

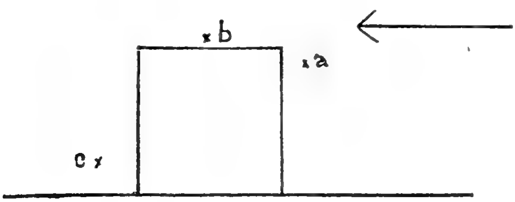
At	a	velocity	1.0	to	1.5	foot	per	second.
"	b	"	3.0	"	3.5	"	"	"
"	c	"	2.0			"	"	"
"	d	"	2.1			"	"	"
"	e	"	2.3			"	"	"

At **f** velocity 2.8 foot per second.
" **g** " 2.9 " " "
" **h** " 3.7 " " "
" **i** " 4.6 " " "
" **j** " 1.0 " " "
" **k** " too small to be measured with the Pitot tube.

In a channel 7½ inches deep and three feet wide, the bottom velocity was 1.5 feet per second; close to the surface the velocity was 2.5 feet per second. A stone almost cubical in form was put in this channel.



At **a** on top of stone velocity 2.9 ft. per second.
" **b** behind stone on bottom velocity 0.5 ft. per second.
" **c** behind stone 2½ inches above bottom velocity .0 ft. per second.
" **d** at side of stone velocity 2.8 to 3.1 ft. per second.



At **a** velocity 2.9 ft. per second.
" **b** " 3.0 to 3.4 ft. per second.
" **c** " 1.5 ft. per second to a reverse of 2.0 feet per second.

There was a strong eddy behind this stone at times and the direction could be determined by turning the copper tubes.

Numerous measurements taken round stones and rubble in the rapids and riffles of the stream have shown that nearly all are so placed that a current of greater or less velocity flows beneath them. It is in this diminished current underneath the stones and rubble that the nymphs of *Chirotenetes* live. Many of the large shelving pieces of rock have a current underneath at one point and no current at another point. The distribution of seine-making caddis worms underneath a stone gives a very good indication as to the presence or absence of a current.

Measurements were taken on July 1, 1915, over the smooth flat rock in the gorge where the water spreads out in a broad sheet and where blackfly larvae and seine-making caddis worms were very abundant. Two such measurements are typical.

Water Three Inches Deep

Close to surface – –	5.1	foot per second.
Bottom – – – –	3.7	" " "

Water Four Inches Deep

Close to surface – –	3.4	foot per second.
Midway to bottom – –	3.0	" " "
Bottom – – – –	2.0	" " "

At various times of high water in the creek measurements of the vertical distributions of velocities were taken. The results of three measurements are as follows:

Inches below surface		Velocity ft. per sec.		Velocity ft. per sec.		Velocity ft. per sec.	
2		4.5		4.5		3.9	
3		4.2		4.4		3.7	
4		4.0		4.3		3.6	
5		3.8		4.1		3.3	
6		3.7		3.8		3.0	
7				3.3		2.9	
8		3.7		3.1		2.8	
9				3.0			
10		3.4		2.9		2.7	
11							
12		3.2		2.7		2.6	
13							
14		3.0		2.4		2.5	
15		2.9				2.2	
16		2.2		2.2		1.7	Bottom
17		1.7	Bottom	1.7	Bottom		

On July 13, 1915, the smooth rock of the floor of the stream in the gorge was covered with a thin film of diatomaceous ooze, of *Navicula* and *Synedra* chiefly, just enough to make the rocks very slippery under foot. The water over the rock had a depth of one to two inches. The Pitot tube was placed on the bottom in the centre of an area of diatomaceous ooze. The velocity was 2.0 feet per second. The ooze was then cleaned off the rock over a large area and the tube placed in exactly the same position as for the first measurement and a velocity of 2.3 feet per second was obtained. There was thus a decrease in velocity of 13 per cent. due to the ooze. Numerous other measurements showed an equal or slightly smaller decrease. On rocks with a fine coating of algal growth and silt, measurements showed losses of as much as thirty per cent.

Experiments were then conducted to determine in how swift a current the nymph of *Chirotenetes* could maintain itself. A wooden trough fifty-one inches long, four inches wide, and three and one-eighth inches deep was placed at the edge of a small waterfall so that water would flow through the trough at a depth of about two inches and arranged so that by raising or lowering the lower end the velocity of the water could be varied. The bottom of the trough was a rough unplaned board which supplied the nymphs with a foothold. Three almost mature *Chirotenetes* nymphs averaging 12 mm. in length were put in the trough about a third of the distance from the lower end where the velocity on the bottom was 1.4 feet per second. The velocity was gradually increased until all the nymphs let go their hold and the velocity of the water then measured. The greatest velocity which these nymphs could withstand was one where the velocity on the bottom of the trough was 4.3 feet per second. With three nymphs 9 to 10 mm. in length it was found that these could maintain their hold until a velocity of 4.8 feet per second was reached.

A series of experiments was then carried out in order to observe the actions of the nymphs of *Chirotenetes* more closely in currents of various velocities and to compare their actions with those of the larvae and nymphs of other insects inhabiting swift water. The procedure was as follows. The trough was arranged with a slight current and the forms to be experimented with were placed in the trough about a third of the distance from the lower end. The current was then increased, and the forms were observed and notes made as to their actions. The velocity of the water was then measured on the bottom in the middle of the trough and just off the bottom. The *Chirotenetes* nymphs used were of almost mature form and fresh specimens were taken frequently so that the results might not be vitiated by fatigue.

Exp. 1. Bottom velocity .4 to .8 feet per second.
Off bottom – 1.0 " 1.2 " " "
Chirotenetes nymphs able to swim and crawl rapidly.

Exp. 2. Bottom velocity .9 to 1.0 feet per second.
Off bottom 1.2 " 1.4 " " "
Chirotenetes nymphs able to crawl but barely able to hold their own against the current in swimming.

Exp. 3. Bottom velocity 1.4 to 1.8 feet per second.
Off bottom 2.2 " 2.4 " " "
Chirotenetes nymphs able to crawl but carried back at once by the current when loosened from foothold.

Exp. 4. Bottom velocity 1.0 to 1.9 feet per second.
Off bottom 2.1 " 2.8 " " "
Chirotenetes nymphs still able to crawl rapidly.

Exp. 5. Bottom velocity 2.2 to 2.4 feet per second.
Off bottom 2.9 " 3.0 " " "
Chirotenetes nymphs able to crawl slowly.

Exp. 6. Bottom velocity 2.8 to 3.6 feet per second.
Off bottom 4.3 " " "
Chirotenetes nymphs able to crawl slowly.

Epeorus and *Heptagenia* may-fly nymphs, a water-penny, a large stone-fly nymph and a black-fly larva were all able to maintain their hold and move about. The large stone-fly walked up against the current with apparent ease.

Exp. 7. Bottom velocity 5.5 to 5.7 feet per second.

May-fly nymphs (*Epeorus*, *Heptagenia* and *Chirotenetes*), a small stone-fly nymph, a water-penny, a seine-making caddis worm, a black-fly larva and a fish-fly larva (*Chauliodes*) were put in the trough and the velocity gradually increased until the stated amount obtained. The stone-fly nymph walked up against the current with apparent ease; *Epeorus* clung securely but remained quiet; the black-fly larva maintained its hold but curled up and lay flat on bottom; the water-penny moved slowly backward; all the others lost their holds before this velocity was reached and did so in this order—*Chirotenetes*, *Heptagenia*, fish-fly larva, caddis worm.

The results of these experiments show that the nymphs of *Chirotenetes* clinging to the under surface of stones escape the main force of the current. The water in such places is moving very much less rapidly than nearer the surface, but it still brings constant and fresh supplies of food and oxygen to the nymph which may wander about in comparative security from many of the dangers which necessarily accompany life in swift water. When the nymph wanders out on the flat rock bed of the stream, it still is in a much reduced current, especially where the rock is covered with diatomaceous ooze or other algal growths. The results also show that the nymph is able to live in rather swift water but that it is scarcely so well equipped for a swift-water habitat as some of its associates with limpet-like forms of body. Nevertheless the nymph of *Chirotenetes* does possess a form of body adapted to life in flowing water. The hard smooth chitinous covering reduces the friction of the water particles to a minimum. The head is well rounded. The thorax gradually widens and is followed by a depressed abdomen which condition tends toward a limpet or Heptagenine form. The following experiments were devised to determine the mechanical or adaptive value of the *Chirotenetes* form for life in running water. A mass of grafting wax weighing 184 grams was moulded into the shape of a cone, the base of which was 5.7 cm. in diameter and the perpendicular 8.25 cm. A fine wire was put through the cone from the apex to the centre of the base. This wire was fastened to a small metal bar in the middle of the cone to prevent it from pulling out. The cone was attached to a 50-gram spring balance by means of a fine wire 33 cm. in length. When placed in a current of 1.65 feet per second the cone sank about 3 cm. below the surface of the water, and with the base upstream exerted a pull of 28 grams. The balance was held nearly horizontal and as close to the surface of the water as possible. There was considerable fluctuation in the amount of pull on the balance as a result of the unevenness of the current and probably to some extent to the imperfect form of the cone. However, it was found that the indicator of the balance remained at a certain point for a greater part of the time and also that this point was approximately the average of the highest and lowest points reached by the indicator. With the apex up stream the pull exerted by the cone, as nearly as could be observed, was 50 grams. The wax was then moulded into the form of a fish of the sunfish type and the pull exerted was 15 grams. A form of the trout type gave a pull of 6 grams with head up stream and 10 grams with tail up stream. A model of a *Chirotenetes* nymph gave a pull of 9 grams with head up stream and 16 grams with head down stream. In all these experiments the total amount of wax was used.

It was found that the kind of edge fashioned at the base of the cone was of great significance. For example in a current of 1.2 feet per second a cone with a sharp edge to the base exerted a pull of 40 grams, whereas with the edges well rounded the pull was decreased to 10 grams.

Another series of measurements in a current 1.5 feet per second gave the following results. A cone with a base 7 cm. in diameter with a sharp edge and a perpendicular of 11 cm.

gave a pull of 50 grams with the base against the current and a pull of 25 grams with the apex to the current. A cylinder 8.5 cm. in length and 5 cm. in diameter gave a pull of 18 grams. With one end pointed and directed toward the current, the pull was 6 grams, while with the blunt end to the current the pull was 17 grams. With both ends pointed forming a spindle the pull was 5 grams. A fish model and a *Chirotenetes* model each gave a pull of approximately 6 grams.

Comparison of the amounts of pull exerted by the various models is open to the objection that the area of greatest cross section was not kept constant throughout. Nevertheless the results demonstrate in a rough manner that the nymph of *Chirotenetes* possesses a remarkably efficient form of body. This explains in part how it is that *Chirotenetes* nymphs are found in association with the flattened limpet-like forms of the stream.

Food.—May-flies are herbivores. They feed almost exclusively upon algae, from the minute diatoms to the higher filamentous forms. The nymph of *Chirotenetes* has developed a very remarkable specialization by means of which it avails itself of the suspended edible plant material carried along by the current. The inner sides of the fore femora, tibiae and tarsi are fringed with long hairs interspersed with shorter fine ones. These are supplemented by copious short hairs on the labrum, and on the maxillary palpi and by longer ones on the labial palpi. When the nymph takes up a position in the current head up stream, the forelegs are held out in front of the head and flexed at the tibio-femoral joint so that the claws are almost contiguous on the surface of the rock. In this position the hairs of the forelegs and mouth parts meet and overlap in such a way as to form a straining apparatus. To demonstrate the use of this strainer a trough $51 \times 4 \times 3\frac{1}{8}$ inches was placed below an outlet from a tank and arranged so that a moderate current flowed through the trough at a depth of one and a half inches. A number of nymphs which had had no food for twenty-four hours were put into the trough at the lower end. They soon began to crawl forward along the bottom. A mixture of silt, diatoms and other forms of algae was sent down in the current and observations were made by means of a reading glass. The strainers were soon loaded with the material and four nymphs were observed to feed upon it. The elongated fringed labial palpi were extended to sweep in the materials caught, while the maxillary palpi working laterally and the glossae of the labium working vertically pushed the food materials back to the mandibles. The legs were moved at times to bring food within reach of the mouth parts. Any materials caught and not wanted were expelled by moving a leg outward and allowing the current to wash them away.

To determine what materials were available in the stream as food for the nymphs a plancton net was put out in the stream at various times throughout the year. The various forms identified are listed and the estimated abundance indicated by the numbers 1, 2 and 3, indicating few, abundant, and very abundant respectively.

A few quantitative determinations were made to ascertain the amount of food available for the nymphs. A small wooden trough four inches wide was placed in the creek in such a way that one end projected over the edge of a small waterfall. A current flowed through the trough to a depth of two inches and at an average rate of 4.0 feet per second. A plancton net of no. 12 mesh silk was hung at the lower end of the trough for sixty minutes. The catch was filtered through fine filter paper and then transferred to a measuring cylinder in 80 per cent. alcohol and allowed to stand for twenty-four hours, and the volume then read. The catch amounted to 14 cc., a considerable proportion of which consisted of silt. Of this catch it was estimated that at least 40 per cent. was silt and inedible matter and another 10 per cent. of fine material which would not be caught by the hairs of the nymphal apparatus, which would mean that 7.0 cc. of edible material was taken in sixty minutes by the plancton net. The data at hand accordingly indicate that at a velocity of 4.0 feet per second there is delivered on an area of 5,160 square mm. in sixty minutes 7.0 cc. of food material. Now

	July 9, '14	Aug. 2	Aug. 13	Aug. 28	Sept. 5	Sept. 11	Oct. 31	Dec. 30	Apr. 25, '15	June 25	July 6	July 13	Aug. 12
Navicula	3	3	3	3	1	1	3	3	3	1	2	3	1
Cymbella	3	1	2		2	1	1	2		1			1
Melosira	1	2		2	2	3	3	2	2		1		
Synedra	2			3		1	1	3	2	1		2	1
Cocconeis		2	1		1	1	1					1	1
Meridion		1							1				
Gomphonema			1				1	2	2	1		1	
Tabellaria					1		1	1					
Gyrosigma					1		1						
Cosmarium	3	1	1	2	1	1							
Scenodesmus	1	1	1		1	1	1					1	
Closterium	1	1	1										
Pediastrum	1	1	1	1	1	1							
Straurastrum	1												
Protococcaceae	1	1											
Cyanophyceae	1	1	3	3	3	1	2	2	1				1
Chantransia							3	2					
Tribonema		2	2	1									
Cladophora	2		3	3	2	2	3	2	2	3	3	3	1
Oedogonium												1	
Spirogyra	2				1		1					1	
Ulothrix	1	1							1			1	2
Microthamnion				3	3	3	3		2			1	3
Higher Plant Tissues	3			3	3	2	3			3	3	3	3
Euglena	1				1				1				
Diplophrys	1												
Ciliata					1		1		1				
Rotifera							1		1				
Crustacea							1			1		1	
Insecta		1					1		1			1	1

the plancton basket of a mature nymph is about 8 square mm. in area. If a nymph lives in a current of 1.5 feet per second, then in twelve hours there should be delivered on the plancton basket .05 cc. of food material. The capacity of that portion of the alimentary canal from the mouth to the end of the mid-intestine of a mature nymph was then calculated as .0065 cc. This would mean that this portion of the alimentary canal would be almost filled eight times in twelve hours with food material. The results of other catches with calculations as just described are given as follows:

Date	Available food per 8 sq. mm. in 12 hrs. at 1.5 ft. per sec.	Times capacity of alimentary tract	
1915			
June 25	.050	8	
" 29	.097	15	
July 6	.041	6	After heavy rains
" 13	.048	7.5	After heavy rains
Aug. 12	.066	10.2	

These results are estimates but conservative ones. They show that there is a considerable abundance of food material coming down in the stream even when conditions are adverse, that is, following flood time. Doubtless the nymphs avail themselves also of algal growths on the stones to which they cling, so that the plancton catch (including particles of higher plant tissue and some animal material) may be considerably augmented.

No calculations were made during the winter but during this season the creek is full of diatoms. All the stones and rocks are covered with a thick brown velvety covering of diatomaceous ooze, so that the food supply should be but little less than in the summer.

Examinations of the stomach contents of nymphs were made throughout a year. Determinations were rather difficult because of the fact that the materials were so very finely ground up. Diatoms were found at all times, but were particularly abundant from September to April and included all the forms listed in the plancton catches. Particles of filamentous algae were recognizable in most of the mounts but were difficult to identify. *Cladophora* and *Microthamnion* were identified and particles of a blue-green alga, probably *Oscillatoria.* Of the smaller green forms a few specimens of *Closterium* and *Scenodesmus* were found. Fragments of higher plant tissues were common. Of animal remains two rotifers were found in one individual, a small claw or mandible of some undetermined form in another, *Simulium* fan rays and remains of *Chironomid* larvae in several and pieces of chitin in a number. In all specimens examined there were considerable quantities of sand particles. Needham ('05) reports that for nine well-grown nymphs taken in Fall Creek (time of year not stated) "plant remains constituted in all cases fully half of the stomach contents." The plant food consisted largely of higher plant tissues but mixed with this were *Cyanophyceae*, *Chlorophyceae* and diatoms. Of animal food, four had eaten *Simulium* larvae and *Caenis* nymphs, seven had eaten nymphs of *Ecdyurus maculipennis* and one had eaten of a small platode and a young nymph of *Chirotenetes.* Morgan ('13) reports having found epidermis of roots, *Zygnema*, *Gomphonema*, may-flies and other insects in more than ten specimens. It appears that the nymph of *Chirotenetes* tends toward an omnivorous diet. No doubt a considerable number of small animals such as small *Simulium* and *Chironomid* larvae and protozoans lodge on the nymph's basket and are eaten as readily as the plant forms.

Relation to the Oxygen and Carbon Dioxide Content of the Water.—Chemical analyses during 1914-1915 showed that the water of Cascadilla Creek was quite normal as regards the dissolved substances during that period. There was no evidence that the amount of pollution was harmful to the organisms of the creek. The effect on the oxygen and carbon dioxide content of a small amount of pollution in a stream flowing several feet per second is probably very slight. Analyses from December 1, 1914, to August 10, 1915, show a comparatively high oxygen content throughout the year and a low carbon dioxide content—two factors of extreme importance to an aquatic organism. The samples for oxygen determination were taken from the creek in the gorge in bottles with a capacity of 250 cc. The bottle was allowed to stand uncorked for two minutes to allow entrained bubbles of air to escape and determinations were carried out at once. There is a possibility that a small quantity of entrained air still remained in the bottle but the results obtained do not represent the total amount of oxygen available, for the tumbling waters hold a large amount of entrained air which would be of extreme value to the nymphs. In winter at 0° C. the results show the water to be almost saturated with oxygen. In summer, although the amount per million cubic centimeters has dropped considerably, still the water is frequently supersaturated. (Fig. 5.) The Ohio State Board

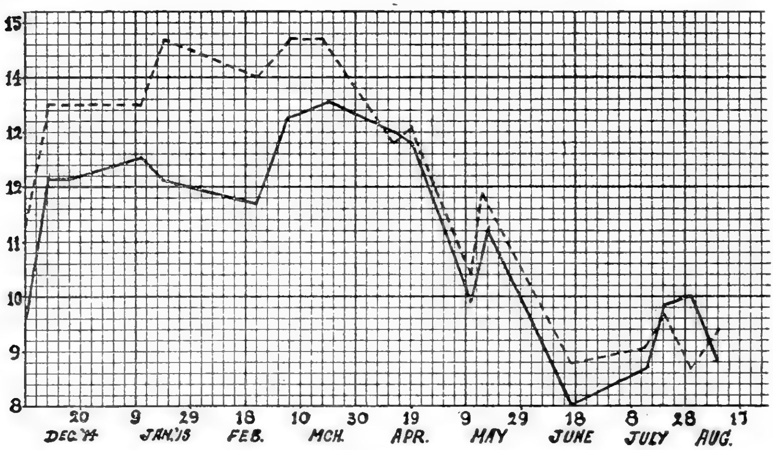


Fig. 5.—Oxygen content of Cascadilla Creek compared with amounts of saturation of water at same temperatures and pressure. ———— = oxygen content in parts per milllion. - - - - - - = amounts of saturation in parts per million.

of Health ('97) has reported water in Ohio supersaturated with oxygen during August, September and October. Shelford ('13) states that the carbon dioxide content is probably the best single index of the suitability of water for fishes because carbon dioxide in excess has a toxic effect. Chemical analyses of the water of Cascadilla Creek show a low carbon dioxide content throughout the year, especially in midsummer when during July and part of August the water was devoid of this gas.

The nymph of *Chirotenetes* obtains its oxygen supply by means of tufts of tracheal gills. There are seven pairs attached to the posterior lateral margins of the abdominal segments one to seven, one pair attached to the bases of the fore coxae and one pair at the bases of the maxillae. An estimate of the gill area presented by the nymph was made by counting the gill filaments in a cluster and measuring the length and diameter of a single filament. The results show a gill surface of about 230 square mm. presented by a mature nymph. The nymph is thus well equipped for obtaining a good oxygen supply in that it possesses fore coxal and maxillary gill tufts which are of unique occurrence among the known may-fly nymphs of our fauna. The extensive gill equipment probably bears some relation to the active habits of the nymph.

The following experiments were conducted to ascertain if the nymphs of *Chirotenetes* are dependent on current for their oxygen supply. On June 27, 1915, there was put into a large glass aquarium 2,000 cc. of water from Cascadilla Creek, containing 8.3 parts per million of dissolved oxygen and one part per million of free carbon dioxide at 18° C. Five nymphs were introduced into the water and on the bottom of the jar was placed a clean stone to which the nymphs might cling. On July 11 a rain added slightly to the amount of water in the aquarium. On July 13 a nymph died, and analysis of the water on July 14 showed 5.16 parts per million of oxygen and three parts per million of free carbon dioxide at a temperature of 21° C. The remaining nymphs died on July 20, having lived in the aquarium twenty-four days without food. Analysis on July 21 showed 9.9 parts per million of oxygen and no free carbon dioxide at a temperature of 15.1° C. Doubtless the nymphs had died of starvation.

For purposes of comparison 5,000 cc. of creek water had been put into a large glass aquarium on June 17, 1915, with no nymphs. Analyses of this water were made as follows:

		Temperature	Oxygen parts per million	Carbon Dioxide parts per million
1915				
June 17		20.2°C	8.01	1.5
" 18	24 hours	17.2	11.6	.5
" 24	7 days	11.0	9.68	.5
July 14	27 days	21.0	7.49	2.1
" 21	34 days	15.1	9.11	.0

On July 21 three *Chirotenetes*, three *Heptagenia* and three *Epeorus* nymphs (may-fly nymphs from flowing water of Cascadilla Creek) were put into this jar. The next morning the three *Epeorus* nymphs were found dead. Of the remaining nymphs four were alive on July 30, the other two having transformed to subimagos. On August 16 one *Chirotenetes* nymph was still alive in the jar, having been able to live for twenty-six days in water which had been standing sixty days. Analyses after the addition of the nymphs gave results as follows:

		Temperature	Oxygen parts per million	Carbon Dioxide parts per million
1915				
July 30	43 days	20.0°C	8.42	.0
Aug. 10	54 days	17.0	8.00	1.5

Just before Cascadilla Creek enters the gorge section, a pond, known as Dwyer's Pond, has been formed by a dam. Analyses of the water from Dwyer's Pond failed to show very marked differences in oxygen or carbon dioxide content from that of the tumbling water in the creek in the gorge. The samples were taken in the pond just below the surface and close to a clump of sedges in a situation where may-flies would be likely to occur. That *Chirotenetes* nymphs do not live in the pond cannot be because of lack of oxygen there or excess of carbon dioxide, nor because of lack of current, since the results of the aquarium experiments show that the nymphs are not dependent upon current for oxygen supply as are *Epeorus* nymphs apparently, for the latter die very soon after being placed in still water.

Associates.—In the classification of the ecological communities of the stream, the nymph of *Chirotenetes* belongs in the strata under the stones to the *Hydropsyche* or riffle formation (Shelford, '13). Its associates in Cascadilla Creek are as follows:

Ephemerida of the genera *Heptagenia*, *Iron*, *Epeorus*, *Ecdyurus*, *Ephemerella*, *Leptophlebia* and *Baetis*.

Plecoptera of the genera *Perla*, *Acroneuria*, *Neoperla* and *Pteronarcys*.

Neuroptera of the genera *Corydalis* and *Chauliodes*.

Trichoptera of the genera *Hydropsyche*, *Helicopsyche*, *Rhyacophyla*, *Leptocerus*, *Chimarrha* and *Polycentropus*.

Lepidoptera of the genus *Eliophila*.

Coleoptera of the genus *Psephenus* ("water-penny").

Diptera of the genera *Atherix*, *Chironomus*, *Diamesa*, *Tanytarsus*, *Tabanus*, *Eriocera* and *Tipula*.

Planarians.

Hirudinea.

Mollusca of the genus *Ancylus*.

On the smooth rock beds of the gorge, where the nymph of *Chirotenetes* occurs occasionally, are found larvae of *Simulium*, *Blepharocera* and *Hydropsyche* and Ephemerid nymphs of the genera *Heptagenia*, *Iron*, *Epeorus* and *Baetis*.

Among the stones of the creek have commonly been taken the blacknosed dace (*Rhynichthys atronasus*), the young of the common sucker (*Catostomus commersonii*), Johnny darter (*Bolesoma nigrum*), the nigger chub (*Exoglossum maxillingua*), the satin-fin minnow (*Notropis whipplii*), small common shiners (*Notropis cornutus*) and the dusky salamander (*Desmognathus fusca*).

Enemies.—Stomach examinations of some of the associates of *Chirotenetes* show that the two chief enemies are the large stone-fly nymphs, particularly *Perla media*, and the black-nosed dace *Rhynichthys atronasus*. Morgan ('11) reports having seen robins in Fall Creek gorge with the setae and abdomens of nymphs and subimagos projecting from the beaks. The period of moulting is an especially helpless time for the nymphs and at such time they are most liable to become the prey of enemies.

Severities of Stream Life.—Life in swift water is beset with many difficulties and dangers. Probably the most trying season for the nymphs of *Chirotenetes* is flood time. Stones and rocks are moved by the force of the current and during the spring flood the out-going ice scrapes and scours the creek bottom. The movement of stones, rocks and ice over the rock bed in the gorge of the stream at a time of high water can be distinctly heard. The nymphs are in danger of being crushed or swept out in the current over waterfalls or into unsuitable situations. A pool about one hundred and fifty feet south of Fall Creek is usually flooded in spring by a portion of the creek being diverted through it. After such a flooding *Chirotenetes* nymphs have been found in the pool. Another illustration as to how the nymphs are carried about during flood time was afforded in the course of the habitat experiments. A heavy rain one night caused the water in the creek to rise and the trough set out for an experiment was carried about ten yards down stream without being upset. The water was flowing over the trough to some extent and the stones, pieces of rock and gravel in the trough had all been shifted. The trough had contained thirteen almost mature *Chirotenetes* nymphs, but when it was examined only three of these remained, but twelve small *Chirotenetes* nymphs 7 to 8 mm. in length were found in the trough besides numerous *Baetis* nymphs and a number of *Hydropsyche* larvae.

After heavy rains the nymphs have to contend with large quantities of silt. Samples of water have been taken from the creek when it was loaded with sediment, the water filtered and measured and the residue weighed after drying in the air of the laboratory for several days. The results obtained are as follows:

Date	Amount of sample	Weight of sediment	Parts per million	Conditions
1914 June 28	2200 cc.	13.8 grs.	6200	Taken two hours after very heavy downpour of rain.
Aug. 20	2400	1.0	415	Taken morning after a heavy night's rain.
Sept. 2	1900	3.4	1800	Taken three hours after heavy rain.
1915 Jan. 7			400	Taken at time of a mid-winter thaw.
July 5	2200	1.3	590	Taken the day after heavy rains.

Professor Chamot has stated that turbidities in Six-Mile Creek frequently exceed 6,000 parts per million. Such enormous amounts of sediment result from the hilly nature of the watershed and the nature of the soil. The soil of Cascadilla valley consists of silty, clayey and stony loams. Heavy rains cover the hillsides with rivulets which bring down to the stream immense quantities of sediment. The water becomes yellow-brown in colour and so loaded with silt that the earthy odour can be detected a long distance from the creek particularly in the vicinity of waterfalls.

Flood time too carries out to the lake the plancton of the pools and ponds of the stream leaving the creek more or less deficient for some time of those suspended organisms upon which the nymphs depend to a large extent for food. This was shown by plancton catches taken before and after floods.

Needham ('16) points out the dangers from ice particles and "anchor ice" during the winter period.

Protection.—The nymphs of *Chirotenetes* receive protection from the stones, to the lower sides of which they cling. While the stones are in position, protection is afforded from the force of the current, from larger objects carried in the current, and where the space is small from larger enemies such as fish. The nymphs no doubt escape enemies by reason of protective colouring and agility. The chocolate-brown colour renders the nymph very inconspicuous on the dark coloured rocks of the stream bed, and the ability to dart quickly from place to place by means of strong strokes of the abdomen and fringed setae is of decided advantage. Nymphs in a current of water in a trough have been observed to loosen their hold allowing the current to carry them down a short distance and then to catch the bottom or side of the trough again. Doubtless such a procedure is used as a means of escape.

Regeneration.—The nymphs possess the power to regenerate certain parts. Frequently it has been observed that a nymph lacking a leg will after moulting possess a small leg. How many instars are passed through before the leg attains normal size has not been determined. The ability to regenerate a foreleg is of vital importance to the nymph.

THE SUBIMAGO

Emergence.—There comes a time in the life of the nymph when some stimulus causes it to crawl up the side of a stone out of the water. The stimulus is probably supplied by a number of agencies of which the maturation of the sexual elements is doubtless the chief. The nymph crawls out just above the surface of the water. In a few seconds convulsive movements pass through the body, the head and thorax split along the mid-dorsal line and the body of the subimago slips out on to the stone. As soon as the wings are freed, they are spread, and at the same time the legs are extended so as to support the body of the insect. It soon takes a few steps or a little jump and the abdomen and setae are freed. After a few movements of the wings, legs and setae, the subimago flutters upward into the trees. Where no trees are near by they often flutter upward out of sight. The body of the subimago sometimes slips out on to the surface of the water and is carried down stream some distance standing on the surface film. A wave occasionally submerges the subimago or sweeps it away before it has freed itself from the old nymphal skin, thus ultimately bringing it to its death. Transformations occur in greatest numbers during the late afternoon and evening but some occur in the morning. The period of emergence is rather extended. The earliest observed emergence was on June 6 and the latest September 8, with the greatest numbers in June and July. Morgan ('11) reports emergings in great numbers in May, 1910.

Factors affecting the length of the Subimaginal period.—The subimaginal period is one of quiescence. The subimagos remain quietly on the leaves and twigs of the vegetation bordering the stream. They take no food, the mouth parts being degenerate. This condition prevails normally from twenty-four to thirty-six hours, at the end of which time the subimago moults, and the may-fly takes on the adult form. A set of experiments was carried out to determine the effects of temperature, light and humidity on the length of the subimaginal period. Three bell jars were set up. In one was placed a tray of calcium chloride, in another a tray of water and saturated blotters. The third was used as a control. Hygrometers hung in the jars showed that in the first the relative humidity was about 32 per cent, in the second practically at saturation, and in the third 66 per cent. Subimagos as they emerged were put into small wire cages. A male and a female were put into each cage and the cages put under the bell jars. Two series are given as typical:

Jar—low humidity (32%)

♀ emerged 12:25 P.M. Aug. 14, trans. 8:30 P.M. Aug. 15 = 32 hrs. 5 min.

♂ emerged 12:40 P.M. Aug. 14,—died.

Jar—normal humidity (66%)

♀ emerged 4:18 P.M. Aug. 14, trans. 9:00 P.M. Aug. 15 = 28 hrs. 40 min.

♂ emerged 4:10 P.M. Aug. 14, trans. 9:00 P.M. Aug. 15 = 28 hrs. 50 min.

Jar—saturation (100%)
♀ emerged 5:20 P.M. Aug. 14, trans. 1:00 A.M. Aug. 16
=31 hrs. 40 min.
♂ emerged 4:50 P.M. Aug. 14, trans. 10:45 P.M. Aug. 15
=29 hrs. 55 min.
♂ emerged 4:50 P.M. Aug. 14, trans. 11:15 P.M. Aug. 15
=30 hrs. 25 min.

Jar—low humidity (35%)
♀ emerged 5:15 P.M. Sept. 10, trans. 6:40 P.M. Sept. 12
=49 hrs. 25 min.
♂ emerged 5:15 P.M. Sept. 10, trans. 6:30 P.M. Sept. 12
=49 hrs. 15 min.

Jar—normal humidity (50%)
♀ emerged 4:15 P.M. Sept. 10, trans. 4:10 P.M. Sept. 12
=47 hrs. 55 min.
♀ emerged 3:55 P.M. Sept. 10, trans. 4:50 P.M. Sept. 12
=48 hrs. 55 min.

Jar—saturation (95%)
♀ emerged 4:25 P.M. Sept. 10, trans. 4:45 P.M. Sept. 12
=48 hrs. 20 min.
♂ emerged 5:05 P.M. Sept. 10, trans. 5:05 P.M. Sept. 12
=48 hrs. 0 min.

Other series brought out the same results, namely that individual variations were greater than the variations among the jars.

Experiments were then conducted to determine the effect of darkness on the length of the subimaginal period. The exact time of emergence was obtained. The subimagos were transferred to wire cages some of which were put in a photographic dark-room and others on a window-sill in the laboratory in the bright light, at times partly in the sunlight.

Cage in light.

♂ emerged 4:10 P.M. Aug. 14, trans. 9:50 P.M. Aug. 15
= 29 hrs. 40 min.

♀ emerged 4:45 P.M. Aug. 14, trans. 1:15 A.M. Aug. 16
= 32 hrs. 30 min.

Cage in dark room.

♂ emerged 4:55 P.M. Aug. 14, trans. 12:20 P.M. Aug. 15
= 31 hrs. 25 min.

♀ emerged 5:20 P.M. Aug. 14, trans. 12:30 P.M. Aug. 15
= 31 hrs. 10 min.

Other experiments gave similar results, showing that darkness has no effect on the subimaginal period.

During the time these experiments were being conducted, the temperature varied considerably and a decided lengthening of the subimaginal period was noted when the temperature of the air lowered and a shortening of the period as the temperature rose. For example, on September 1 and 2, 1914, the temperature rose to 28.3° C. and the subimaginal period lasted 22 to 25 hours. On September 11, 1914, the temperature dropped to 15.5° C. and the period lasted 48 to 49 hours. A difference of 12.8° C. had doubled the length of the subimaginal life. A number of subimagos were placed in a cage which was then placed in the ice box of an ordinary refrigerator where the temperature was 8° C. The subimagos lived four days before transforming and some failed to transform. The length of the period thus varies greatly with the temperature but not with humidity or light.

Enemies.—The chief enemies of the subimagos are birds and spiders. Birds have been observed to fly out of the trees bordering the creek and catch the subimagos fluttering upward after emerging. All tree-inhabiting insect-eating birds doubtless feed upon the subimagos. Many subimagos are caught in spider webs. A fence along Fall Creek near Forest Home village usually has a great number of spider webs filling its spaces. One afternoon a large number of subimagos were emerging from the creek and a strong wind carried them toward the fence. Every web along the fence had one or more *Chirotenetes* subimagos caught in the meshes. Heavy rains and winds are destructive to the subimagos, beating them down and wetting the wings so that transformation cannot be successfully carried out.

Protection.—The only protection for the subimago consists in its dull colour and its quiescent habits. A subimago on the vegetation is usually difficult to detect.

THE IMAGO

Transformation.—At the subimaginal moult, the head and thorax of the subimago split along the mid-dorsal line, the wings are spread almost horizontally and with a few contractions of the body the adult form appears. When transformation occurs on a vertical surface, the body of the imago is bent down backward until the wings and legs are freed and then by movements of the wings the body is brought up until the legs are able to grasp the object above. The adult then walks away from the moulted skin.

Flight.—The males of *Chirotenetes* have a flight characteristic of the majority of may-flies. They appear over the stream usually after sunset, about twenty minutes before nightfall, in small swarms of thirty to fifty individuals. They are very graceful in flight, rising and falling in deep undulations of eight to fifteen feet, fluttering upward with the body held obliquely and then falling slowly on expanded wings and spread setae, with the body horizontal. The females do not take part in these flights but fly singly up and down the creek in long undulations. What factors induce the imagos to fly in the late evening have not been determined. It may be that this time of day is the safest, having been determined by natural selection, or it may be a negatively phototactic tendency carried over from the nymphal stage. When a female enters a swarm of males she is quickly caught by a male flying up beneath her. The male places his long forelegs over her prothorax and head and grasps her abdomen with his forceps. The arching of the body of the male in order to grasp the body of the female with the forceps brings the penes in position to be inserted into the openings of the oviducts at the apex of the seventh abdominal segment. Copulation lasts twenty-five to sixty seconds. The couples do not rise high but remain at almost constant level, frequently making quick turns and occasionally sudden drops. The male in separating lets go his hold with the forelegs first and finally with the forceps. Apparently the male returns to the swarm while the female flies up and down the stream in long undulations and soon begins ovipositing.

The mouth parts of the imago are degenerate and no food is taken during the short aerial life. The alimentary canal, however, is not degenerate but is filled with air and serves as a buoyant organ (Sternfeld, '07).

Oviposition.—Preceding oviposition the eggs make their appearance from the openings of the oviducts and form a spherical mass which is apparently held in position by the bending forward of the sternal prolongation of the ninth abdominal segment. The eggs are held together by very fine strands of a viscid substance. The female flies over the water with long deep undulations carrying the greenish egg mass and dips to the flowing water so that the egg mass is carried away in the current. The eggs scatter somewhat in the water and adhere to objects by means of the viscid strands.

The Egg.—The egg is almost spherical with a diameter of .2 mm. It is greenish in colour when mature, with the surface divided into very small polygonal areas and slightly roughened. The egg complement consists of 1,900 to 2,000 eggs. It was found that at a temperature of 22.5 to 25° C. they hatch in about fourteen days, while at a temperature of 13° C. in twenty-five days. In the eggs ready to hatch the eyes and ocelli of the embryos can be seen moving up and down. After a considerable period of movement of the head in this way, a crescentric slit appears on the egg shell at the point where the head has been moving, and then the head pushes out through the opening. Soon the tips of the antennae are freed and extended. The pairs of legs follow in succession accompanied by considerable movement of the body. At the end of ten minutes all the body is freed except the tip of the abdomen and the setae; and in two minutes more the nymph is able to shake off the egg shell. The nymphs at hatching are .8 to .9 mm. in length, without gills, with forelegs unfringed and having eyes and ocelli of equal size. They moult six days after hatching and still show no signs of gills but the forelegs possess a few hairs along the inner margins. It was found that the eggs of *Chirotenetes* could be artificially fertilized. The testes of three males were put into water in a Syracuse watch glass and teased out. The eggs of a female were then put in the vessel and stirred about gently for a few minutes. The contents of the watch glass were left standing for an hour, then the water was poured off with the bits of tissue resulting from the dissections. Fresh water was poured over the eggs, and the watch glass covered and kept on the laboratory table. The eggs began to hatch eleven days later and continued to do so for nine days.

Length of Life.—How long the adults live under normal conditions and whether males return to swarm a second or third evening has not been determined. Reared imagos kept out of doors in a large wire cage in which was put a leafy branch of a tree, lived four and one-half days.

Summary

The results of the investigation are as follows:

1. The nymphs of *Chirotenetes* show a very decided habitat preference for the lower surfaces of stones and rubble as against smooth open sheets of rock, and a slight preference for rubble as against small stones.

2. The nymphs are negatively phototactic.

3. The nymphs live in a very much diminished current beneath the stones and rubble of the stream.

4. The nymphal form of body is well adapted for a more or less active life in running water.

5. By means of fringes of hairs and bristles on the forelegs the nymphs are able to strain out suspended organic materials of the stream for food purposes.

6. The suspended plant and animal forms in the current are sufficient in amount to supply the food requirements of the nymph.

7. The water of Cascadilla Creek throughout nine months was neither excessively polluted nor contained excessive amounts of dissolved substances, so as to be harmful to the nymph. The oxygen content was high and the free carbon dioxide content low.

8. The nymph is not dependent on current for oxygen supply.

9. Temperature has a very marked effect on the length of the subimaginal period, while humidity and light have no effect.

10. The eggs of *Chirotenetes* can be fertilized artificially.

It appears that food has been the factor determining the habitat of the nymph. With special equipments in bodily structure it has pushed out into the current and made use of the current to bring it food. Out in the swift water it has taken to the lower surfaces of the stones and rubble for shelter from the dangers accompanying life in swift water and for protection from enemies.

While the activities of the nymph are concerned primarily with the acquisition of food, the activities of the adult are concerned with reproduction. The degeneration of the mouth parts, the inflation of the alimentary tract, the well developed wings, the elongated forelegs and large compound eyes of the male are modifications tending to insure the perpetuation of the race.

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EXPLANATION OF PLATES

PLATE I

FIG. 1. Nymph of *Chirotenetes albomanicatus* Needham.
2. Pitot-tube as used in Cascadilla Creek.

PLATE II

3. Upland portion, Cascadilla Creek.
4. Upland portion, Cascadilla Creek.

PLATE III

5. Gorge portion, Cascadilla Creek.
6. Gorge portion, Cascadilla Creek.

PLATE IV

7. Cascadilla Creek after descent into Cayuga Valley.
8. Flats portion, Cascadilla Creek.

PLATE V

9. Winter conditions, upland portion, Cascadilla Creek.
10. Flood conditions, upland portion, Cascadilla Creek.

PLATE I

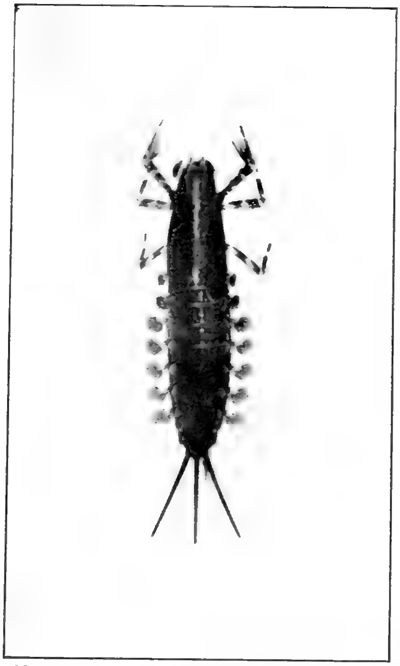

Fig. 1.—Nymph of *Chirotenetes albomanicatus* Needham.

Fig. 2.—Pitot-tube as used in Cascadilla Creek

PLATE II

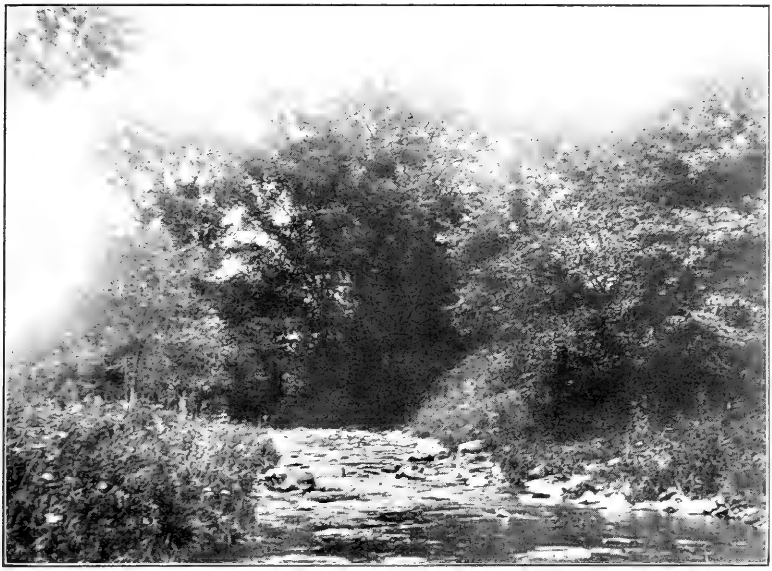

Fig. 3.—Upland portion, Cascadilla Creek.

Fig. 4.—Upland portion, Cascadilla Creek

Fig. 5.—Gorge portion, Cascadilla Creek.

Fig. 6.—Gorge portion, Cascadilla Creek.

PLATE IV

Fig. 7.—Cascadilla Creek after descent into Cayuga Valley.

Fig. 8.—Flats portion, Cascadilla Creek.

PLATE V

Fig. 9.—Winter conditions, upland portion, Cascadilla Creek.

Fig. 10.—Flood conditions, upland portion, Cascadilla Creek.

UNIVERSITY OF TORONTO STUDIES

BIOLOGICAL SERIES

No. 18: THE ISOPODA OF THE BAY OF FUNDY, BY N. A. WALLACE

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THE ISOPODA OF THE BAY OF FUNDY

BY

N. A. WALLACE, B.A.

(Prepared for Publication by A. G. Huntsman, Biologist to the Biological Board of Canada)

FOREWORD

During the summers of 1912 and 1913 Mr. Norbert A. Wallace worked at the Atlantic Biological Station, St. Andrews, New Brunswick. At the beginning he spent some time studying the *Argulidae* and in addition determined the food of a number of fishes. Latterly he spent his whole time in investigating the Isopod fauna of the region, the dredgings which were being made during those seasons throughout the Western Archipelago and at St. Mary bay, Nova Scotia, furnishing him with the material for his investigations. He was most indefatigable and painstaking in this work, which he continued to some extent during the succeeding winters at the Biological Department, University of Toronto. His untimely death on December 3rd, 1914, cut short a brilliant career.

Unfortunately he had only reached the stage where he was about to prepare the manuscript of his report, which was, therefore, in an incomplete state. His drawings of the species were not all completed, and he had made only preliminary drafts of the descriptions and accounts of distribution. It has been necessary for us to collate these and at the same time eliminate, add, or reconstruct freely. Where feasible his accounts are used *verbatim*. He had neither named the new species nor examined all the literature to make certain that they had not already been named and described. We have not been able to refer them to any of the described species and, therefore, believe them to be new. No attempt has been made, however, to examine critically the species of the genera to which they belong so as to determine their relationships with the described species.

If Mr. Wallace had lived, he would undoubtedly have rendered this account much more complete. We hope that no serious mistakes have been made in its final preparation. The study embodied in this paper was carried on with the assistance of the Biological Board of Canada and of the Biological Department of the University of Toronto.

A. G. H.

THE ISOPODA OF THE BAY OF FUNDY

INTRODUCTION

In 1853 Stimpson reported in his "Synopsis of the Marine Invertebrata of Grand Manan" a total of nine species of Isopods from that island. These are in current nomenclature

Leptochelia filum,
Gnathia cerina,
Calathura branchiata,
Cirolana polita,
Chiridotea tuftsii,
Idothea baltica,
Edotea triloba,
Jaera marina,
and *Janira alta*.

Harger in his "Report on the Marine Isopoda", published in 1880, added six species to the fauna of the Bay of Fundy, which are

Ptilanthura tenuis,
Limnoria lignorum,
Idothea phosphorea,
Munna fabricii,
Munnopsis typica,
and *Bopyroides hippolytes*.

Mr. Wallace now adds twelve species, of which five are new to America although known from Europe, and three are new to science.

Those merely new to the Bay of Fundy are

Aega psora,
Chiridotea caeca,
Synidotea nodulosa,
and *Phryxus abdominalis*.

Those new to the American coast are
Typhlotanais aequiremis,
Pleurogonium rubicundum,
Pleurogonium inerme,
Pleurogonium spinosissimum,
and *Eurycope mutica*.

The species new to science are
Typhlotanais mananensis,
Leptognathia (?) *psammophila*,
and *Leptochelia profunda*.

It is significant that the species new to America are all very small and that those new to science are not only small, but belong to the difficult group of the Tanaidacea. Future additions to the list of Isopods will doubtless be in this same direction, namely, that of the minute forms, including parasites.

In addition to the marine forms, Mr. Wallace has listed three species of terrestrial Isopoda from the shores of the Bay of Fundy. They are all well known species, but their distribution in eastern Canada has not been signalized. With these the list of species from the Bay of Fundy has reached the number of thirty.

A. G. H.

ACCOUNT OF THE SPECIES

Family *Tanaidae*

Typhlotanais aequiremis (Lilljeborg). Figure 1.
Sars, 1899, p. 21.

The single specimen obtained—a female—was taken off Big Duck Island, Grand Manan, at a depth of 55 fathoms on muddy bottom.

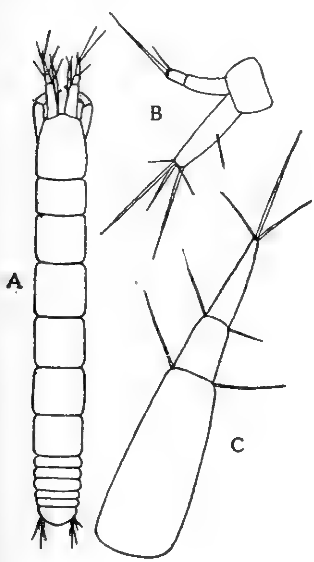

FIG. 1. *Typhlotanais aequiremis*; (A), female, dorsal view, x 30; (B), uropod x 240; (C), first antenna, x 240.

The body is elongated and very slender, slightly over seven times as long as broad, and much depressed. The cephalosome is slightly longer than it is broad and the anterior margin slightly excavate on either side of a blunt median point. The first pair of antennae have the first article longer than the other two combined. The second pair of antennae are similar to those of the next species. The thorax is cylindrical in shape, having the first segment the shortest, the second, third, fourth, and fifth subequal, and the sixth slightly shorter than the fifth, but longer than the first.

The chelipeds are somewhat stouter than those of the next species, while the other legs are much as in that species, the three posterior pairs having the basal article expanded and stout.

The abdomen is composed of six segments, the last one being rounded posteriorly. The uropods are biramous, the peduncle of each is quite stout, and the two branches are approximately equal in length, the outer being biarticulate and ending in a strong bristle, while the inner is uniarticulate, but gives an indication of subdivision in having a hair at about its middle.

Typlotanais mananensis, sp.n. Figure 2.

A single female of this species was dredged outside Big Duck Island, Grand Manan, at a depth of 42 fathoms on a muddy bottom.

The body is elongated and very slender, being nearly nine times as long as broad (about 1.8 mm.: 0.23 mm.). The head is about twice as long as broad and narrower in front. The anterior margin is produced in the mid-line to form a short, sharp rostrum. The first pair of antennae are short, conical, and very stout at their base. Each consists of three articles of which the first is very stout and a little longer than one half of the whole antenna, the second is less than a quarter as long as the first and much narrower, and the third is one and one-half times as long as the second and narrower. The second pair of antennae are more slender than the first and are composed each of six articles, of which the first is very short and slender, the second somewhat dilated and a little longer than the first, the third a little longer and narrower than the second, the fourth twice as long as the third, the fifth a little over one-half the length of the fourth, and the sixth very short and almost inconspicuous.

The first thoracic segment is united to the head, while the remaining segments are free. The second is the shortest, the third, fourth, fifth and sixth are subequal in length and about twice as long as the second, and the seventh is shorter than the sixth.

The abdomen consists of six free segments, of which the first five are subequal in length, while the sixth is a little longer than the others, approximately quadrilateral in shape, and very obtusely angular behind.

The uropods are biramous, the peduncle consisting of a single, stout article, the outer branch of two subequal articles,

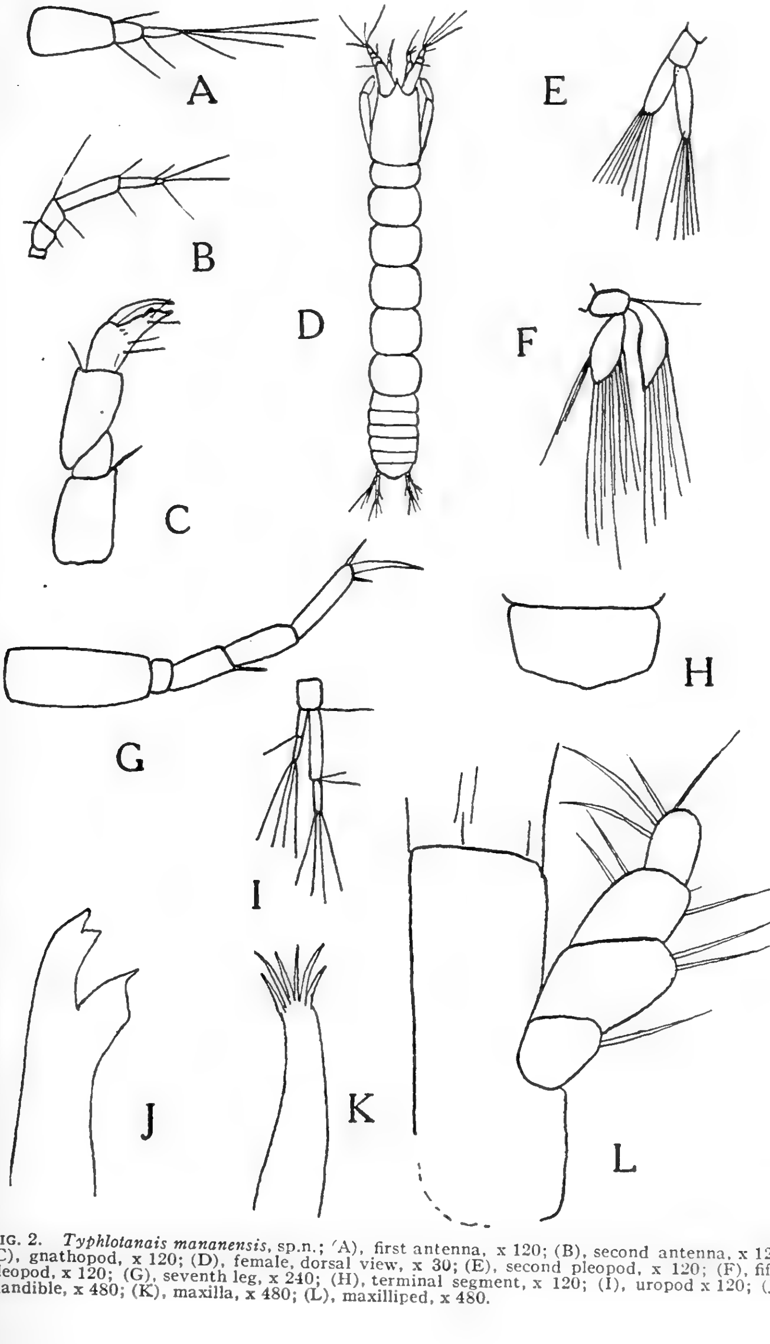

FIG. 2. *Typhlotanais mananensis*, sp.n.; (A), first antenna, x 120; (B), second antenna, x 120; (C), gnathopod, x 120; (D), female, dorsal view, x 30; (E), second pleopod, x 120; (F), fifth pleopod, x 120; (G), seventh leg, x 240; (H), terminal segment, x 120; (I), uropod x 120; (J), mandible, x 480; (K), maxilla, x 480; (L), maxilliped, x 480.

and the inner branch of two articles, of which the first is three times as long as either of those of the outer branch, and the second one-half as long as the first.

The gnathopods are very slender. The propodus is very poorly armed, the inner surface being only slightly roughened and having one short spine at the tip. The articles of the legs are all slender, except that the basal ones of the fifth, sixth and seventh legs are expanded and quite stout. Of the five pairs of well developed, biramous pleopoda, the first four are alike, while the fifth differs in that the inner edge of the inner ramus is slightly emarginate near the distal end. The mouth parts are normal.

Leptognathia (?) *psammophila* sp.n. Figure 3.

Females only of this species were found and in sand at two localities—near West Quoddy at a depth of nine fathoms, and at Woodward's cove, Grand Manan, from low tide mark to a depth of two fathoms.

The body is elongate and narrow, being more than six times as long as broad (about 3 mm.: 0.48 mm.). The head is longer than it is broad and wider behind than in front. The anterior margin of the head is produced medially into a very short, rounded, blunt rostrum, on each side of which is a shallow, angular excavation which lodges the peduncle of the first antenna. The latter, which is directed forwards, is composed of three articles, of which the first is long and stout, the second narrower than and only one-third as long as the first, and the third as long as the second. The second antenna is not so long as the first, and is composed of six articles. Of these the first is short and stout, the second one-third longer than the first, the third equal to the first, the fourth as long as the first three articles together and usually curved, the fifth one-fifth the length of the fourth, and the sixth very small and inconspicuous.

Of the thoracic segments, the second (the first free one) is the shortest, the third, fourth, fifth and sixth are all subequal and each one and one-half times as long as the second, and the seventh approximately equal in length to the second. The thorax narrows to the seventh segment.

The sixth segment of the abdomen is longer than any of the others, which are subequal, and is rounded posteriorly.

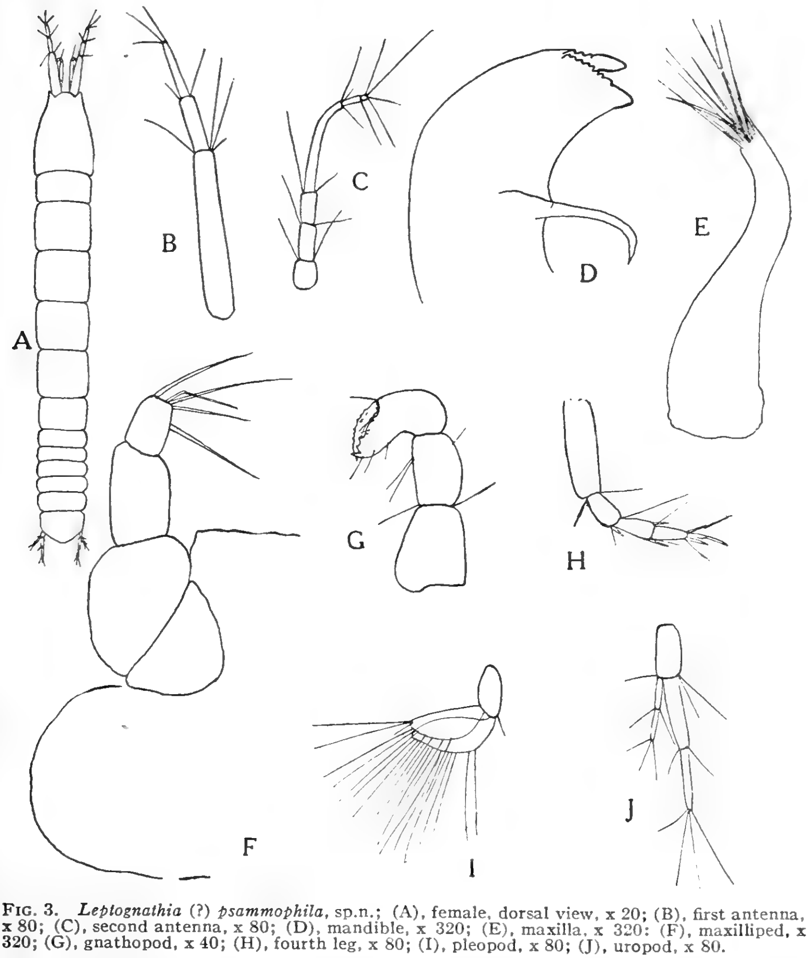

FIG. 3. *Leptognathia* (?) *psammophila*, sp.n.; (A), female, dorsal view, x 20; (B), first antenna, x 80; (C), second antenna, x 80; (D), mandible, x 320; (E), maxilla, x 320; (F), maxilliped, x 320; (G), gnathopod, x 40; (H), fourth leg, x 80; (I), pleopod, x 80; (J), uropod, x 80.

The peduncle of the biramous uropods is stout. The outer branch consists of two subequal, short articles, while the inner consists of two subequal, long articles, each of which is as long as the entire outer branch.

The gnathopods are large and ovate. The propodus is produced at its extremity into a long, narrrow thumb, which is armed on its inner side with two prominent teeth, the point being produced to form a third. The dactylus is long and narrow and produced into a sharp tip which on closure of the chela falls between the teeth at the end of the propodus and the one next to it. The outer surface of the dactylus has a number of short teeth or tubercles. The remaining legs are all ambulatory in character and have not the basal article appreciably expanded as in *Typhlotanais*. The fifth, sixth and seventh are furnished each with a couple of spines on the fourth, fifth, and sixth joints, but those of the second and third legs have only a few setae.

The mandible has a cutting edge of two teeth and a finely serrated anterior border. The molar expansion is very slender. Each maxilla is tipped with a circle of stiff bristles. The maxillipeds have each a palp of four articles.

The position of this species is open to doubt. In the degraded condition of the molar expansion of the mandible it agrees with the genus *Leptognathia*, but differs from it in having the first pair of antennae with only three instead of four articles. It may be necessary to erect a new genus for its reception, but we have considered the condition of the mandibles as of major importance, and have, therefore, placed it in the genus *Leptognathia*.

Leptochelia filum (Stimpson). Figure 4.

Stimpson, 1853, p. 43.

This species occurs throughout the whole region at depths varying from 9 to 75 fathoms, chiefly on hard, rocky bottom among *Boltenia ovifera*, but also in old shells, mud or sand. The males are not so numerous as the females, there being as a rule about 8 to 10 females for every male.

Records: Off Biological Station, St. Croix River, 10 to 15 fathoms; off Eastport, Me., 10 fathoms; off Cherry Island,

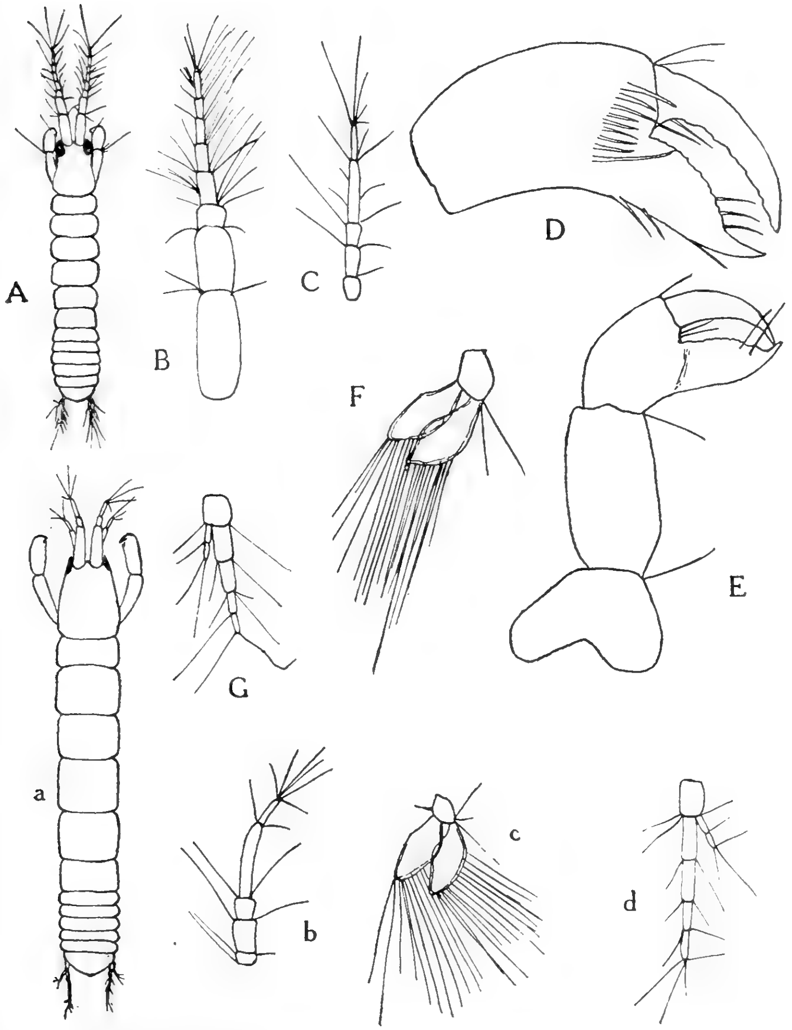

FIG. 4. *Leptochelia filum* (Stimpson); (A), male, dorsal view, x 21; (B), first antenna, x 84; (C), second antenna, x 84; (D), chela of gnathopod, x 154; (E), gnathopod, outer surface, x 84; (F), pleopod, x 84; (G), uropod, x 84; (a), female, dorsal view, x 21; (b), second antenna, x 84; (c), pleopod, x 84; (d), uropod, x 84.

Head Harbour Passage, 42 fathoms; off Spruce Island, 36 fathoms; Head Harbour, 9 fathoms; off Head Harbour Island, 27 and 70 to 75 fathoms; the Wolves, 16 to 30 fathoms; off Low Duck Island, Grand Manan, 34 fathoms; off Big Duck Island, 42 fathoms; off Three Islands, Grand Manan, 17 fathoms. Hake Bay, Grand Manan, 20 fathoms (Stimpson, 1853).

As this species has never been described more thoroughly than in the brief account given by Stimpson, we will consider its structure somewhat fully.

Female: The body is elongated and narrow, about five times as long as broad (2½ mm.: 0.5 mm.). The head is longer than it is broad, and has the anterior end narrower than the posterior. The eyes are small, compound and distinct, and situated anterolaterally. The first pair of antennae have the first article long and stout, the second very short, and the third about twice as long as the second. The second pair of antennae are shorter than the first pair, and consist of five articles, of which the first is short and broad, the second a little longer and thinner than the first, the third shorter than the second, the fourth more than twice as long as the third, and the fifth half as long as the fourth.

Of the thoracic segments, the second (first free segment) is about half the length of one of the four that follow it, which are subequal. The seventh is about as long as the second.

The sixth segment of the abdomen is longer than any of the other five and is rounded posteriorly. The outer branch of the biramous uropods is composed of two very short articles, which are not clearly marked off from each other, but which usually have a stout hair at the joint between them. The inner branch is four times as long as the outer and is composed of four articles, of which the first two are subequal in length and short, and the last two also subequal in length but at the same time one and one-half times as long as the first two.

The gnathopods are large, the propodus being produced at its extremity into a long, narrow thumb, which is armed on its inner side with a row of low, blunt teeth together with a sharp, prominent tooth at the very tip. The dactyl is long, narrow and sharply pointed. The other legs are ambulatory, with the terminal joint sharply pointed and recurved.

The abdomen has five pairs of well developed biramous pleopods, not quite so large as those of the male and having shorter setae, which do not extend beyond the limits of the terminal segments.

Male: The body is about three-fifths as large as that of the female and equally elongated (1.58 mm.: 0.3 mm.). The head is slightly longer than it is broad and narrows toward the front. The eyes are proportionately much larger than in the female, and occupy the sides of the head lateral to the first pair of antennae. The latter have the first article long and stout, the second nearly as stout but only a little over half as long, and the third only one-third as long as the second and narrower. The flagellum is nearly as long as the peduncle and is multi-articulate, consisting of five articles, which, with the exception of the exceedingly minute terminal one, are subequal in length. There is some indication of the separation of the first and fifth articles into two parts in the presence of numerous hairs. The second pair of antennae are shorter than the first pair and not as stout. Each consists of six articles, of which the first is short and stout, the second twice as long as the first, the third shorter than the second, the fourth three times as long as the third, the fifth twice as long as the third, and the sixth quite inconspicuous.

The thoracic segments are similar to those of the female except that the fifth and sixth segments are a little longer than the third and fourth. The thorax narrows to the sixth segment.

The last abdominal segment is very obtusely pointed posteriorly, being nearly round. The abdomen is broadest in the middle and tapers to each end. The uropods are as in the female.

The gnathopods are similar to those of the female, but the thumb is not so well armed, and the inner surface of the propodus has a comb of long, sharp spines, usually 7 to 10 in number, which extend across the article parallel to the joint with the dactyl. Of the legs the second pair are longer than those following.

The abdomen has five pairs of well developed, biramous pleopods, which are slightly smaller than those of the female, but have long setae extending beyond the terminal segment and, therefore, appearing in a view from above.

Leptochelia profunda sp.n. Figure 5.

Males and females of this species were obtained off Head Harbour Island at a depth of from 70 to 75 fathoms, from a bottom of sandy mud and stones on September 2nd, 1913.

Female: The body is elongate and filiform, being about six times as long as broad (about 2.7 mm.: 0.48 mm.). The head (cephalosome) is a little longer than wide, and is narrower at its anterior end than posteriorly. The anterior margin is excavated at each side of a small median projection for the reception of the first pair of antennae. The eyes are proportionately smaller than in the male. The first pair of antennae are triarticulate, the first article being long, the second one-third as long as the first, and the third nearly twice as long as the second. The second pair of antennae are as in the male.

The second (first free) thoracic segment is the shortest, the third, fourth, and fifth progressively longer, and the fifth, sixth and seventh progressively shorter. The gnathopods and the other thoracic legs are as in the male. The abdomen resembles that of the male. The pleopods have shorter setae than in the male, while the uropods may have only five segments in the inner branch, in which case the first article gives an indication of subdivision in the presence of a bristle about its middle.

Male: The body is long and filiform, being nearly six times as long as broad (about 2 mm.: 0.35 mm.). The

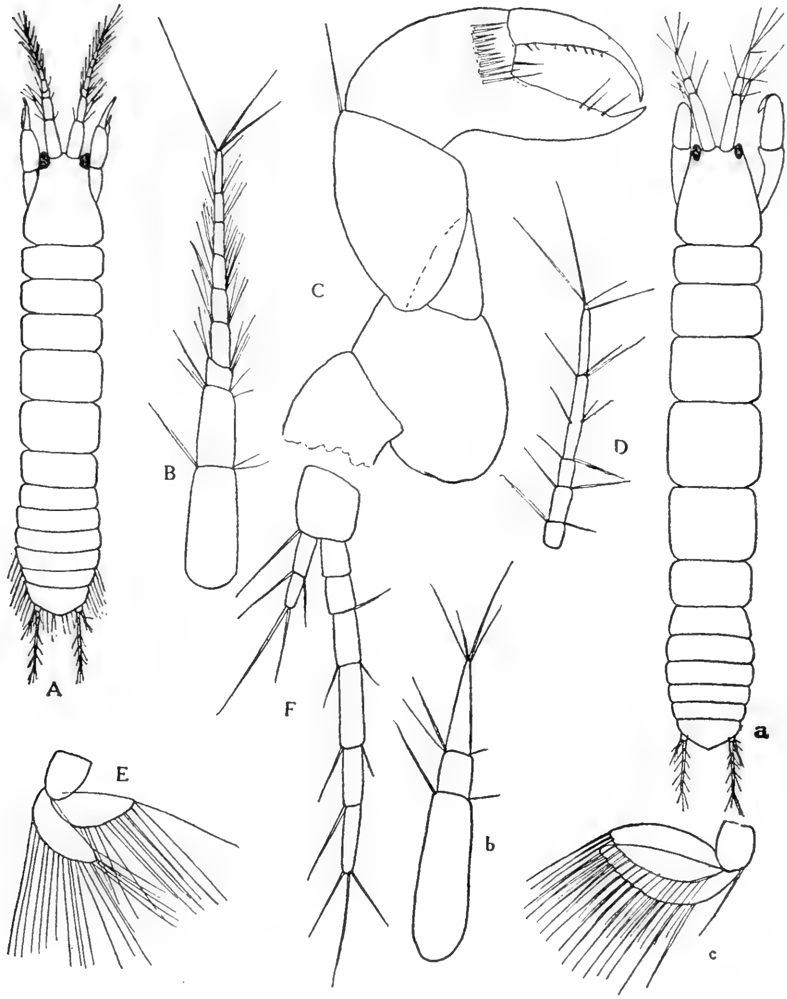

FIG. 5. Leptochelia profunda sp. n.; (A), male, dorsal view, x 30; (B), first antenna, x 120; (C), gnathopod, x 120; (D), second antenna, x 120; (E), pleopod, x 120; (F), uropod, x 180; (a), female, dorsal view, x 30; (b), second antenna, x 120; (c), pleopod, x 120.

head is about as long as it is broad and is narrower in front. The anterior margin is slightly excavated on each side of a short, median, blunt point for the first pair of antennae. The eyes are very large and occupy the anterolateral angles of the head. The first pair of antennae have the first article long and stout, the second about three-quarters of the length of the first and nearly as stout, and the third one-third as long as the second and with a slight projection on the medial side. The flagellum consists of six articles. The second pair of antennae consist of a peduncle with five articles and a single, minute, flagellar article. The first three peduncular articles are short, the fourth is nearly as long as the first three together, and the fifth is three-quarters as long as the fourth.

The second, third, fourth and seventh thoracic segments are subequal in length, the second being a little shorter than the others. The fifth and sixth segments are longer than any of the others and subequal.

The gnathopods are quite stout, and the propodus of each has on its inner, medial surface a comb of strong setae arranged in a line parallel to the joint with the dactyl. The other legs, which are ambulatory, have the dactyl produced into a sharp point, that of the second leg being much longer than those of the following.

The sixth abdominal segment ends posteriorly in an obtuse angle. The pleopods are like those of *L. filum* and have long setae projecting beyond the edges of the abdomen. The biramous uropods have the inner branch as long as the last three abdominal segments together and six-jointed. The outer branch is biarticulate and short, being equal in length to the first two articles of the inner branch.

This species differs from *L. savignyi* in that (1) the outer branch of the uropods is biarticulate, (2) the propodus of the gnathopods is devoid of teeth, and (3) the articles of the peduncle of the first pair of antennae have different relative lengths. It differs from *L. filum* in that (1) it is larger, (2) the males are relatively more numerous, (3) there are more articles in the flagellum of the first pair of antennae, (4) the inner branch of the uropod has six articles, and (5) the inner surface of the thumb of the propodus of the gnathopod is without teeth.

Family *Gnathiidae*

Gnathia cerina (Stimpson).

Richardson, 1905, p. 59.

This species was found in abundance throughout the Bay of Fundy and in Passamaquoddy Bay at depths of from five to fifty-five fathoms on sand or mud or among old shells, and on hard stony bottoms. Also the larvae were taken from the surface of the following fishes: winter flounder (*Pseudopleuronectes americanus*), cod (*Gadus callarias*), hake (*Urophycis tenuis* or *U. chuss*), and haddock (*Melanogrammus aeglifinus*).

Records: St. Croix River, off Atlantic Biological Station, 15 fathoms; Gleason's Cove, 1-5 fathoms; off Bald Head, Campobello, 20 fathoms; the Wolves, 16 to 35 fathoms; Grand Manan, off Fish Head, Duck Islands, Green Islands, and Southern Head, 12 to 55 fathoms. Eastport, 10 to 20 fathoms; off Head Harbour, 40 fathoms; Bay of Fundy, 25-30 and 60 fathoms (Harger, 1880). Off Cheney's Head, Grand Manan, 10 fathoms (Stimpson, 1853). In most cases males, females and larvae were obtained. Larvae alone were found living parasitically on fishes at the following localities: on flounder at Campobello Island; on cod and hake at Bliss Island; and on haddock in the St. Croix River and Passamaquoddy Bay.

Family *Anthuridae*

Ptilanthura tenuis, Harger.

Harger, 1880, p. 406.

Body very narrow and elongate, being ten times as long as broad (7.8 mm. long, 0.8 mm. broad.) Head a little broader than long with the anterior margin produced into a short and blunt rounded process which covers over the bases of the antennae. Eyes are small, rounded, and very distinct. The first antenna has the first two articles subequal in length, while the third is a little longer than the second. The fourth, or first article of the flagellum, is equal to the third, while the fifth is very minute.

The second pair of antennae have the first article very short; the second is about three times as long as the first; the third article is about one-half as long as the second; the fourth and fifth are a little longer than the third and are subequal. The flagellum is composed of three articles and is covered with hairs. The first pair of antennae extend to the end of the peduncle of the second pair. The maxilliped has a palp consisting of two articles. Each maxilla terminates in a number of conspicuous, sharp teeth. The labium terminates in two rounded lobes.

The first thoracic segment is longer than the head. The second and third are equal in length and each is a little longer than the first. The fourth and fifth are slightly longer than the third, and the sixth is a little shorter than the fifth, while the seventh is about half as long as the sixth.

The abdomen is more than twice as long as the seventh thoracic segment. Its first five segments are coalesced, only sutures indicating the segments. The sixth segment is free and bears the uropods. The terminal segment is evenly rounded posteriorly.

The peduncle of the uropods is as long as the superior branch, which is rather lanceolate in shape and acutely pointed posteriorly. The inferior branch is one-half as long as the peduncle and is rounded posteriorly.

The first three pairs of legs are prehensile in character while the others, though with recurved dactyls, are ambulatory in character.

The colour is a mottled brownish-red and white.

One specimen was taken in Seal Cove Sound, Grand Manan, at a depth of eleven and a half fathoms, fine sand bottom. Grand Manan (Harger 1880).

(Mr. Wallace believed this to be a species of *Cyathura*, judging by the partially fused condition of the abdomen, and by the presence of two joints in the palp of the maxilliped. There can, however, scarcely be any doubt but that this is the female of Harger's species, and consequently any distinct difference between the genera *Cyathura* and *Ptilanthura* must be restricted to the second pair of antennae of the male. A. G. H.).

Calathura branchiata (Stimpson).
Richardson, 1905, p. 72.

This form is very abundant in the Bay of Fundy, but not in Passamaquoddy Bay. Numerous specimens were taken near the Wolves Islands, near White Horse Island, and off Head Harbour Island at depths of from twenty to seventy-five fathoms on muddy bottom or in mud with sand and gravel. Off Duck Island, Grand Manan, 20 fathoms (Stimpson, 1853). Off Head Harbour, 75-80 fathoms; between Head Harbour and the Wolves, 60 fathoms; Grand Manan (Harger, 1880).

Family *Cirolanidae*

Cirolana polita (Stimpson).
Richardson, 1905, p. 99.

Specimens of this species were not very numerous, being taken only near West Quoddy head, Maine and at Grand Manan at depths varying from low tide mark to forty fathoms. The nature of the bottom on all occasions was soft fine sand.

Records: Inside West Quoddy Head, Maine, low tide and 9 fathoms; Whale Cove, Grand Manan, 30 to 40 fathoms; Woodwards Cove, Grand Manan, low tide and 2 fathoms. High Duck Island, Grand Manan, low tide (Stimpson 1853).

The specimens agreed with the description given by Richardson (1905, p. 99) except that there was a considerable variation in the number of articles in the flagellum of the second pair of antennae, the number ranging from 7 to 19, but usually there were 10.

Family *Aegidae*

Aega psora (Linn.).

Richardson, 1905, p. 168.

Only three individuals of the "salve-bug" were seen, and none of these was taken in Passamaquoddy Bay.

Records: From cod (*Gadus callarias*), near Campobello Island; from skate (*Raia radiata*) caught off North Head, Grand Manan; from skate (*Raia stabuliforis*) caught in St. Mary Bay, N.S.

Family *Limnoriidae*

Limnoria lignorum (Rathke). "Gribble".

Richardson, 1905, p. 269.

This isopod is abundant all through the region on nearly all submerged pieces of wood and timber, which it destroys by burrowing into them. Bay of Fundy (Harger, 1880).

Family *Idotheidae*

Chiridotea caeca (Say).

Richardson, 1905, p. 353.

The animals of this species were not so abundant as those of the next species and occurred only in very shallow water (two fathoms or less in depth) and on fine sand bottom.

Records: Inside West Quoddy Head, Maine, at low tide; Woodwards Cove, Grand Manan, at low tide and at a depth of about two fathoms.

The specimens ranged in size up to a length of about 15 mm.

Chiridotea tuftsii (Stimpson).

Richardson, 1905, p. 354.

This species was taken in abundance at depths of from 5 to 12 fathoms on sandy bottom.

Records: Duck Pond, Campobello, 5 fathoms; off West Quoddy Head, 9 fathoms; Seal Cove Sound, 12 fathoms; off Green Island, Grand Manan, 11 fathoms. At low water in Prince's Cove, Eastport (Harger, 1880). Off Cheney's Head, Grand Uanan, 10 fathoms (Stimpson, 1853).

An examination of numerous specimens showed the number of articles in the flagellum of the second pair of antennae to be variable, ranging from 10 to 14.

Idothea baltica (Pallas).

Richardson, 1905, p. 364.

This form is not very common in the Bay of Fundy nor in Passamaquoddy Bay. It was found usually at low tide among seaweed and eelgrass, and also on floating seaweed and at depths as great as 5 fathoms on gravel or sand bottom.

Records: Minister's Island, low tide; St. Croix River near Biological Station, at the surface on seaweed; Katy Cove, low tide; Deep Cove, Campobello, low tide mark; Woodward's Cove, Grand Manan, low tide; Grand Harbour, Grand Manan, 2 to 5 fathoms; Little River, St. Mary Bay, N.S., in lobster pond. Grand Nanan, rare (Stimpson, 1853). Bay of Fundy (Harger, 1880).

Idothea phosphorea (Harger).

Richardson, 1905, p. 366.

This is found more generally in the Bay of Fundy than is the preceding species, being taken in many places, at depths ranging from low tide mark to 15 fathoms, on mud, sand or sawdust, or on hard, rocky bottom.

Records: Minister's Island, low tide; Oak Bay, 5 to 9 fathoms; St. Croix River near Biological Station, 5 and 15 fathoms; Gleason's Cove, 1 to 5 fathoms; Woodward's Cove and Grand Harbour, Grand Manan, 2 to 5 fathoms; Lepreau ledges, low tide. Whiting River (Harger, 1880). St. Andrews region (MacDonald, 1912).

The number of articles in the flagellum of the second pair of antennae was noted to be as low as 10 in what were apparently adult individuals.

Synidotea nodulosa (Kröyer).
Richardson, 1905, p. 388.

Only two specimens were seen. One, taken near Green Islands, Grand Manan, at a depth of 11 fathoms, was olive green in colour and corresponded with the description given by Richardson (1905, p. 388). The other, dredged in Seal Cove sound, Grand Manan, at a depth of 12 fathoms on a bottom of fine sand, was dark, yellowish-brown, excepting the fourth thoracic segment, which was distinctly red. It differed otherwise in that the flagellum of the second pair of antennae consisted of eight articles instead of six, the tubercles on the body were much sharper, and the abdomen was more sharply pointed.

Edotea triloba (Say). Figure 6.
Synonyms:
Idotea triloba, Say, 1818, p. 425.
Epelys trilobus, Harger, 1873, p. 571, et auct. var.
Edotea triloba, Miers, 1883, p. 70 et auct. var.
Idotea montosa, Stimpson, 1853, p. 40.
Epelys montosus, Harger, 1873, p. 571, et auct. var.
Edotea montosa, Miers, 1883, p. 72, et auct. var.
Edotea acuta, Richardson, 1900, p. 228, and 1905, p. 395.

This species was found to be very abundant throughout the region, and occurred in depths ranging from low tide mark to 15 fathoms, and on a variety of bottoms—mud, sand, shells, rock and sawdust.

Records: Brandy Cove, off Joe's Point, and off Navy Island, St. Croix River, 2 to 15 fathoms; St. Andrews Harbour, 2 to 3 fathoms; Gleason's Cove, 1 to 5 fathoms; off Eastport, 10 fathoms; Deep Cove, low tide and Duck Pond, Campobello, 1 to 5 fathoms; off West Quoddy Head, 9 fathoms; entrance to Head Harbour, 5 fathoms; Bliss Island, low tide; Grand Harbour, 2 to 5 fathoms and Woodward's Cove, Grand Manan, 0 to 2 fathoms. Grand Manan (Stimpson, 1853). Eastport; Whiting River; Seal Cove, Grand Manan (Harger, 1880).

The size reached 10 mm.

The body is ovate, the length varying from two to two and one-half times the breadth, and the abdomen is usually about one-third the length of the entire animal.

The head is about twice as broad as long with the lateral angles markedly produced and varying in form from rounded lobes to knob or horn-like projections, as described by Richardson for *Edotea acuta*, all the intermediate stages being repre-

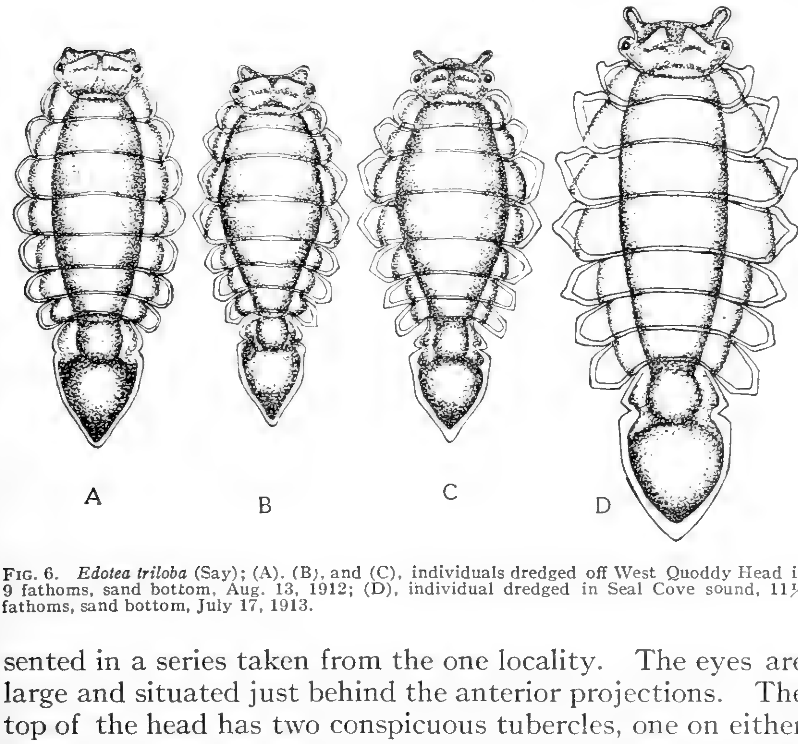

FIG. 6. *Edotea triloba* (Say); (A), (B), and (C), individuals dredged off West Quoddy Head in 9 fathoms, sand bottom, Aug. 13, 1912; (D), individual dredged in Seal Cove sound, 11½ fathoms, sand bottom, July 17, 1913.

sented in a series taken from the one locality. The eyes are large and situated just behind the anterior projections. The top of the head has two conspicuous tubercles, one on either side of the median line, close together and near the anterior end. Most of the individuals showed a slight depression just behind the tubercles, but not nearly so well defined as figured by Richardson for *Edotea acuta*, although in relatively the same position (see Figure 6).

The third and fourth thoracic segments are the longest and also the widest, being nearly equal in width. The epimera are firmly fixed to each segment. The lateral margins of the thoracic segments vary from being sharply angular and, in the case of the anterior ones, having more or less knob-shaped projections, to being broadly rounded or nearly straight, the intermediate conditions found forming a perfect series. The thorax in some individuals was quite convex centrally while in others it was comparatively flat, although those with the greater convexity were more numerous. The lateral portions of the segments are flatter showing a slight elevation towards the edge.

The abdomen is composed of a single segment with incisions of various depths near the base indicating a partly coalesced segment. The sides of the abdomen converge rapidly from a point a little below the middle, and the extremity varies from a triangular condition to a bluntly pointed one. Near the base is a large rounded eminence, which seems to be continuous with the convexity of the thorax; and separated by a deep depression from this tubercle is another elevation which extends nearly to the tip of the abdomen.

After a careful examination of a large series of individuals from the Bay of Fundy, there was found to be a complete gradation in the characters typical of *E. triloba*, *E. montosa* and *E. acuta*, there appearing all conditions of variation from one to another as regards length and form of the lateral projections of the head, borders of the thoracic segments, and general shape of the abdomen. The differences in the relative lengths of the antennae were so slight as to be useless for distinguishing distinct species. There appears to be, therefore, no good reason for separating *E. montosa* and *E. acuta* from *E. triloba*.

Family *Janiridae*

Jaera marina (Fabr.).
Richardson, 1905, p. 450.

This species is commonly found in tide-pools and under stones between tide-marks throughout the region. Grand Manan (Stimpson, 1853). Eastport; Dog Island (Harger, 1880).

The size attained was as great as 5.5. mm. in length.

A great variation in the number of articles in the flagellum of the second pair of antennae was found, one specimen having as many as fifty and yet in other respects agreeing with the typical individuals.

Janira alta (Stimpson).

Richardson, 1905, p. 475.

Specimens were taken in the Bay of Fundy at depths of from 14 to 75 fathoms on bottoms consisting of hard rock, sand, mud or shells. None were found in Passamaquoddy Bay.

Records: Wolves Islands, 20 fathoms; off Head Harbour Island, 70 to 75 fathoms; Head Harbour Passage (off Cherry Island), 42 fathoms; Whale Cove, Grand Manan, 20 to 30 fathoms; off Southern Head, Grand Manan, 14 fathoms. Grand Manan (Stimpson, 1853). Clark's Ledge near Eastport, low water; off Buckman's Head; off Todd's Head (Harger, 1880).

Family *Munnidae*

Munna fabricii, Kröyer. Figure 7.

Richardson, 1905, p. 480.

This was taken frequently in the Bay of Fundy, Passamaquoddy Bay and the St. Croix River, at low tide and at depths as great as 42 fathoms, on bottoms consisting usually of sand or mud, but also on those of hard rock or of sawdust.

Records: St. Croix River near Biological Station, 2 to 15 fathoms, Passamaquoddy Bay, off Tongue Shoal light, 5 fathoms; Head Harbour Passage (off Cherry Island), 42 fathoms; near North Head, Grand Manan, low tide mark; off Big Duck Island, Grand Manan, 42 fathoms. South Bay, Eastport, 12 fathoms (Harger, 1880).

The first pair of antennae reach nearly to the penultimate joint of the peduncle of the second pair. The flagellum has three or four joints, usually four.

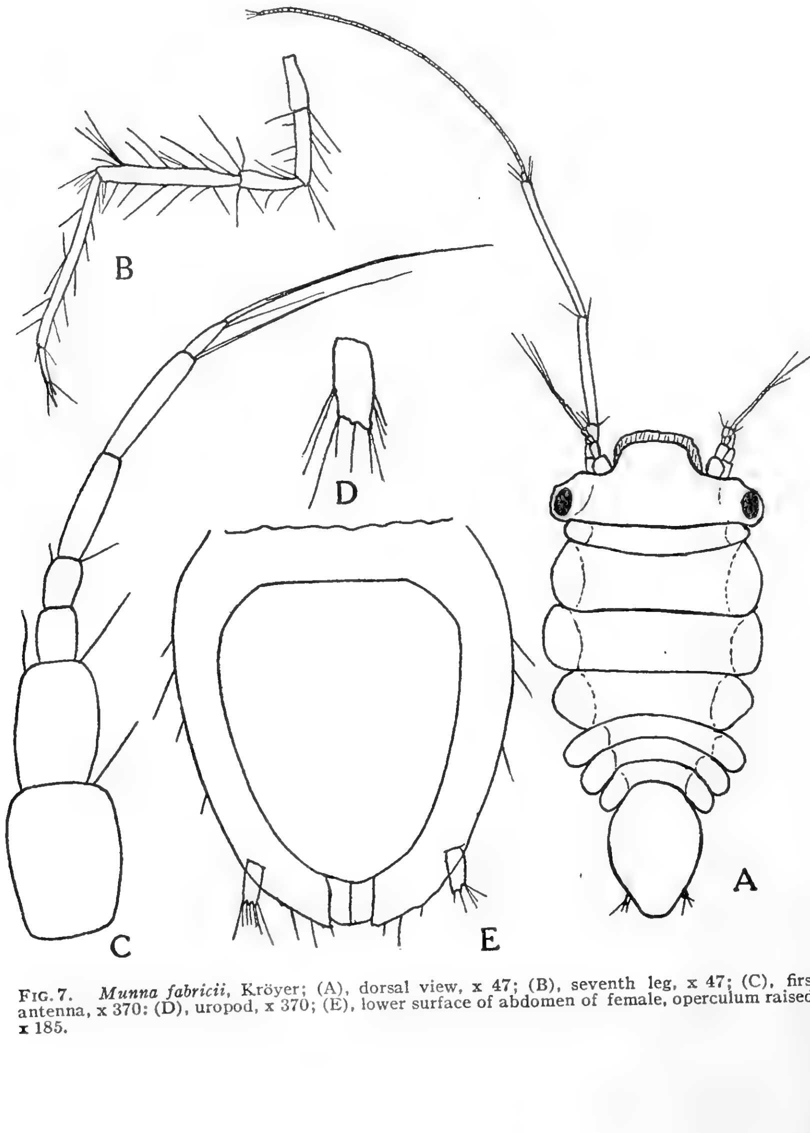

FIG. 7. *Munna fabricii*, Kröyer; (A), dorsal view, x 47; (B), seventh leg, x 47; (C), first antenna, x 370; (D), uropod, x 370; (E), lower surface of abdomen of female, operculum raised, x 185.

The flagellum of the second pair of antennae is longer than the peduncle, but varies slightly.

The uropoda are obliquely truncate, but usually show three processes from the free edge.

The caudal segment in large specimens has the apical lamella distinctly serrated and a small hair in place of the lateral denticle, although the size varies. Small individuals often failed to show the serrations on the apical lamella.

The colour was usually a dark dusky brown and often with black spots of pigment.

Pleurogonium rubicundum (G. O. Sars). Figures 8 and 9.
Sars, 1899, p. 113.

This species of *Pleurogonium* is much more restricted in habitat than are the other two that occur in this region. It was found only in the vicinity of St. Andrews, never in the open Bay of Fundy. It was confined to shallow water at depths of from 2 to 5 fathoms on bottoms of sand, mud or sawdust.

Records: Brandy Cove and near Joe's Point, St. Croix River, 2 to 4 fathoms; outside Tongue Shoal light, Passamaquoddy Bay, 5 fathoms.

Female (Fig. 9): The body is short and stout, being a little less than twice as long as broad. The head is not quite twice as broad as long and is rounded anteriorly. The eyes are entirely absent. The first pair of antennae project laterally from the head and have a peduncle of three articles, of which the first two are subequal, while the third is only about half as long as the others. The flagellum consists of three articles which are nearly subequal in length, the last article being surmounted by a stout bristle and a tuft of hairs. The second pair of antennae project dorsally and laterally from the head, and each is composed of a peduncle of six and a flagellum of seven articles. The first two articles of the peduncle are very small and inconspicuous from above, the third is long and has a decided protuberance on its outer side near the proximal end, the fourth is about one-half as long as the third and slightly expanded distally, the fifth article is one and one-half times and the sixth about twice as long as the fourth.

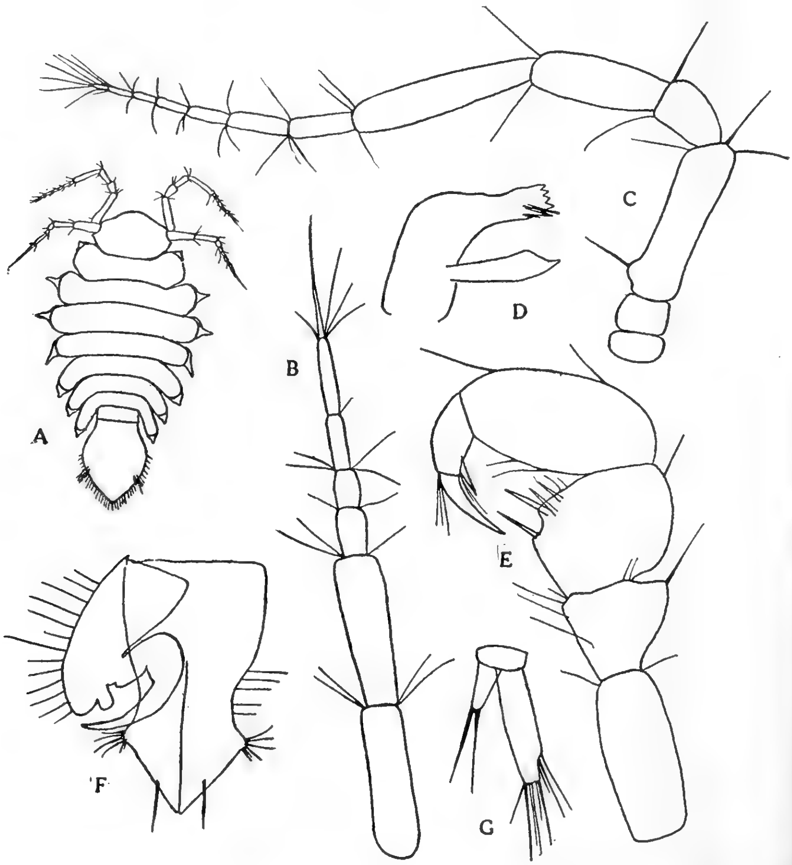

FIG. 8. *Pleurogonium rubicundum* (G. O. Sars); (A), male, dorsal view, x 30; (B), first antenna, x 240; (C), second antenna, x 240; (D), mandible, x 240; (E), gnathopod, x 240; (F), operculum, x 120; (G), uropod, x 240.

The first four segments of the thorax with the head are nearly circular in outline, while the last three are markedly narrower and are directed posteriorly. The body is broadest at the level of third thoracic segment. The lateral edges of the thoracic segments are rounded and from the middle of each projects a long, rod-like spine, those on the third segment being the longest.

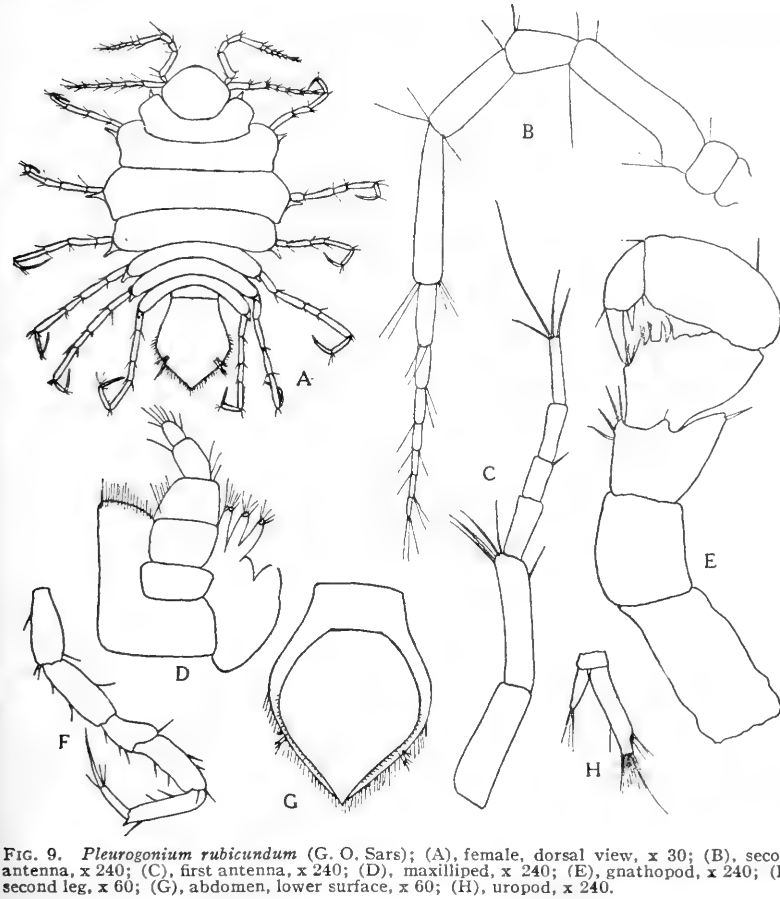

FIG. 9. *Pleurogonium rubicundum* (G. O. Sars); (A), female, dorsal view, x 30; (B), second antenna, x 240; (C), first antenna, x 240; (D), maxilliped, x 240; (E), gnathopod, x 240; (F), second leg, x 60; (G), abdomen, lower surface, x 60; (H), uropod, x 240.

The abdomen is very narrow at the base but widens very much, and again narrows to end in an obtusely pointed tip. The sides of the abdomen are evenly curved and fringed with hairs. The operculum is a little narrower and more sharply pointed than the abdominal segment.

The uropods are terminal and biramous, the outer branch being extremely small, while the inner one is about three times as long and has a slight notch in its inner edge.

The mandible has a slender molar expansion and a cutting part with four teeth. The palp of the maxilliped consists of five articles. The first thoracic leg on each side is strongly recurved for seizing, the carpus strongly armed with spines, and the propodus oval and dilated. The other legs are ambulatory in character.

Male (Fig. 8): The body is short and oval being about twice as long as broad (1.2 mm.: 0.66 mm.). The head is a little broader and not as long as in the female. The eyes are entirely absent. The two pairs of antennae are practically the same as those of the female.

The thorax does not show a distinct division into a rounded anterior portion and a narrower posterior part, but broadens gradually to the third and fourth segments and then narrows. The lateral spines are not quite so pronounced as in the female.

The abdomen, uropods, first legs, and mouth parts are similar to those of the female, but the operculum differs from that of the female in consisting of three parts, an unpaired medial and paired lateral parts. The medial portion is lanceolate in shape and bears a tuft of short, stout hairs at the ends of the expanded points and the lateral parts are oval and flat, and each has a palp-like pointed process on the inner edge.

Pleurogonium inerme, (G. O. Sars). Figure 10.

Sars, 1899, p. 114.

This species is somewhat restricted to the inner bays, where it is fairly abundant at depths of from 2 to 10 fathoms on bottoms of mud, sand or sawdust, but a few were taken on hard bottom at a depth of 15 fathoms. It was taken in the open Bay of Fundy at the Wolves on one occasion.

Records: Oak Bay, 5 to 9 fathoms; Brandy Cove, Joe's Point reef, and opposite Robbinston, St. Croix River, 2 to

15 fathoms; St. Andrews harbour, 2 to 3 fathoms; off Tongue Shoal light, Passamaquoddy Bay, 5 fathoms; Wolves Islands, 16 fathoms.

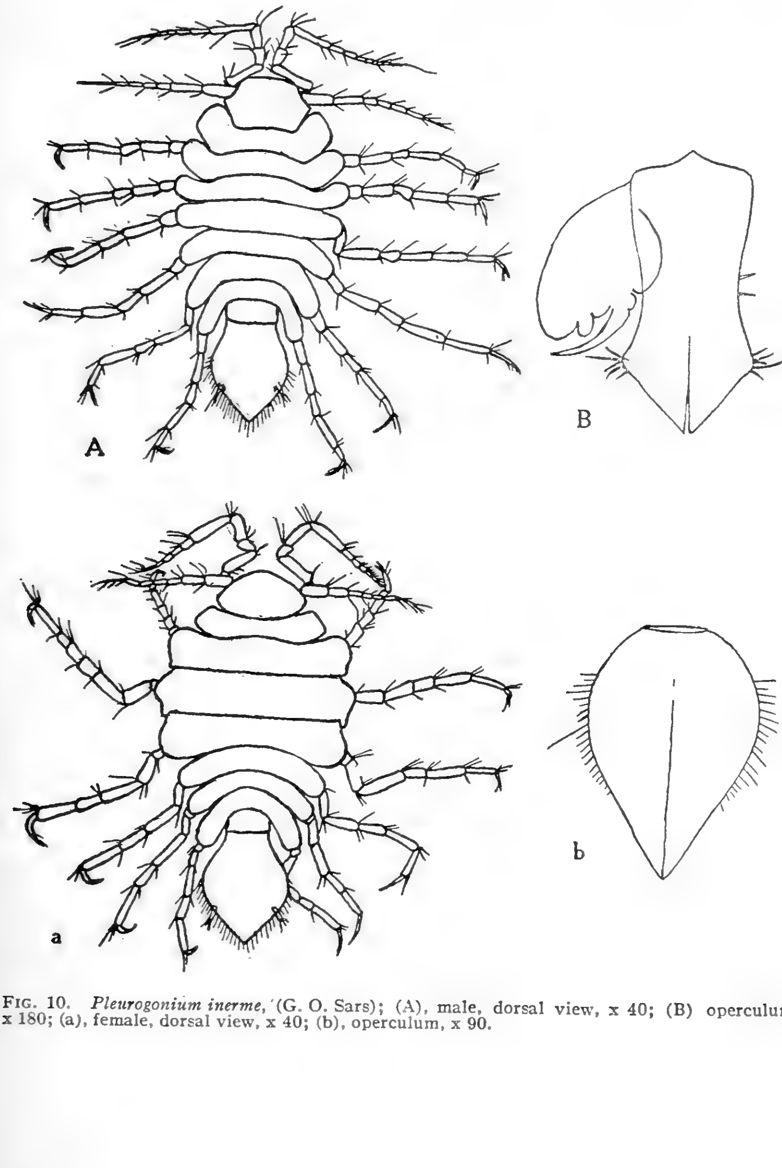

FIG. 10. *Pleurogonium inerme,* (G. O. Sars); (A), male, dorsal view, x 40; (B) operculum, x 180; (a), female, dorsal view, x 40; (b), operculum, x 90.

Female: The body is short and stout, being a little less than twice as long as broad (1.5 mm.: 0.85 mm.). The head is about twice as broad as long and rounded anteriorly. Eyes are entirely absent. The first pair of antennae have a peduncle of three articles of which the first two are long and subequal, and the third one-half as long as the second. The flagellum consists of three articles, of which the first is about one-half the length of the last article of the peduncle, and the second and third subequal and one and one-half times as long as the first. The third article is surmounted by a stout bristle, which is as long as the last two articles together. The second pair of antennae have a peduncle of six and a flagellum of seven articles. In the peduncle the first two articles are very short and equal in length, the third is long and has a prominent protuberance on the outer side near the proximal end, the fourth is less than one-half as long as the third, the fifth is slightly longer than the fourth, and the sixth is twice as long as the fifth.

The four anterior segments of the thorax are nearly circular, while the last three are decidedly narrower, the thorax being broadest at the third segment. The lateral edges of all the thoracic segments are rounded.

The abdomen is much constricted at its base from which it broadens and then narrows to end in an obtusely pointed posterior extremity. The lateral edges are evenly curved and fringed with hairs. The operculum is not as broad as the abdomen and tapers to a sharper point.

The uropods are terminal and biramous, the peduncle consisting of a single short article. The outer branch is extremely small while the inner one is nearly three times as long.

The first leg has the dactyl strongly recurved and is almost exactly the same as that of the preceding species, as is the case also with the other legs. The mandibles are much as in the preceding species, having a slender molar expansion and a cutting part with four teeth. The other mouth parts also are almost the same as those of *P. rubicundum*.

Male: The body is small and oval, being only a little more than twice as long as broad (1.17 mm: 0.55 mm.), resembling that of the young female. The head is about twice as broad as long and is rounded anteriorly. The two pairs of antennae are as in the female.

The thorax does not show two distinct regions as in the female, and is widest at the level of the third and fourth segments, which are subequal in width. The lateral edges of all the thoracic segments are rounded.

The abdomen and uropods are practically the same as those of the female, except that the operculum consists of the usual three parts, of which the medial is lanceolate, with expansions near its middle, each expansion bearing a tuft of short strong bristles, and the two lateral flat and ovate, each having a palp-like pointed process on its medial side.

The first leg and mouth parts are as in the female.

Pleurogonium spinosissimum (G. O. Sars). Figure 11.
Sars, 1899, p. 115.

This species has a wider distribution than either of the other two species of the genus in our waters, and it was found as frequently in the open Bay of Fundy as in Passamaquoddy Bay. It occurred at depths ranging from 2 to 75 fathoms, chiefly on bottoms of sand and mud, but also in old shells, or on gravel or stones.

Records: Oak Bay, 5 to 9 fathoms; Brandy Cove and opposite Robbinston, St. Croix River, 2 to 15 fathoms; off Head Harbour Island, 70 to 75 fathoms; Wolves Islands, 16 to 30 fathoms; off Low Duck and Big Duck Islands, Grand Manan, 34 and 42 fathoms; Grand Harbour, Grand Manan, 2 to 5 fathoms.

Female: The body is about twice as long as broad (about 2.25 mm. : 1.2 mm.). The head is twice as broad as long and rounded anteriorly. It is emarginate on each side of the origin of the antennae. The eyes are entirely lacking. The peduncle of the first pair of antennae consists of three articles, of which the first is slightly longer than the second, and the third one-half as long as the second. The flagellum consists of three articles, of which the first two are subequal, and the third somewhat longer and surmounted by a stout bristle. The second pair of antennae have a peduncle of six and a flagellum of seven articles. In the peduncle the first two articles are short and inconspicuous viewed dorsally, the third is long and has a distinct tubercle on its outer side near the proximal end, the fourth is one-third the length of the third, the fifth is slightly longer than the fourth, and the sixth is twice as long as the fifth.

The first four segments of the thorax are subequal in length while the last three are short and nearly equal in length. The lateral edges of the first four segments are produced each into an irregular angle, from the anterior side of which there projects a long, sharp, diverging, serrated process. The angles of the fourth segment are not nearly so marked as those of the preceding three. Each of the last three segments has a long serrated spine on each side, just as in the anterior ones.

The abdomen is very broad and sharply pointed posteriorly. The operculum is very broad at its middle and is produced into a very sharp, acute tip posteriorly. The uropods are much as in *P. rubicundum*.

The mouth parts and the legs (except the first pair) closely resemble those of the two preceding species, while the carpus and propodus of the first pair of legs are more strongly armed than in those species.

The colour is usually brownish or reddish-brown.

Male: The body is longer and narrower than that of the female, being nearly twice as long as broad (about 1.4 mm.: 0.6 mm.).

The head is much as in the female, as are also the antennae and mouth parts.

The thorax differs from that of the female in that the angular processes from the lateral edges of the first four segments are not nearly so pronounced and are almost entirely absent in the fourth segment. The legs, including the first pair, are like those of the female.

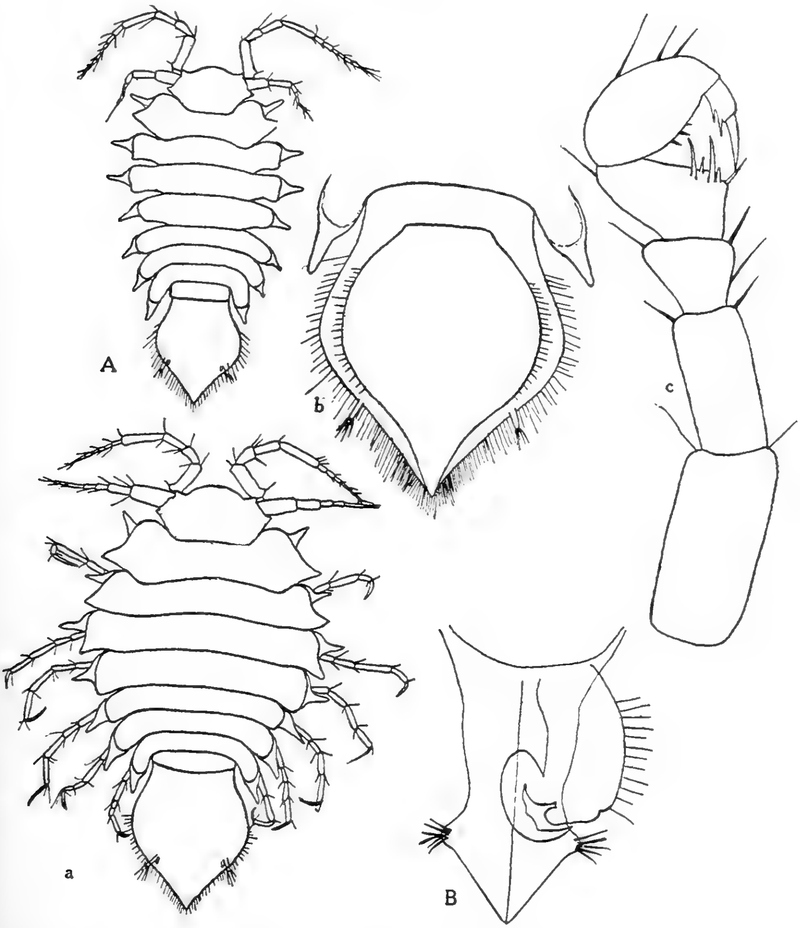

FIG. 11. *Pleurogonium spinosissimum* (G.O.Sars); (A), male, dorsal view, x 30; (B), operculum x 120; (a), female, dorsal view, x 30; (b), abdomen, ventral surface, x 60; (c), gnathopod, x 60.

The abdomen and uropods resemble those of the female. The operculum, which varies much in both sexes, is in the male composed of the customary three segments, the central part being lanceolate in shape and having an expansion in the middle bearing on each side a tuft of short, stout hairs, and the two lateral portions being flat and oval in outline, and each having a palp-like projection from its medial side, much as in the male of *P. inerme*.

Family *Munnopsidae*

Munnopsis typica. M. Sars.
Richardson, 1905, p. 486.

A single specimen was taken, swimming freely at the surface at the mouth of Harbour de Loutre, Campobello Island. The vertical currents resulting from the vigorous flow of the strong tides through the narrow and deep Head Harbour passage have apparently brought this deep water species to the surface. It had previously been dredged by the United States Fish Commission expedition between Head Harbour and the Wolves at a depth of 60 fathoms.

Eurycope mutica. G. O. Sars. Figure 12.
Sars, 1899, p. 149.

Only five specimens in all were obtained, three of these in the St. Croix River off Robbinston at a depth of 15 fathoms, on hard, rocky bottom, and two near Tongue Shoal light, Passamaquoddy Bay, at a depth of 5 fathoms on muddy bottom.

The body is short, oval and compact, being slightly less than twice as long as broad and having the greatest width at the middle (1.33 mm.: 0.75 mm.) The anterior end of the head is broad, rounded, and deeply excavated on either side for the reception of the antennae. The lateral margins of the head are produced into short, sharp processes. The superior antennae are short, and each has a very stout basal article. The second article is much more slender and not quite so long, the third and fourth are subequal and together equal to the second, and the flagellum is composed of four articles. The second pair of antennae consist each of a peduncle of five articles and a multiarticulate flagellum twice the length of the peduncle, the entire antenna being twice as long as the body.

The thorax consists of six distinct segments, the fifth showing indications of a subdivision by sutures which reach

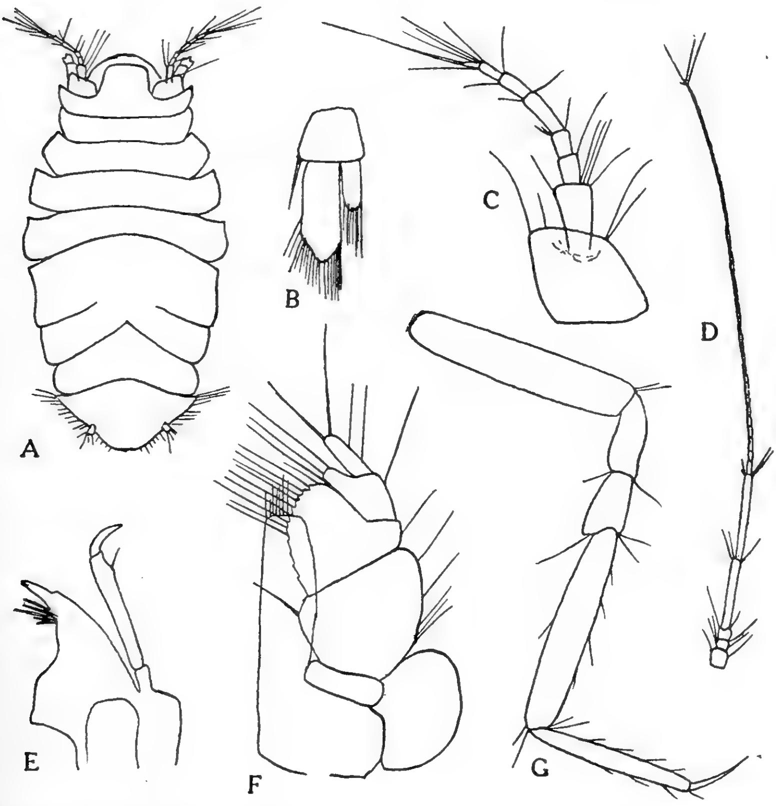

FIG. 12. *Eurycope mutica*, (G. O. Sars); (A), female, dorsal view, x 40; (B), uropod, x 160 (C), first antenna, x 160; (D), second antenna, x 40; (E), mandible, x 160; (F), maxilliped, x 160; (G), first leg, x 160.

half way across the body. The lateral margins of the segments are not very sharply produced anteriorly. The abdominal segment is rounded posteriorly while its lateral margins are slightly coarctated.

The legs of the first pair are comparatively short, and have the propodal joint shorter than the carpus, and the dactylus very small. The natatory legs have the carpal joint oval in shape with a slight expansion on one side. The uropods are very small and biramous, each branch being uniarticulate. The outer branch is oval and about one-half as long as the inner, which is lanceolate in shape.

The mandibles have cutting edges of sharp teeth and large, broad, molar expansions; the palp is large and curved. The maxillae are normal. Each maxilliped has a palp of five articles and an epignath which is short, broad and obtusely truncated at the tip.

Family *Bopyridae*

Phryxus abdominalis (Kröyer).

Richardson, 1905, p. 500.

This parasite was found only on specimens of *Spirontocaris pusiola*, which were collected at the following places: — Minister's Island, Passamaquoddy Bay, low tide; Head Harbour, Campobello Island, 5 fathoms; Grand Passage, off Dartmouth Point, St. Mary Bay, N.S., 15 fathoms; between North-west ledge and Brier Island, N.S., 32 to 36 fathoms.

Bopyroides hippolytes (Kröyer).

Richardson, 1905 p. 567.

This species was taken at the following places:—Digdequash Harbour, 9 to 11 fathoms, on *Spirontocaris polaris*; south-east from Swallow Tail light, Grand Manan, "hake grounds", on *Spirontocaris spinus;* High Duck Island, Grand Manan, low tide, on *Spirontocaris pusiola*. Bay of Fundy on *Spirontocaris spinus* and *S. pusiola*. (Harger, 1880).

Family *Oniscidae*

Cylisticus convexus (De Geer).

Richardson, 1905, p. 609.

Specimens of this species were obtained from under decaying bark at Chamcook Mill near St. Andrews, and others were found by Dr. Philip Cox at Fredericton under stones.

Porcellio rathkei (Brandt).

Richardson, 1905, p. 617.

A few specimens of this form were taken in dry sand and also in shaded woods near St. Andrews, also some by Dr. Cox at Fredericton.

Porcellio scaber (Latreille).

Richardson, 1905, p. 621.

This species is common under driftwood above high tide throughout the region.

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BIOLOGICAL SERIES

No. 19: AN EGG OF *STRUTHIOLITHUS CHERSONENSIS* BRANDT, BY B. A. BENSLEY

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University of Toronto Studies

AN EGG OF STRUTHIOLITHUS CHERSONENSIS BRANDT

BY

B. A. BENSLEY
Professor of Zoology in the University of Toronto

AN EGG OF STRUTHIOLITHUS CHERSONENSIS BRANDT

In February, 1919, the Royal Ontario Museum of Zoology, Toronto, acquired a fossil or semi-fossil egg, the features of which agree in all essential respects with the original and later descriptions of the type upon which Brandt's species *Struthiolithus chersonensis* was founded. The specimen was presented to the Museum by the Reverend Harold M. Clark, of the Presbyterian Foreign Mission, formerly resident in Honan, China.*

Remains of *Struthiolithus chersonensis* are of interest from several points of view. Some half dozen eggs are known with certainty, and three have been described or noted. The specimens indicate a struthious bird, even if not of the genus *Struthio*, and evidently much larger than existing ostriches. No skeletal remains have been reported, though they must occur abundantly in the extensive Pleistocene deposits of eastern Asia. The continental distribution indicated by the points of discovery is not paralleled by any existing or fossil species, the former having a range which is African and Arabian (*S. camelus*), while the latter so far have been reported from the Tertiary deposits of Samos and of the Siwalik Hills of India as skeletal remains not differing greatly from the modern species, and not of size relations suggesting *Struthiolithus*. At the same time the occurrence of *Struthiolithus* remains in north-eastern China suggests a connection of the old world species with the nandu or three-toed ostrich of South America, though again there is no evidence of struthious birds in North America and accordingly no evidence of the utilization of the Behring Straits bridge as for the holarctic Tertiary mammals.

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*Vide Proc. and Trans. Roy. Soc. Can., vol. XIII, 1919. A second specimen also obtained by Mr. Clark has since been acquired, and has been presented to the British Museum.

Struthiolithus chersonensis was established by Brandt ('72) for the original egg, found in 1857 at Malinowka, Cherson Government, in southern Russia. The specimen was found floating in the water behind a mill weir, where it had evidently been washed out of the stream bed. Brandt's description of the egg includes the principal measurements, and he had also prepared a rough plaster mould. The specimen, however, was held for a price of one thousand roubles, and, not being sold, remained for many years in the possession of the owner or of his family, until finally it was accidentally broken into thirty-six pieces. At least some of the fragments ultimately found their way into the Petrograd Museum. The whole episode of the egg and its fate is reported by Brandt ('85) in a subsequent article, the contents of which are by no means lacking in human interest. The ill-wind, in this instance at least, furnished an opportunity for examining the structure of the egg shell, on the strength of which Nathusius ('86) confirmed its ostrich-like nature, even going so far as to declare it generically inseparable from the existing *Struthio*.

No further specimens were reported until 1898 when a second egg was brought to America and acquired for the Museum of Comparative Zoology of Harvard College. The specimen was found at a place some fifty miles south-west of Kalgan in Manchuria, and has been minutely described by Eastman ('98), who states that there were two of the eggs, probably in association, one, however, having been broken.

In 1915 a third specimen was found in the province of Honan by a Chinese workman who saw it protruding from the bank of the Yellow River. A short note concerning its acquisition by the American Museum of Natural History is contained in the *American Museum Journal* ('17), the reference to which, together with particulars of the egg, were kindly furnished by Mr. Walter Granger and Dr. F. A. Lucas. The discovery of this specimen is referred to in *Nature* ('18) in a review which has also a bearing on the present specimen.

"Eggs of an extinct ostrich are already known from the surface deposits of northern China. One specimen from Yao Kuan Chang, fifty miles south-west of

Kalgan, was obtained by Harvard University in 1898, and another specimen from the banks of the Yellow River in Honan was acquired by the American Museum of Natural History last year. Mr. Harold M. Clark of Wuan, Honan, now writes to the North China Herald that eggs of this kind are not uncommon in his neighbourhood, and are washed out of the river banks by floods. They seem to occur in the same manner as the eggs of Aepyornis on the shores of lakes in Madagascar. The Chinese eggs are about 7 in. in length, and thus scarcely larger than those of an average ostrich. No bones of birds which laid the eggs have hitherto been noticed in the same deposits."

Concerning the present specimen, Mr. Clark states that he obtained it from a native friend who is a travelling collector and dealer in curios. There is no exact information as to the geological setting. The egg was originally owned, and probably obtained, by a native workman in the village of Chwan Hu, in the extreme northern part of Honan, near the Pe Chi Li boundary. It was later borrowed by some rich relatives and taken to a neighbouring village of I Cheng, some ten miles distant, where it was exhibited at fairs. After purchasing the specimen, Mr. Clark heard of the existence of a very large egg in this village and was able to establish that it was the one in his possession.

As to the common occurrence of these eggs Mr. Clark states that the newspaper report as quoted above is inaccurate. In addition to the second specimen acquired by him, and knowledge of the American Museum specimen, he has a fairly definite recollection of having been told of a fourth specimen which was formerly in an educational museum at Tungchow, near Peking, but was destroyed during the Boxer uprising of 1900.

The specimen (Plate I) is complete except for a small perforation of about 15 mm. in diameter near one end. The longitudinal contour is evenly elliptical as in ostrich eggs generally, showing no indication of the polar inequality of the eggs of birds otherwise. Less than one-third of the surface, comprising an oval patch, is considerably eroded, while the balance is intact, giving the impression that the egg had been partly exposed for some time and had then suddenly been washed out of the earth. The intact portion of the surface is more closely, and in some respects more finely pitted than in any ostrich eggs available for comparison. Unfortunately the available descriptions of the eggs of the four existing species of African ostriches are widely divergent as regards the appearance and texture of the shell. The pits show a tendency to run together into short irregular depressions, due in part perhaps to the finer erosion of the surface. The interior of the shell is smooth, without encrustations and has a remarkably clean and fresh appearance. It shows a yellowish colour interspersed with dots of brown.

The chief measurements are set forth below in comparison with those reported by Eastman for the Harvard specimen and that of Brandt.

	Brandt Type	Harvard sp.	Toronto sp.
Longitudinal axis	18.0 cm.	18.0 cm.	18.1 cm.
Transverse axis	15.0	14.75	14.6
Ratio of axes	1.20	1.22	1.24
Major circumference	52.0	51.35	51.3
Equatorial circumference	46.0	46.45	45.75
Shell thickness	2.65	2.20	1.98
Capacity	2075.0	1896.90	1829.0

It will be seen from the data included above that the principal measurements are almost identical with those of the specimens previously described. There is a difference of some 67 c.cs. in cubic content of the Harvard and Toronto examples, but there are also undoubtedly differences of uniformity in contour in the latter and some indication of differences in the thickness of the shell, the measurements being made directly at the opening with a micrometer gauge. Concerning the weight of the shell in relation to its alteration, the figures for the Harvard and Toronto specimens are respectively 310.05 and 380. grams.

It is evident both from the ordinary appearance of the egg of *Struthiolithus* and a comparison of the principal axes and cubic contents that the size is much greater than in the four existing species of African ostriches. Thus the largest specimen of the latter quoted by Eastman (loc. cit.) gives longitudinal axis 16.38 cm., a difference of 1.62, while the cubic content is 1423.63, a difference of 473.27 c.cs. or of 405.37 c.cs. as compared with the Toronto specimen.

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EGG OF STRUTHIOLITHUS CHERSONENSIS

HONAN PROVINCE, CHINA

Full size photograph

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No. 1

A PLAN FOR THE BIOLOGICAL INVESTIGATION OF THE WATER AREAS OF ONTARIO

BY

B. A. BENSLEY

OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

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A PLAN FOR THE BIOLOGICAL INVESTIGATION OF THE WATER AREAS OF ONTARIO

During the past two years a considerable amount of attention has been given to the organization within the Department of Biology of the University of Toronto of a research branch to be devoted to the investigation of the water areas of Ontario with reference to existing biological conditions and economic problems. It has been proposed to carry on the work of this branch under the title "Ontario Fisheries Research Laboratory", some distinction being necessary to indicate its scope and outlook, as also to draw a line of demarcation between this and other interests of the Department, and being especially advisable in view of the work now conducted in marine biology. Moreover a special name is advisable in order to establish a basis for the better classification of publications which in this instance may be expected to appeal for the most part to those interested in general limnology or in conservation and fishery problems. Apart from the provision of apparatus and equipment the initial step in the formation of the new organization was the appointment of Professor W. A. Clemens as Limnobiologist, an arrangement which renders possible full time service and supervision of field operations at any part of the year, and also provides for continuous investigation of the collected material and data. The first reports of a technical nature are now in course of publication. They refer principally to some special fisheries work on Lake Erie, but will be followed by a series of papers dealing with Lake Nipigon. The latter will be in a sense the products of the first field party, consisting of Professor Clemens and other members of the university and museum staffs who spent the greater part of the summer of 1921 in practical operations on the lake.

The study of the scientific aspects of fishery questions is one for which the University Biological Laboratory is especially fitted. Its position as part of the provincial educational system identifies its interest in matters touching the natural resources with that of the province at large. Nearly thirty years ago the desirability of a systematic biological survey of the provincial waters was urged by Professor Ramsay Wright ('92), and in the interval the need of a thorough investigation of the factors underlying the distribution of aquatic organisms has become increasingly evident. Neither individual efforts nor the collective participation of members of the university staff in the work of the Georgian Bay Biological Station, which was maintained for some years in that region, led to the consideration of any measures upon which the hope of a continuous if not permanent organization for the biological investigation of provincial waters could be based. That the latter now appears within the range of possibility is therefore a matter of some satisfaction.

The following pages are devoted to a general discussion of the proposed line of investigation. This is mainly a matter of the relation of limnology at large to local conditions as represented by the waters of the Province of Ontario, with particular reference to general and economic problems. The principal topics considered are (a) the relation of the proposed investigation to the practical and administrative aspects of conservation, (b) the foundations of limnology, (c) the extent of the local fish fauna, and (d) the chief physical features of the provincial water areas, including, first, the provincial portions of the Great Lakes and, second, the land-enclosed areas, from the point of view of their limnological study and the nature of economic questions. Except in the case of the fishes, which occupy a central position in respect of the economic outlook, no reference will be made to particular groups of organisms.

The distinction often made between theoretical and applied or economic considerations is generally recognized as purely a matter of convenience in description. Its value, if any, consists in denoting the purpose or outlook implied. There is, however, a relation between investigation of an economic kind or purpose and practical or administrative measures. In Canada, as elsewhere, various questions, partly of revenue, partly of control of exploitation of natural resources, wastefulness and many other matters having to do with natural wealth, gave rise long ago to regulative measures, and more recently to a public movement in the direction of conservation. More intricate perhaps than in other fields, because of the elusiveness of wild life and the obscure factors upon which its success depends, the problems of conservation as applied to living organisms were early recognized as involving scientific knowledge of an exact kind. On the other hand, the desire to arrive at what would usually be considered expert information has, in a great many instances, painfully evident in the literature of conservation, given rise to confusion as to the extent and method of its application, resulting in the concealment of many sound practical ideas in a mass of information relating to general natural history. Measures of conservation as applied to the fisheries, including under the term also regulatory legislation, which has or ought to have a similar effect, consist broadly in striking a reasonable balance between forces of utilization and those of natural and articifial replacement. In this process the administrative function is the first necessity; technical practice, as, for example, fish breeding and economic industrial processes, is next in order of urgency, while scientific investigation is accessory or contributory. Its value consists in the analysis of all factors physical, chemical and biological, and in drawing attention to particular factors the neglect of which may result in ineffective practice or futile legislation.

The early development of fresh water biology in Europe, in many respects the foundation of similar work in America, established first of all the identity and distribution of the various species of aquatic organisms, and, second, the association of these organisms with environmental conditions; to a certain extent also it carried out the classification of these conditions on the basis of their mutual associations. After nearly one hundred years of individual, and for the most part isolated, effort on the part of early biologists, among whom will be found some whose names are foremost in the records of biological science, it gave rise, mainly through the efforts of Forel, Apstein, Zacharias, Zschokke and others, to an attempt at correlation of limnological results, best expressed by Zacharias ('91) and his co-workers in their compilation dealing with the fauna and flora of fresh water. The extensions of this earlier work not only resulted in a more thorough enumeration of species in local European areas, but also gave rise to the study of physical and chemical factors, environmental communities, plankton determination, and the formal and institutional recognition of limnology, as best exemplified by the complete limnological study of Lake Geneva by Forel ('92) and the establishment through Zacharias ('93) of the Biological Station of Plön after the pattern of the marine institution at Naples.

American limnology, which naturally had a later origin, has the same foundation and in some respects a similar development. That it may be said to have only recently arrived at the stage of collective recognition is due to a variety of circumstances, including no doubt the great area to be covered in the classificatory study of the various groups, and the fact that the accumulation of information bearing in one way or another upon general limnology, as, for example, in the fisheries, natural resources in general, conservation and the like, has been almost from the beginning the particular interest of government bureaus, and of surveys and commissions under state or national auspices. Though the study of the water areas as entities, or complete physical-biological complexes, has not yet arrived at a stage of development commensurate with its great importance, its recognition is at least assured. As long ago as 1887 the principle was advocated by Professor Forbes ('87) and its application is observable in his later work ('08) in association with Richardson, Kofoid ('03) and others on the Illinois river system. The same principle is exemplified in the work of others, some of whom owe their inspiration to the example of Professor Forbes, including that of Reighard ('94) on

Lake St. Clair, Ward ('96, also '18) on Lake Michigan, Birge and Juday ('11) on the inland lakes of Wisconsin, the study of physical factors and their association by Needham and Lloyd ('16), Shelford ('13) and Adams ('13), and finally the recent work of Evermann and Clark ('20) on Lake Maxinkuckee, Indiana, in some respects the most complete study of an individual lake yet available in America. Not a small part in the collection of data bearing upon limnology has been taken by state organizations, by the establishment of temporary or permanent biological field stations (Ward '98, Needham and Lloyd '16) and the recognition of the state university as the natural centre of such investigation. On the other hand, while the results of investigation wherever conducted have at least some measure of general applicability, it is unfortunate that the study of limnology has not proceeded along more uniform and better organized lines. The paucity of information concerning the water conditions of all the Canadian Provinces and certain of the States is in marked contrast to the extensive information available in respect of certain States, notably Illinois and Wisconsin. What is chiefly significant, however, is the contrast between European and American efforts in general in view of the opportunities offered. If there is any one single outstanding fact concerning the importance of American water areas, it is the fact of the existence of a mid-continental area of some 80,000 square miles represented by the Great Lakes of the St. Lawrence basin. Parts of a great international waterway, locally shared by one Canadian province, and eight states of the Union, the centre of an old established fishery, the Great Lakes constitute in all respects the outstanding fresh water area of the world. Had the example of Forel and of Zacharias been followed we should have had available on the Great Lakes either an extensively equipped limnological institution or at least some specific organization devoted to the study of the area in all its aspects. The question is not one of simply local concern, though it is evident from geographical considerations that it is one in which the Province of Ontario is vitally interested.

While various groups of aquatic organisms are directly or indirectly involved in questions of an economic kind, it is obvious that the fishes are the ones chiefly concerned. To what extent are they represented in Ontario? The commercially recognized fishes, including the more desirable species, lake trout, whitefish, ciscoes, tullibee, doré and sturgeon, as well as the coarser species, pike, carp, mullets and catfish, and the game fishes, principally speckled trout, small and large mouthed bass and maskinonge, are collectively a small, though very important part of the local fauna. The number of fish species, fresh water and marine, occurring in Canadian and Newfoundland waters, is stated by Halkett ('13) to be 569. Evermann and Goldsborough ('07) place the number of fresh water species occurring in Canada as a whole at 145, representing 67 genera and 25 families. In the first computation of the number occurring in Ontario (Wright '92) reference is made to forty or fifty species, but the local records were at that time very incomplete, and the computation was doubtless based to some extent on the earlier reference compilation of Jordan and Gilbert ('83) later greatly extended and revised by Jordan and Evermann ('96). The most complete index of Ontario fishes is that of Nash ('08), based partly on the foregoing compilation checked against collections from various points in the province. The total number is placed at 112, representing 69 genera and 26 families. Though this computation precedes some other taxonomic work, notably that of Jordan and Evermann ('11), and though much is yet to be done in the matter of critical diagnosis of species from individual areas, it is probable that the number of species occurring in Ontario is in the neighbourhood of 125. While this representation is fairly large as to species and apparently very inclusive as to families and genera as compared with Canada as a whole, it is probable that the number of species occurring at any one point is less than half the total. The number reported by Nash ('13) for the Toronto region is 49 and by the writer ('15) for Georgian Bay 48. These figures correspond fairly well to those given by Evermann and Clark ('20) for Lake Maxinkuckee (64) and other single areas (vol. I, p. 262).

The total extent of water area in Ontario as estimated is in the neighbourhood of 80,000 square miles,[1] probably a very conservative estimate when it is realized that a large part of the province is as yet only superficially surveyed. As compared with the total area of the province itself, 407,262 square miles, the submerged portion constitutes about one fifth. This relatively large extent of water area is accounted for in part by the provincial portion of the Great Lakes and by the occurrence within the province of the great Precambrian region, the rock depressions of which, left by the glacial period, now lodge an almost continuously connected series of overflow basins, ranging in size from the smallest ponds and muskegs to lakes of considerable or even of large size. Both geographically and from the point of view of their different economic associations, the Great Lakes and land-enclosed areas may best be considered separately. The former include as provincial waters the Canadian portions of Lakes Superior, Huron, together with Georgian Bay and the North Channel, St. Clair, Erie and Ontario, a total provincial area of some 38,000 square miles in extent, with some 1,500 or 2,000 miles of shore line forming the land boundary of the province on its south and west sides. The land-enclosed area, estimated at 41,385 square

[1]The figures reported are taken for the most part from the Atlas of Canada; published by the Department of the Interior, Ottawa, 1906. Those contained in the following table are from White ('05). Cf. also Map I.

Physical Data, Great Lakes

Lake	*Area*	*Length*	*Width*	*Ontario Drainage*	*Maximum Depth*	*Maximum Height*
	sq. mi.	*mi.*	*mi.*	*sq. mi.*	*feet*	*feet*
Ontario	7053	193	53	11,342	738	246
Erie	9968	241	57	5,480	210	572
St. Clair	503	26	24	41,160	180	575
Huron	22978	206	101	35,400	750	581
Superior	32060	350	160	30,780	1012	602

miles, includes lakes and rivers distributed unequally over a land area which for convenience may be divided into five portions, each having a more or less definite facies, depending originally no doubt upon the geological foundation and the final effects of glacial action. These portions are:—

(*a*) The south western peninsula, or that portion lying to the west of a line connecting the south end of Georgian Bay with the north shore of Lake Ontario to the west of Toronto. This portion comprises the older agricultural part of the province, is noteworthy for the paucity of water areas, and is underlain by strata of Silurian and Devonian age (cf. Map II)* covered by glacial soil deposits of considerable thickness. It is also that portion of the province having the principal frontage on the Great Lakes.

(*b*) A portion lying to the south of a line connecting the southern end of Georgian Bay with Lake Ontario in the region of Kingston. It forms the north shore of the larger part of Lake Ontario, contains some characteristic lakes, including Simcoe (300 square miles), Rice (27 square miles) and Scugog (39 square miles), is underlain by Cambrian and Ordovician strata, and is transitional in many ways between the portion already described and the Precambrian area to the north.

(*c*) The northern Precambrian area of relatively great extent, including the Laurentian Highlands, and characterized by its exposed igneous and metamorphic rocks with innumerable lakes distributed over its surface. The larger lakes include Nipissing (330 square miles) and Nipigon (1,730 square miles).

(*d*) A north west portion containing the Lake of the Woods (1,851 square miles) and similar water areas lying beyond the height of land, and related both in aspect and origin (Lake Agassiz) to Lake Winnipeg and other lakes with the drainage system of which they are connected, though underlain by rock formations similar to the foregoing.

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*Prepared under the supervision of Professor W. A. Parks, University of Toronto.

(*e*) The Hudson Bay drainage area, a region characterized by the broad coastal plain, and on the whole moderately inclined river basins of the Severn, Moose and Albany Rivers, and underlain in part with strata of Devonian age, an area hitherto, on account of its inaccessibility, only superficially considered in its relations to the province, but presenting as a matter of fact some 600 miles of provincial marine coast line.

From the point of view of limnological investigation the Great Lakes offer almost unlimited opportunity. Except for the identification of aquatic organisms and, at least to some extent, their distribution, the most detailed information concerning the lake area refers to soundings and levels,[1] of importance in navigation, water supply and sewage disposal, of interest to municipalities, and practical matters relating to the fisheries.[2] Information is desirable concerning a great variety of physical factors, depth and seasonal variation of water temperatures, suspended materials, dissolved substances and absorbed gases, light penetration, substratum, as well as dynamic forces concerned in transportation of materials, water currents and circulation. Of especial importance are also environmental or ecological associations, in respect of which there are not only great local variations entering into the life cycle of organisms, but also marked general contrasts between individual lakes as complete environmental entities on a large scale. Thus even a superficial comparison of Lake Superior with Lake Erie in respect of their geographical position and physical characteristics reveals contrasts of geological formation, depth, transparency and temperature, the last-named

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[1]Admiralty, Dominion and United States Charts, listed Department of Naval Service, Catalogue of Official Canadian Government Publications of Use to Mariners, Ottawa, 1920. Cf. Report of the International Waterways Commission, same reference; also Russell ('95), White ('15).

[2]Reports of Dominion Department of Marine and Fisheries, Department of Naval Service, Commission of Conservation, United States Bureau of Fisheries; Ontario Department of Game and Fisheries, Geological, Natural History and Fish Commission publications of individual States.

difference doubtless involving several factors in addition to the more obvious ones of depth and maximum latitude difference amounting to some eight degrees. Furthermore the development of the Great Lakes is one of the most interesting chapters of glacial history, and one which will be found to bear very directly upon the origin and history of the fauna and flora, especially the origin of the northern fishes, their migrations, spawning periods, the effects of natural barriers and of natural and articifial means of communication. The study of the origin of the life of the Great Lakes is in fact one of the most interesting of general scientific questions.

The significance of the provincial great lake area from the point of view of economic research is indicated both by the extent and value of the commercial fisheries and by the measures already adopted by the Dominion and Provincial Governments for the control of fishery operations and of the practical means of restocking. The annual value of the fisheries is subject to considerable variation, and it is necessary to examine the returns over a long period of years in order to form any real conception as to the possible relations to one another of the number of men engaged, gear, poundage of catch and probable supply. Taking the year 1918 as the last one for which figures for all the provinces including Ontario are available,[1] it is found for this year that the total value of the Ontario fisheries amounted to $3,175,111. As compared with the total for Canada of $60,250,544 this is approximately 5 per cent., a very creditable showing when it is realized that the latter figure includes the value of the Atlantic and Pacific marine fisheries, among the richest in the world. In relation also to the total for the fresh water fisheries of the Dominion, amounting in 1918 to $6,019,005, the Province of Ontario produced of this total an amount equal to 52.7 per cent., while the

[1]Fisheries Statistics, 1918, Dominion Bureau of Statistics, Ottawa, 1920. Cf. also Report of the Department of Game and Fisheries, Ontario, 1918; Toronto, 1919.

great lake fishery of the province alone produced 44 per cent. When it is considered that the Great Lakes are the mainstay of the commercial fishery, that this fishery has been cultivated assiduously for very many years, and that it is first to be considered in all measures of Dominion or provincial legislation, it is evident that there should be available not only detailed information concerning the natural occurrence, migration, growth stages and dimensions, time of maturity, local variations of the spawning period, as well as concerning the natural associations and enemies of every species of direct market value, but also full particulars of all species directly or indirectly serving them as food.

The land-enclosed water areas, though they at least equal, and in all probability greatly exceed the combined areas of the provincial portions of the Great Lakes, are so varied and irregularly distributed with reference to the topography of the country otherwise that they can scarcely be treated as having conditions in common. With the exception of the Lake of the Woods and Rainy Lake, which are boundary waters, they lie wholly within the province. They have a certain facies depending on their respective relations to the underlying substratum and rock formation, which in Ontario shows a marked contrast as between igneous and sedimentary, a contrast enhanced in every way by the extremes of soil formation and other effects of the glacial period. Some of the lakes as purely inland waters are of large size, notably the Lake of the Woods (1,851 square miles) and Nipigon (1,730 square miles), others though much smaller are nevertheless bodies of considerable magnitude, such as Rainy Lake (324 square miles), Nipissing (330 square miles) and Simcoe (300 square miles). Of the thousands of smaller lakes of perhaps less than 100 square miles in extent, some such as the Rideau waters are significant in the early development of the province, others are summer resort lakes of long standing, such as the Muskoka Lakes, while still others, like Lake Timagami are newer game fish areas of which hundreds have been made accessible within recent years through improvements of rail transportation.

Apart from any question of the utilization of the lake areas otherwise, as travel routes or for transportation of timber, the economic factors concerned are chiefly two in number, namely, in what way and to what extent are the lakes in general capable of utilization from the point of view of marketable fishes, and second, what restrictions must be made, or practical means adopted, for increased utilization of the areas for game fishing, considering the great revenue to be derived from the presence in the province of the summer resident and sportsman.

No limnological investigation of these collectively immense areas or indeed of any one of them has hitherto been attempted. Unlike the Great Lakes their waters have not been the object of hydrographic surveys even for determination of depth. Except for ordinary geographical information, what is known about the physical character of the inland waters is chiefly a matter of canals and water power. Though there have been a good many individual investigations dealing with particular groups of plants and animals, much more is known about the whole country from the standpoint of the traveller and sportsman than has been arrived at through scientific study. Every area which as a matter of development is subject to human interference, and this involves the extreme of conditions in areas like the Muskoka Lakes, which are relatively of long standing occupation and therefore of game fish depletion, as opposed to others which with the improvement of means of ready access, always the deciding factor, are now beginning to be occupied, should be thoroughly known from the point of view of the factors entering into the conditions of existence within its limits. The limnological study of such areas, on account of their easy transitions from ponds and puddles to lakes of sufficient magnitude to present typical lacustrine conditions, ought also to yield important data concerning the general stages of lake formation in different situations, and the relation to this development of the groups of aquatic organisms.

No comparative consideration of the annual yield of marketable fishes coming from the land-enclosed waters of Ontario is worthy of attention which does not first take into account the principles adhered to in framing legislation which would establish the respective spheres of the sportsman interested in game fish waters and the commercial fisherman. Recognizing the Great Lakes as primarily adapted for commercial fishing, and at least some of the inland northern waters as most attractive and eagerly appreciated by the game fisherman, the principle naturally became established in Ontario of the reservation and protection of inland areas from commercial fishing both in respect of sale and the operation of ordinary types of gear. Fortunately in general this principle has been uniformly supported both in Dominion and provincial legislation. A first and very natural exception was made in the case of the Lake of the Woods and related waters, in part because of the predominance as in the Winnipeg area of fishes of a marketable type. A second exception of more recent origin was made in respect of Lake Nipigon and Lake Nipissing, though in general the inclusion of these areas was recognized as requiring close government supervision. On the whole it will be observable both from the small values presented for the commercial fishes and the evidence of large sums of money brought into the country by summer residents and sportsmen that the element of the commercial fishery is only a small part in the total revenue accruing to the province from the existence of the land-enclosed area.

The value of the fisheries of land-enclosed waters of the province was, in 1918, $503,858. This value amounts to about 16 per cent. of the total for Ontario as compared with 84 per cent. for the Great Lakes. Apart from the latter which give a decided advantage to the province, the total value of the fisheries of all land-enclosed waters of the Dominion amounted in 1918 to $3,347,600, of which the corresponding part of Ontario produced only 15 per cent. as compared with Manitoba's contribution amounting to 55 per cent., while Saskatchewan almost equalled Ontario at 13 per cent. Furthermore, of the total for the land-enclosed areas of Ontario more than half, or $285,169 was produced by the Lake of the Woods and related waters, which, as indicated above, are in a similar position to the Great Lakes as regards the commercial fishes. Lake Nipigon accounts for $128,647, or roughly one fourth, while the balance, amounting to only $90,042 includes the product of Lake Nipissing, valued at $32,294. The sum of the matter is that, excepting some four or more of the principal lakes, the commercial product for the province as regards the inland areas is negligible; the real significance of these areas lies elsewhere.

So far as the economic aspects of the question are concerned the problems to be investigated in connection with the growth of fishes and related matters are exactly of the kind already outlined for the Great Lakes. But, in addition, the existence of a body of water both isolated in relation to other basins, and, because of its circumscribed boundaries, more naturally accessible to the commercial methods of fishing, gives rise to conditions which make the problem of balance and replacement more immediate. If the Great Lakes escaped total depletion before the advent of corrective measures, it was because the spaces were sufficiently vast in relation to the amount and efficiency of the gear employed to give the fishes most sought after some loop-hole of escape. In an enclosed area, even the size of Lake Nipigon, and the matter is more serious the smaller a lake becomes, it is evident that with continued fishing with modern gear, no large species, valuable or not, would have the least chance for survival, if not through the exercise of moderation, protection of small fish to sexual maturity, and practical propagation. More than this, the maintenance of the natural balance of all organisms is a matter of importance, whether as between predacious species and those feeding upon lower organisms, or as between spawn-destroying coarse fishes and others more desirable, or as between the various species of minnows and similar small species and the larger fishes which depend on them for food. In fact an enclosed lake is a small and complete world in itself. Whatever happens in the way of modification of its living contents, practically in all cases a matter of human interference, the question of the balance of all organisms, and the balance between the poundage removed and that replaced by natural or artificial means is all important. Doubtless the closer study of conditions would also call into question the advisability of introducing into such area species not adapted either as young or fry to survive, or on the other hand give some point to the introduction of other species whose presence is desirable as marketable or game fishes or even to serve as food for such.

Conservation of the game fishes is quite as much an economic problem as that of the commercial fishes. That it is not usually so recognized is perhaps on the whole a matter of gratification, since it is evident that the protection of game animals and the freedom of the great natural playgrounds are principles which from the beginning have been accepted by legislative authorities. On the other hand no attempt has been made to determine in what respects the invasion of the game country by the tourist and sportsman results in improved circulation of money and prosperity to a larger area, nor to compute what must be a very large amount expended by the non-resident, and contributing to the wealth of the province, if not directly to the provincial treasury through the sale of lands and licenses. It is evident on all hands that the matter of organizing this source of revenue, in a certain sense of capitalizing the natural resources, is one which is being seriously considered elsewhere in America and in Ontario is well worthy of attention. In the game fishes of Ontario we have a wide natural distribution of certain species, notably speckled trout and black bass, and also the occurrence in areas not open to commercial fishing of species, notably lake trout and doré, which deserve to rank as game fishes. The local abundance of these species in the smaller lakes, from most points of view of the game fisherman also the more desirable lakes, is a matter of fundamental importance, since it is the deciding factor, or, if not, a very serious one, in establishing permanency of summer residence. The maintenance of the supply is also immediate or urgent exactly in proportion as these lakes are frequented. Exact information concerning the complete life histories and the factors bearing upon their success or failure is essential for every occupied area. It is probable too that the communication of such information to the more permanent population would not only contribute to practical sentiment in the matter of conservation but also demonstrate the fact so generally neglected throughout the game country that the protection by the local inhabitants of the game animals is worth to them in money far more than their immediate utilization for food or sale.

Another question with which scientific investigation will ultimately have much to do is that of artificial propagation. Already a hundred years ago, before the settlement of the country was yet solidly established, the better fishes of the Great Lakes were recognized as an important source both of food and profit. By 1850, after a period in which the only restrictions upon the extent of capture were those imposed by primitive means of communication, the effects of excess and wastefulness were already evident. Notwithstanding the better organization of fishing administration from Confederation onwards (cf. Prince '20), by 1880 depletion began to be evident in all the Great Lakes, and questions of replacement became of increasing importance. Artificial propagation owes its inception in Ontario to Samuel Wilmot who began private hatching operations at Newcastle in 1865, and who later as a Dominion officer established the entire hatchery system. The development of this system and the steady increase of the output from year to year[1] has doubtless saved the commercial fishery of the Canadian portions of the Great Lakes from complete destruction. At the present time (cf. Map III) the Dominion system includes eight hatcheries[2] in Ontario, the output of which is supplemented by that of hatcheries established by the

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[1]Cf. comparative figures, Fisheries and Game, Report of the Commission of Conservation, Canada, Ottawa, 1911.

[2]Cf. Annual Reports on Fish Culture, Department of Naval Service, Ottawa

Provincial Government to the number of six,[1] while the general supply of the Great Lakes is enormously augmented by the operations of various United States hatcheries under the supervision of the Bureau of Fisheries.

Fish propagation is a technical process, the more difficult because of its aquatic environment, and therefore demanding not only practical ability but also organization of method. The opportunity presented by a spawning period comes only once a year and if lost is irretrievable. The success of a single season's operations depends on controllable elements of precise organization and on uncontrollable factors such as weather, scarcity of spawners, hatchery accidents and the like. If it were possible to effect some organization of scientific work in relation to the hatcheries, an arrangement which would require considerable preparation, a contributory source of information would undoubtedly result which would be analogous in some ways to the usefulness of the agricultural experiment station to the practice of agriculture. Many sides of the hatchery question should be studied by investigators not bound to technical practice, having free time at the proper periods of the year, and provided with equipment adequate to the case; in other words, experimental hatchery work should be carried on with the same kind of equipment as that in regular use, but with additional facilities for scientific study. Bearing in mind that the object of propagation is not simply to make the fisheries hold out a few years longer, but to establish a balance between utilization and replacement, if not indeed an increased output, such as would be the aim of true pisciculture, it is evident that important sources of information are yet unavailable. The case of the hatchery and the commercial fishery is very much that of a mill in which the product is known but the extent or adequacy of the supply is unknown. In order to answer the question it will be necessary to know as nearly as may be practicable the percentage survival of fry and young at different stages and in localities differing both immediately

[1]Cf. Annual Reports, Department of Game and Fisheries, Ontario. Toronto.

and seasonally in respect of their physical characters. It will be necessary to know the true extent of depletion and of artificial increase by corrected figures indicating the poundage of the catch as modified by differences of the total amount of gear and its relative efficiency. There are, however, other considerations.

The recent developments of experimental embryology in relation to the behaviour and growth of aquatic eggs have shown to what extent these features are modified by physical differences in the surrounding medium, the constitution of the medium, absorbed gases and temperature. The investigation of such influences in its bearing upon the development of the eggs of desirable species under hatchery conditions would at least be of great scientific interest and most likely here and there of practical value. The same is true of the study of hybridization, the laws of which, under the influence of the recent work in genetics, are now much more clearly understood. In some of the fresh water fishes, notably *Salmonidae*, there are varietal, racial or environmental modifications which are almost baffling in their complexity, and which should now be thoroughly studied from a genetic point of view under experimental hatchery conditions. Finally the process of re-stocking which involves in part the utilization of young fish or fry, and to which reference has already been made, should be critically examined. While nominally a matter of assisting a natural replacement, the underlying idea is naturally expanded into that of the introduction into depleted waters of the same species from supposedly related waters; in which case it is a question whether the disturbance of the natural balance has not proceeded too far to ensure survival of the introduced stock, also whether as a matter of fact the physical conditions are similar, or if environmental differences are at the moment of introduction beyond the powers of adjustment of the organism. The case is analogous when it is a matter of the introduction of foreign species. Artificial transfer to a hitherto unoccupied area may overcome for the introduced species a natural barrier, permitting it to attain a dominance over native species perhaps more desirable, or it may readily happen that the desire to introduce a species of recognized merit from elsewhere overcomes the obvious reflection that the new environment is perhaps not suitable in any way, resulting in a process not very different in principle from liberating an infantile south sea islander on the shore of Hudson Bay. One of the recent pronouncements on this point is that of Evermann and Clark ('20, vol. I, p. 279). Concerning Lake Maxinkuckee these authors state:—"Four plants of lake trout aggregating 10,587 fish have been made in this lake. So far as we have been able to learn there is no evidence that any of these survived; there is no authentic record of the capture of a lake trout in this lake. If the physical and biological conditions obtaining in Lake Maxinkuckee had been as well understood before the lake trout were planted, as they are now, those plants would not have been made." The records of failures as well as the sometimes uninformed opposition to hatchery measures should be equally considered and a serious attempt made to bring together all facts and factors, practical and scientific, which bear upon the maintenance of natural balance in every area of economic importance.

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No. 2

A STUDY OF THE CISCOES OF LAKE ERIE

BY

WILBERT A. CLEMENS

OF THE DEPARTMENT OF BIOLOGY

UNIVERSITY OF TORONTO

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1922

A STUDY OF THE CISCOES* OF LAKE ERIE

By Wilbert A. Clemens,
University of Toronto

This study was carried out under the auspices of the Biological Board of Canada in response to a request from the Lake Erie Fishermens' Association for an investigation of some of the problems in connection with the cisco fishing industry. In the request it was desired particularly that some information be obtained as to why smaller ciscoes in general are taken in the eastern end of the lake than in the western part.

The major portion of the work having to do with the measurements of the fish and the taking of scales was carried out at various points on Lake Erie during the summer and fall of 1920, but shipments from various points were examined in Toronto during the years of 1919 and 1920.

The author desires to express his appreciation of the assistance given by many fishermen, in particular by Mr. A. E. Crewe, who kindly provided accommodation for the carrying out of the work during the summer of 1920, freely placed all the material of his catches for examination, and gave assistance in many ways. Other gentlemen who facilitated the work in supplying material and in other ways were: Messrs. Charles Ross, Roy Ross, Wilson S. McKillop, A. B. Hoover, C. W. Barwell, R. Kolbe, and W. D. Bates.

Identification of Species

For the separation of the species of shallow water ciscoes (subgenus *Thrissomimus*) as described by Jordan and Evermann† (1911) it appears that three proportional measurements are more or less critical, namely, head in length, depth in length, and depth of caudal peduncle in head. Jordan and Evermann give the following proportions:

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*The word cisco is here used instead of herring for all members of the genus *Leucichthys* except for the tullibees, in accordance with the list of standardized names of North American fish as agreed upon by the U.S. Bureau of Fisheries, the Biological Board of Canada and the Canadian Fisheries Association.

†Jordan, D. S., and Evermann, B. W. 1911. A Review of the Salmonoid Fishes of the Great Lakes with notes on the Whitefishes of other Regions. *Bull. U.S. Bureau Fish.*, Vol. xxix (1909). Document No. 737 (1911).

Species	Head in length	Depth in length	Depth of caudal peduncle in head
L. harengus	4.33	4.3–4.6	3.0
L. sisco huronius	4.66	4.2–4.5	2.9
L. ontariensis	4.5	3.7–4.2	2.66
L. artedi	4.4	3.5–4.0	2.0–2.5
L. eriensis	4.4	3.3–3.5	2.2

Accordingly for each fish examined the necessary measurements were made for the calculation of the above proportions. In addition the girth and the weight were determined and scales removed for age estimation. From June 14 to August 24, 1920, the ciscoes taken in twenty pound nets at the Crewe Bros. Fishery near Merlin were examined daily. In August and November the fish taken at Port Dover, Nanticoke, McKillop's Fishery (near Port Maitland) and Dunnville were examined. The following species have been identified:

(1) *Leucichthys sisco huronius* (J. & E.), Lake Huron cisco.

This species was readily distinguished by the long spindle-shaped body. The average proportions for 60 individuals were as follows: head in length 4.6, depth in length 4.3, depth of caudal peduncle in head 2.95. These figures are practically identical with those given by Jordan and Evermann for Lake Huron. This species is taken rather abundantly in the pound nets at Merlin but very few specimens were seen east of Long Point.

(2) *L. eriensis* (J. & E.). Jumbo cisco.

This is the most abundant species taken in pound nets from Rondeau to Point Pelee. It also occurs in large numbers eastward to Long Point but appears to become very much less abundant beyond. It is noted for the large size attained as compared with the other species of the genus *Leucichthys*. The outstanding characters are (1) the deep body, (2) the more or less pronounced hump at the nape, (3) the deep caudal peduncle, (4) the relatively large scales. The average proportions for 150 individuals were: 4.41, 3.42 and 2.44.

(3) *L. artedi* (Le Sueur). Lake Erie cisco or grayback.

This species occurred in numbers at Merlin next in abundance to *L. eriensis* and appears to occur abundantly throughout the lake. It has been distinguished from the jumbo cisco by (1) the somewhat narrower peduncle, (2) the narrower body with usually little or no hump at the nape, (3) the smaller scales with less of the shiny appearance, (4) the much slower rate of growth as shown in the following table and also later in the discussion of the results of the scale examinations.

L. artedi					L. eriensis				
No.	Date	Length cm.	Weight oz.	Age Years	No.	Date Date	Length c.m.	Weight oz.	Age Years
600	July 8	20.7	6	4	234	July 8	20.8	6	3
601		21.8	6	5	235		21.9	7	3
602		21.0	6	5	237		21.1	7	3
603		21.5	6	5	238		22.2	8	3
604		21.0	6	5	239		22.6	8	3
605		22.2	6	6	240		22.8	9	2
606		21.8	6	5	241	July 9	23.7	9	3
607	July 9	22.8	7	6	242		26.5	12	4
609		22.9	7	5	243		21.5	7	3
610		23.4	7	5	244		24.1	10	3

Figure 1 shows a drawing of a scale from specimen No. 606, *L. artedi* and a drawing of a scale from specimen No. 235, *L. eriensis.*

The average proportions for 50 individuals as they occurred at Merlin were 4.26, 3.7 and 2.86. These figures are somewhat different from those given by Jordan and Evermann and may be due in part to the fact that the young of *L. eriensis* are somewhat difficult to separate from this species, and in the selection of the above 50 individuals rather extreme forms were chosen. There is an indication, however, that *L. artedi* is more closely related to the species of the other lakes than perhaps the figures of Jordan and Evermann show.

(4) *L. prognathus* (Smith). Lake Ontario deep water cisco or longjaw.

In both the pound nets and gill nets from Port Dover to Port Maitland a cisco occurs very abundantly whose exact identity and relationships have not been determined as yet. Dr. B. W. Evermann, to whom ten specimens were submitted for identification, refers them provisionally to the species *prognathus* pending further examination of these and additional specimens. The outstanding features of this form are the following: (1) the long mandible which usually projects beyond the upper jaw and in extreme cases almost hooks over it, (2) the relatively long bony snout, (3) the narrow caudal peduncle, (4) the shiny appearance of the scales, (5) the rather deeply forked caudal fin. In a great many individuals the above characters are extreme as well as other features, as indicated by the following proportions, 4.0, 4.2, and 3.2. In other specimens the proportions are about as follows: 4.3, 3.75, and 2.85. The average for 148 individuals is 4.22, 3.88, and 2.85. However, Dr. Evermann states that *L. prognathus* varies greatly. Only a single longjaw was taken at Merlin during the summer of 1920 on August 24, and it had the proportions 4.1, 3.3, and 2.8. A fisherman at Point Pelee has stated that he recalled having seen during one spring rather large numbers of small longjaws taken in the pound nets in that region. This would indicate a migration occurring during the winter or spring months when temperature conditions would be rather uniform throughout the lake.

The longjaws examined at Dunnville and Port Dover early in November, 1920, were almost ready to spawn. Typically, members of the subgenus *Cisco* (Jordan and Evermann) are said to spawn in late summer but it would not be surprising to find the deep water forms in the shallower, warmer waters of Lake Erie spawning later than those in the other Great Lakes, especially in a mild fall such as occurred in 1920. Two females of *L. johannae* received from Wiarton, Georgian Bay, November 24, 1920, were found not to have spawned.

The following table shows comparative measurements of certain characters of the longjaws in Lake Erie. Measurements are given in decimal fractions of body length.

	PORT MAITLAND						PORT DOVER		
	1032	1042	1037				919	907	918
Head	.26	.25	.25	.245	.25	.24	.23	.23	.24
Depth	.24	.21	.22				.24	.26	.30
C.P. depth	.087	.078	.081	.082	.082	.089	.084	.079	.082
Eye	.054	.058	.060	.06	.06	.055	.066	.055	.065
Snout	.063	.063	.064	.063	.063	.057	.058	.053	.058
Maxillary	.085	.083	.09	.08	.087	.085	.079	.08	.089
Snout to occiput	.17	.17	.17	.17	.17	.16	.166	.15	.173
Gill rakers	45	46	45	41	41	45	45	45	41
Head in length	4.0	4.0	4.0	4.0	4.0	4.1	4.3	4.3	4.1
Depth in length	4.2	4.7	4.6				4.1	3.9	3.3
C.P. depth in head	3.2	3.2	3.2	3.0	3.0	2.7	2.8	3.0	2.9

(5) *L. harengus* (Richardson). Georgian Bay cisco.

A few individuals were taken which agreed in measurements and description with the Georgian Bay cisco. Jordan and Evermann report this species in Lake Erie and no doubt it occurs in small numbers.

For purposes of comparison and for confirmation of the value of proportional measurements, specimens of *L. ontariensis* were obtained from Port Credit on Lake Ontario, and specimens of *L. harengus* from Wiarton and Midland on

Georgian Bay. The average proportions of 20 individuals of *L. ontariensis* were 4.5, 3.8, and 2.6. The average for 25 individuals of *L. harengus* were 4.2, 4.3, and 3.1.

The following table shows the measurements of typical individuals of the various species examined. Measurements are given in decimal fractions of body length.

	[1]*L. harengus* 21	*L. sisco huronius* 328	[2]*L. ontariensis* 3	*L. artedi* 666	*L. eriensis* 1026	*L. prognathus* 1038
Head	.24	.22	.21	.23	.23	.25
Depth	.21	.22	.26	.26	.33	.24
Caudal peduncle length	.11	.12	.11	.11	.10	.11
Caudal peduncle depth	.073	.074	.084	.085	.095	.081
Eye	.062	.051	.054	.057	.057	.065
Snout	.057	.053	.051	.055	.050	.056
Interorbital space	.068	.064	.062	.068	.067	.065
Maxillary	.079	.074	.066	.081	.073	.086
Snout to occiput	.16	.14	.15	.16	.15	.17
Ventral to pectoral	.31	.36	.35	.36	.36	.33
Pectoral to P-V distance	2.25	2.2	2.4	2.2	2.3	1.9
Pectoral length	.14	.14	.14	.16	.16	.17
Ventral length	.13	.12	.14	.15	.16	.17
Dorsal height	.14	.13	.15	.16	.17	.18
Adipose length	.053	.06	.062	.064	.073	.053
Anal height	.88	.88	.94	.11	.11	.13
Gill rakers	49	47	48	43	46	45
Scales	9-85-8	9-82-8	9-78-8	8-70-7	8-75-7	8-75-7
Head in length	4.2	4.6	4.6	4.3	4.4	4.1
Depth in length	4.7	4.5	3.8	3.5	3.1	4.2
C.P. depth in head	3.2	3.0	2.7	2.8	2.4	3.0

[1]From Georgian Bay. [2]From Lake Ontario.

The following table shows proportions as given by Jordan and Evermann and those obtained for the ciscoes in Lake Erie with the exception of *L. harengus* and *L. ontariensis*.

Species	Jordan and Evermann			Lake Erie		
	Head in length	Depth in length	Depth C.P. in length	Head in length	Depth in length	DepthC.P. in length
L. harengus............	4.33	4.3–4.6	3.0	[1]4.2	4.3	3.1
L. sisco huronius........	4.66	4.2–4.5	2.9	4.6	4.3	2.95
L. ontariensis..........	4.5	3.7–4.2	2.66	[2]4.5	3.8	2.6
L. artedi...............	4.4	3.5–4.0	2.0–2.5	4.26	3.70	2.86
L. eriensis.............	4.4	3.3–3.5	2.2	4.41	3.42	2.44
L. prognathus..........	4.0	3.5	3.5	4.22	3.88	2.87

A B

Fig. 1.—Drawings of scales of ciscoes.

A, from specimen No. 606, *L. artedi*, showing 5 winter bands, the fish therefore being in its sixth summer. *B*, from specimen No. 235, *L. eriensis*, showing three winter bands, the fish therefore being in its fourth summer.

[1]From Georgian Bay. [2]From Lake Ontario.

The scales were used in determining the rates of growth of the various species of ciscoes. The growth areas are usually well marked. Scales from approximately the following number of fish of each species were examined: *L. eriensis*

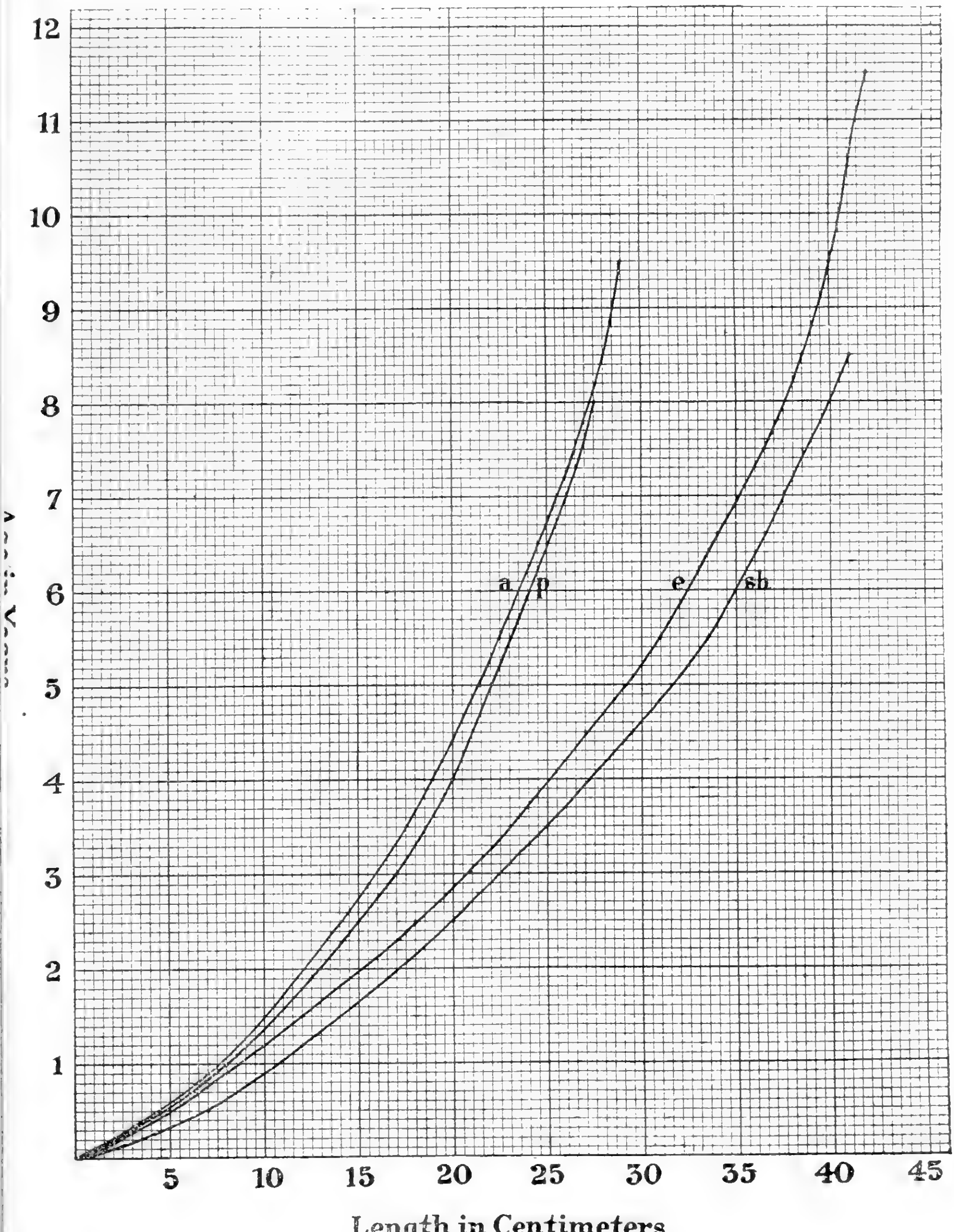

Fig. 2.—Graph illustrating rates of growth of ciscoes in Lake Erie a = *L. artedi*, p = *L. prognathus*, e = *L. eriensis*, sh = *L. sisco huronius*.

140; *L. artedi* 55; *L. sisco huronius* 55; *L. prognathus* 150. The results are shown in Fig. 2. Considerable difficulty was experienced in estimating the rate of growth of *L. sisco huronius*. In the majority of scales some of the winter bands were difficult to distinguish and there was evidence that in some cases at least one winter band was not recorded. It is possible, therefore, that the curve for this species should lie to the left of the curve for *L. eriensis*. Fig. 3 shows the relation of age to weight. The following table gives the data obtained for the three important commercial species in Lake Erie. The length in centimeters is from the tip of the snout to the base of the caudal fin; the girth just anterior to the dorsal fin.

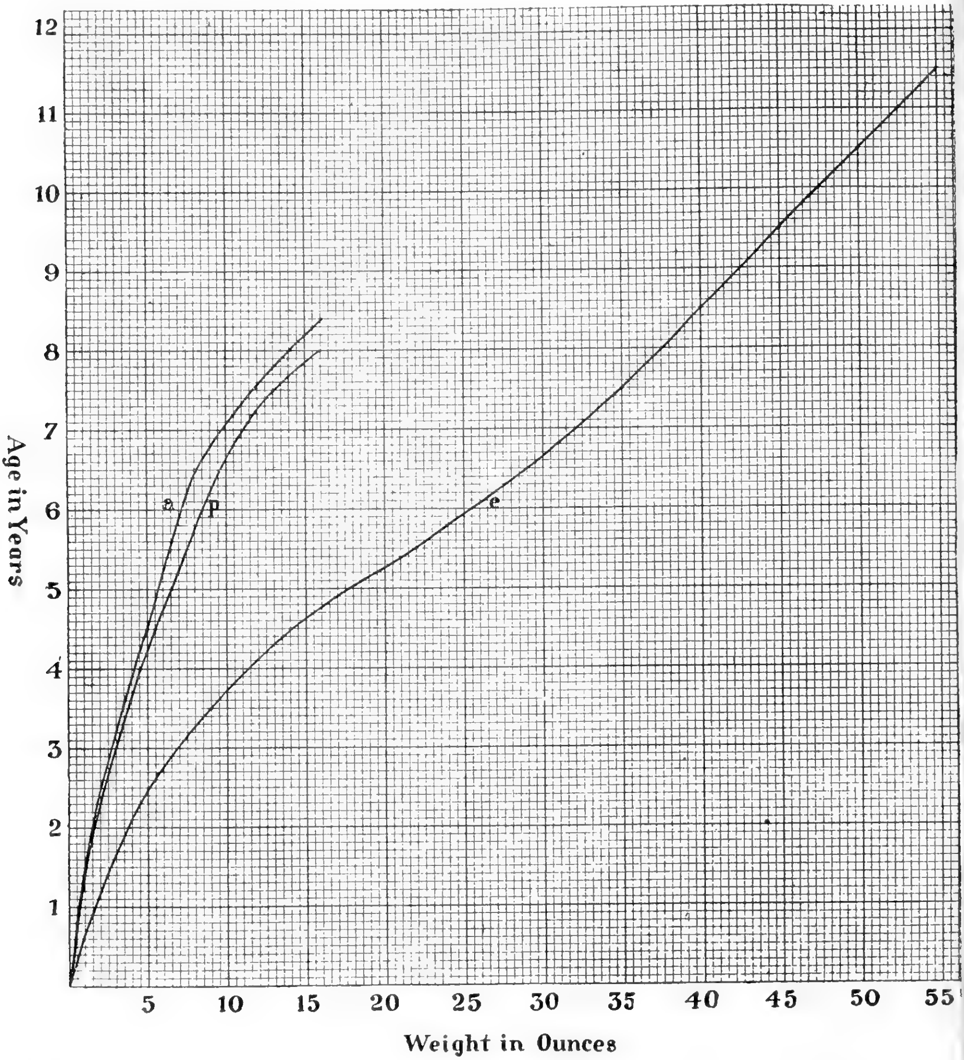

Fig. 3.—Graph illustrating relation of weight to age of ciscoes in Lake Erie. a = *L. artedi*, p = *L. prognathus*, e = *L. eriensis*.

	L. eriensis				*L. artedi*				*L. prognathus*			
Age	Length c.m.	Length in.	Weight oz.	Girth in.	Length cm.	Length in.	Weight oz.	Girth in.	Length cm.	Length in.	Weight oz.	Girth in.
1	8.5	4.0	1.5	....	7.5	3.0	....	...	8.0	3.0	....	....
2	15.0	6.6	3.5	....	12.5	5.2	....	...	13.0	5.2	....	....
3	20.5	9.1	7.0	6.1	16.0	7.0	3.0	4.5	17.0	7.0	3.0	4.5
4	25	11.4	11.5	7.4	19.0	8.5	4.5	5.2	20.0	8.5	4.5	5.2
5	29	13.3	17.5	8.5	21.5	9.6	5.5	5.8	22	9.8	6.5	5.7
6	32.5	14.8	25.5	9.4	23.5	10.3	7.5	6.3	24	10.7	8.5	6.3
7	35.5	16.0	32.0	10.1	25.5	10.7	9.5	6.7	26	11.4	11.0	...
8	37.5	17.0	37.5	10.8	27.5	11.8	12.5	...	....	....	....	...
9	39.5	17.6	42.5	11.3	28.5	....	....	...	....	....	....	...
10	40.5	18	47.5	11.8	....	....	....	...	....	....	....	...
11	41.5	18.5	52.5	...	....	....	....	...	....	....	....	...

The difference in weight between *L. artedi* and *L. prognathus* is partly due to the fact that the specimens of the latter species were examined chiefly in November and the females were then heavy with spawn.

SUMMARY

1. Three species form the bulk of the cisco catch in the Canadian waters of Lake Erie, namely, *L. eriensis*, *L. artedi* and *L. prognathus*.

2. *L. eriensis* is the dominant form westward from Long Point, and *L. prognathus* eastward from Long Point. This statement holds in general, for the former appears to prefer the shallower water while the latter is apparently a deep water form. However their ranges tend to overlap and their migrations at times take them into one another's territory. For example, fishermen have reported occasional schools of longjaws as far west as Point Pelee, and, on the other hand, the jumbo is reported as abundant, at times, off Port Maitland. *L. artedi* occurs abundantly throughout the lake, but probably in greatest numbers west of Long Point.

3. *L. artedi* and *L. prognathus* have rates of growth and increases in weight which are practically identical, while *L. eriensis* increases about 1 1/3 times faster in length and two to three times faster in weight.

4. Examinations of the graphs and tables for rates of growth and increases in weight show that the optimum size for the taking of the jumbo cisco is from the fifth summer upward when they are at least 12 inches in length and 1 pound in weight. Whether the food supply would permit of this as the minimum size it is impossible to say. In regard to *L. artedi* and *L. prognathus* a minimum length of about 10 inches and a weight of about 6 or 7 ounces, when the fish are in their sixth summer, would appear to be quite satisfactory.

5. Concerning the occurrence of smaller ciscoes in the eastern end of the lake, this much can be safely said: that in respect to gill net catches the fishermen in the western portion of the lake secure a larger percentage of jumbo ciscoes and, therefore, get large fish, while the fishermen in the eastern end, particularly off Port Maitland, secure chiefly the smaller species, *L. artedi* and *L. prognathus*. The same facts apply to the pound net catches, with the addition that, since the young inhabit the shallow waters and the shallow water area east of Long Point is more limited, there appears to be a concentration of young ciscoes along the shore, particularly in Long Point Bay, and hence the young are apt to be impounded in large numbers in the pound nets.

6. No data were obtained as to the age when the various species spawn for the first time. Spawning is probably at the end of the third summer, and, if so, the six-ounce regulation protects the two species, *L. artedi* and *L. prognathus* in respect to being allowed to spawn once, but does not protect *L. eriensis* since it attains a weight of six ounces in its third summer.

7. The girth measurements were taken around the body just anterior to the dorsal fin, that is where the greatest girth occurs. The results show that the three inch gill net regulation is quite satisfactory for the species *L. artedi* and *L. prognathus* since they do not attain a girth of six inches until the sixth summer, but barely protects *L. eriensis* since this species attains a girth of six inches in three years.

8. In any undertaking for the artificial propagation of ciscoes in Lake Erie, at least for the region west of Long Point, particular attention should be given to *L. eriensis*, because of its rapid growth and its excellent qualities as a food fish.

CONCLUSION

This study has proved to be merely preliminary. The ciscoes of Lake Erie form a complex association and it has been impossible in this investigation to determine their inter-relations or to study the physical factors in relation to the various forms. Solution of the many difficult problems must await a thorough study of the physical conditions of existence in the various parts of the lake, such as distribution of temperatures, oxygen, carbon dioxide, currents, etc., and the relation of these factors to spawning, growth, movements of the fish, as well as to the production and distribution of their food organisms.

UNIVERSITY OF TORONTO STUDIES

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No. 3

THE FOOD OF CISCOES (*LEUCICHTHYS*) IN LAKE ERIE

BY

WILBERT A. CLEMENS

AND

N. K. BIGELOW

OF THE DEPARTMENT OF BIOLOGY

UNIVERSITY OF TORONTO

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1922

THE FOOD OF CISCOES (*Leucichthys*) IN LAKE ERIE

By Wilbert A. Clemens,

and

N. K. Bigelow,

University of Toronto.

The results of the examination of the contents of the digestive tracts of 211 ciscoes (fresh-water herring) are presented herein. The bulk of the material was obtained early in June, 1919, and from July to November in 1920, from Lake Erie at various points along the north shore. The species examined were *Leucichthys eriensis*, the jumbo cisco; *L. artedi*, the Lake Erie cisco; *L. sisco huronius*, the Lake Huron cisco; and *L. prognathus*, the Lake Ontario deep water cisco (longjaw). These were taken at Merlin, Rondeau, Port Dover, Nanticoke, McKillop's fishery (near Port Maitland), and Dunnville. In addition 19 individuals of *L. harengus*, the Georgian Bay cisco, from Wiarton, Georgian Bay, and 7 individuals of *L. ontariensis*, the Lake Ontario cisco, from Port Credit, Lake Ontario, have been examined for comparative purposes. The material from Merlin, Rondeau, Nanticoke and McKillop's was obtained in pound nets while the material from all the other points was obtained in gill nets.

The results are given in the following tables. In the table "Unidentified species" are placed those fish whose identity was not determined. The figures indicate the relative abundance, namely: (1) that only a few individuals were noted; (2) that the organisms occurred rather abundantly; (3) very abundantly.

SUMMARY.

1. An examination of the tables shows that the ciscoes are pre-eminently plankton feeders. The study practically covers the fishing season, and during that time at least, the free swimming crustacea form the bulk of the food of these fish. Of Canadian waters, Lake Erie produces more ciscoes than all the other Great Lakes combined. For example, in 1919 Lake Erie produced 7,425,713 lbs., while the remainder of the Great Lakes produced 4,022,711 lbs. It is not improbable that the production of ciscoes is directly dependent upon the amount of plankton Crustacea produced. The numbers of these Crustacea which must abound in Lake Erie in order to support the millions of ciscoes, as well as the great numbers of white fish and young of many other species, is almost beyond the imagination. Comparative quantitative plankton studies in the Great Lakes would, no doubt, afford considerable information as to the fish productive capacities of these lakes.

2. It is doubtful if the various species of ciscoes show any preference among the entomostraca as food material. They doubtless take whatever forms occur in the waters they happen to inhabit.

3. In the great majority of alimentary tracts examined, *Daphnia* formed the great bulk of the contents, while other forms were represented by scattered individuals. In many cases *Daphnia* alone were present. This was particularly true of the jumbo and the Lake Ontario ciscoes. It appears, therefore, that *Daphnia* are very much the most important of the entomostraca as food organisms. *Daphnia longispina* occurred in all the material examined, as variety *hyalina galeata*. *Daphnia* ephippia were abundant in October in Lake Ontario and in November in Lake Erie. Occasional ephippia with three eggs were noted.

4. Of the Copepods *Diaptomus sicilis* and *Limnocalanus macrurus* were perhaps the most abundant forms occurring in the digestive tracts, although *Epischura lacustris* occurred frequently and occasionally in considerable numbers. Very often the oil globules of these forms gave the contents a bright red colour.

5. In the eastern end of Lake Erie one of the most important food organisms was *Mysis relicta*. As far as we are aware this is the first record of the occurrence of this form in Lake Erie. Its presence indicates at least an approach of conditions in the eastern end of this lake to conditions in the other Great Lakes.

6. Three individuals were found to have eaten small fish. In each case digestion had proceeded too far to allow of identification. All three ciscoes were taken in the eastern end of the lake, two were longjaws (*L. prognathus*) and the third, while not definitely identified, was probably also a longjaw. A fisherman near Point Pelee has stated that one winter he found that some ciscoes which he took through the ice, had eaten "minnows."

7. As is shown in the table for the longjaws (*L. prognathus*) these fish in June, 1919, had fed practically entirely upon *Ephemeridae* (*Ephemera simulans*), both adults and subimagoes. The importance of these insects as fish food is thus further demonstrated. Moreover, there is no doubt that the transformation of the nymphs to the subimaginal stage takes place at the surface of the water, as occurs in the closely related genus *Hexagenia* (Needham, 1920).* This means that the subimagoes, as well as the imagoes, were taken at the surface of the water by the ciscoes. The projecting lower jaw of these forms is well suited to such surface feeding.

8. The following table, compiled from the food tables, shows the distribution of the food organisms in the lake.

The outstanding points in the table are:

(*a*) The absence of *Mysis relicta* from the western portion and the absence of *Daphnia pulex* and *D. retrocurva* from the eastern portion. Further investigation, however, may show the presence of these species throughout the lake.

(*b*) Although only 43 gill net fish were examined, and the list of forms is, therefore, incomplete, yet the results are an indication of what would be expected in any large body of water, namely, that the shore waters contain a greater number of species of food organisms than the more open waters. The gill net

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*Needham, James G. 1920. Burrowing Mayflies of our Larger Lakes and Streams. *Bull. U.S. Bur. Fish.*, Vol. XXXVI, 1917-18.

	Western Portion	Eastern Portion	
	87 pound net fish from Merlin and Rondeau	55 pound net fish from McKillop's and Nanticoke	43 gill net fish from Port Dover and Dunnville
Epischura lacustris	+	+	+
Diaptomus sicilis	+	+	+
Limnocalanus macrurus	+	+	+
Cyclops sp.	+	+	
Sida crystallina	+	+	
Diaphanosoma brachyurum	+		
Holopedium gibberum	+		
Daphnia pulex	+		
" *retrocurva*	+		
" *longispina*	+	+	+
Bosmina longirostris	+		+
Eurycercus lamellatus	+		
Chydorus sp.	+		
Leptodora kindtii	+	+	
Mysis relicta		+	+
Hyallela knickerbockerii	+		
Ephemeridae	+	+	+
Small fish		+	

ish were taken over 5 miles from shore while the pound net fish were taken vithin 2 miles of shore.

(*c*) A comparison of the first two columns shows the possibility of there being a greater number of species in the western part of the lake than in the eastern end. There is a possibility also that quantitative differences exist in hese regions as well as qualitative.

The results of this study serve to emphasize anew the importance of the plankton fauna of our inland waters, and the necessity for a thorough quantitative, qualitative and distributional investigation of these organisms, including particularly their relations to the production, distribution and movements of sh.

L. ERIENSIS—JUMBO CISCO IN LAKE ERIE.

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
118	June 1/19	Rondeau	25.8	13	5	1		1	1	1	3	3						Insect fragments 1.
101	" "	"	27.0	14½	4				1		3	1						
129	" "	"	31.0	21	5						3							*Ephemeridae* 2; *Chironomidae* 1; *Amphipoda* 1.
127	" "	"	35.5	31	6						3							*Epheremidae* 1.
229	July 6/20	Merlin	23.5	8	4				1	2			3					
15 indiv.	" "	"	24.5	10		1	1		1	1			1			3		
15 "	" "	"	24.5	10		1	1		1	1			2			3		
15 "	July 8/20	"	22.5	6½		1	1		1	2	3		2			1		*Diaphanosoma brachyurum* 1; *Holopedium gibberum* 1.
12 "	July 10/20	"	22.5	6½		1	1						1			3		
299	Aug. 2/20	"	26.4	16	4					1			1			3		*Diaphanosoma brachyurum* 1.

1,206	Nov. 12/20	Rondeau	21.3	7		1	1				3							
1,201	" "	"	21.6	6½			1				3							
1,210	" "	"	21.8	7			1				3				1			*Eucercus lamellatus* 1; Crustacean debris 1; *Volvox* 1.
1,213	" "	"	22.2	7½							3							
1,208	" "	"	22.3	8							3							
1,214	" "	"	23.7	10							3							
1,211	" "	"	24.3	11							3							
1,204	" "	"	27.7	17½							3							
1,203	" "	"	33.3	31							3							
	Nov. 24/20	Merlin	24.5				1				3							
	" "	"	26.5			1	2				3							

L. ARTEDI—LAKE ERIE CISCO OR GRAYBACK IN LAKE ERIE

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
104	June 1/19	Rondeau	21.4	$5\frac{3}{4}$	4	2	1		1		2	2						*Hyallela knickerbockerii* I.
807	Nov. 10/20	"	21.6	$7\frac{1}{2}$			3	2						1				Crustacean debris 2.
1,027	" "	McKillop's	19.6	$4\frac{1}{2}$	4		2	2						2				
1,046	" "	"	20.2	5				3					2					
1,045	" "	"	20.5	5	5			3					2					
1,043	" "	"	20.9	6	5			3						2			1	
666	" 24/20	Merlin	23.5	9	6		1				3					1		

L. SISCO HURONIUS—LAKE HURON CISCO IN LAKE ERIE

Collection Number.	Date.	Locality	Length in cms.	Weight in ozs.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
371	Nov. 24/20	Merlin	26.1	11½							2					3		
1,200	" 12/20	Rondeau	26.3	9							3							

L. PROGNATHUS—LAKE ONTARIO DEEP WATER CISCO IN LAKE ERIE

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
17	June 1/19	Nanticoke	17.8	3	4		1							1				*Ephemera simulans* subimagoes 3; Chironomid adults 1
8	" "	"	18.5	3½	4				1									*Ephemera simulans* subimagoes 3.
7	" "	"	19.3	3½	4	1	1		1									" " 3.
10	" "	"	19.5	4	5		1											" " 3; Dipterous adult 1.
42	" "	"	20.8	6	4	1	1		1									*Ephemera simulans* subimagoes 3; Dipterous adult 1.
1	" "	"	20.9	5	5				1									*Ephemera simulans* subimagoes 3; Dipterous adult 1.
16	" "	"	20.9	4½	5				1									*Ephemera simulans* subimagoes 3.
30	" "	"	21.0	5	4		1		1									" " 3.
2	" "	"	21.3	5	5	1	1		1					1				" " 3.

21	June	1/19	Nanticoke	21.4	4¼	6		1		1									" " 3.
13	"	"	"	21.5	4½	4		1		1									" " 3.
38	"	"	"	21.8	6	4		1											" " 3.
6	"	"	"	22.5	4½	6				1					1		1		" " 3.
120	June	1/19	Rondeau	18.6	4	4	1					3	3						
119	"	"	"	21.3	5	4						3	3						
115	"	"	"	23.4	7½	5	3	1		1		3	3	1					
111	"	"	"	24.6	7	6	1	1				3	3						
716	Nov.	1/20	Dunnville	21.1	8	3	1	1	1					3					
15 indiv.	"	"	"				1	2	1					3					
15 "	"	"	"				2	2	2					3		1			Insect fragments 1.
837	Nov.	10/20	Nanticoke	20.3	5½	5			3										
843	"	"	"	20.7	5½	5		1	1	1				3					Glochidium.
834	"	"	"	20.7	5				2					3				1	
845	"	"	"	20.7	5	5												3	
841	"	"	"	20.9	5½	5												3	
817	Nov.	10/20	"	21.5	6	5	1	1	1									2	Crustacean debris 1.
820	"	"	"	21.8	5	4												3	

L. PROGNATHUS—LAKE ONTARIO DEEP WATER CISCO IN LAKE ERIE—Cont.

Collection Number.	Date.	Locality.	Length in cms.	Weight in os.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops sp.*	*Sida crystallina.*	*Daphnia pulex*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia sp.?*	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
829	Nov. 10/20	Nanticoke	23.0	7	4													Small fish fragments
816	" "	"	23.0	7½	6			1									3	
826	" "	"	23.2	6½	5			2						1			1	Small fish fragments.
808	" "	"	25.4	9½	6		1						2				2	
1,051	Nov. 10/20	McKillop's	21.4	5½	5		1										3	
1,044	" "	"	21.5	5	5		1	1					2				3	
1.039	" "	"	22.0	5½	5												3	
1,032	" "	"	22.3	5½	5												3	

L. HARENGUS—GEORGIAN BAY CISCO IN GEORGIAN BAY.

Collection Number.	Date.	Locality.	Length in cms.	Weight in ozs.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longirostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
23	Nov. 24/20	Wiarton	19.1	$3\frac{3}{4}$	4		3	2					2					
25	" "	"	22.4	6	5	1	2	2					2					
21	" "	"	22.7	$5\frac{1}{2}$	6		2	2						2	1			Ostracods 1.
27	" "	"	23.4	7	6	1	2	2					1				1	
15 indiv.	" "	"	similar			1	2	2	1				1		1			

L. ONTARIENSIS—LAKE ONTARIO CISCO IN LAKE ONTARIO

Collection Number.	Date.	Locality.	Length in cms.	Weight in oz.	Age.	*Epischura lacustris.*	*Diaptomus sicilis.*	*Limnocalanus macrurus.*	*Cyclops* sp.	*Sida crystallina.*	*Daphnia pulex.*	*Daphnia retrocurva.*	*Daphnia longispina.*	*Daphnia* sp.?	*Bosmina longiostris.*	*Leptodora kindtii.*	*Mysis relicta.*	Miscellaneous.
2	Oct. 21/20	Port Credit	22.0	7½	3								3					
7	" "	"	22.7	8	3		1						3					
6	" "	"	23.9	9¼	3								3					
1	" "	"	24.5	9½	4								3					
5	" "	"	25.9	10½	4								3					

L. PROGNATHUS?—LAKE ONTARIO LONGJAW IN LAKE ONTARIO

11	Nov. 25/20	Port Credit	22.6	8	3						3							
9	" "	"	26.4	12½	4												3	

123	June 1/19	Rondeau	19.9	4¼	4					1	3	3						
107	" "	"	23.8	8	4	2	1		1		3	3				1		Hydrachnid 1.
15 indiv.	Aug. 5/20	Nanticoke				2		2	1	1			2			1		Insect fragments (*Chironomidae, Trichoptera Ephemeridae*) 3.
1 "	" 9/20	McKillop's																*Ephemeridae* (*Ephemera, Heptagenia*, imagoes and subimagoes) 3.
12 "	Nov. 3/20	Port Dover															3	Insect fragments 1.
809	" 10/20	Nanticoke	21.1	6	4												3	
830	" "	"	22.9	7	5									1			3	
810	" "	"	23.2	11	7		2										2	Small fish.
824	" "	"	21.0	6	5		1	1										Crustacean debris 3.
812	" "	"	23.5	9½	6	2	3	2						1				
819	" "	"	23.6	11	4		1										3	
1,048	" "	McKillop's	24.3	11										1			3	
1,212	Nov. 12/20	Rondeau	23.5	11							3							*Chydorus* sp.? 1.
1,207	" "	"	26.2	11½			1				3							

UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 4

A PROVISIONAL LIST OF THE FISHES OF LAKE ERIE

BY

JOHN R. DYMOND
OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

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1922

A PROVISIONAL LIST OF THE FISHES OF LAKE ERIE

Considering the value of its fisheries, surprisingly little systematic study has been devoted to the fishes of Lake Erie. Our knowledge of the species occurring in the lake appears to have been gained incidentally in connection with investigations on some of the species of commercial importance and through surveys of neighbouring areas.

Although Lake Erie is one of the most productive fishing grounds in the world, its productivity could no doubt be increased by proper management. Investigations with this object in view have been made from time to time, but for the most part these investigations have been confined to the species whose numbers it was desired to increase. No study of the problem as it affects the lake as a whole has yet been undertaken. When such a study comes to be made, information as to the species that occur in the lake, their distribution and relative prevalence will be of fundamental importance. The present list is intended to be a contribution towards such a study. It at least indicates how unsatisfactory is our present knowledge of the fish fauna of the lake, especially in Canadian waters.

The list contains 91 species of fish and two species of lamprey. No species is included which has not been authentically recorded from Lake Erie. Except in the case of commercial species or those recorded in official reports, the authority for including it is given in the case of each species. Brief reference has also been made to the general range or habitat of the less common species found in the lake.

In the preparation of this list, the publication "Fishes of Ohio", Osburn ('01), has been found to be of great assistance. It includes not only the results of his own observations, but also those of Rafinesque, Kirtland, Jordan, Henshall and others. Many species not elsewhere recorded for the lake are included as a result of Osburn's observations in Sandusky bay in the summers of 1899 and 1900. I am also indebted to Professor Osburn for the identification of several specimens of *Cyprinidae* and of *Cottus ictalops* reported herein.

Other lists consulted contain only occasional references to the occurrence of species in Lake Erie. The expression "Great Lakes Region", often met with in describing the range of species, is unsatisfactory for the preparation of a list such as the present one. Even where a species is said to occur "in the Great Lakes", the reference is hardly less unsatisfactory, for the fauna of each of the lakes exhibits peculiarities of its own. Among the works consulted the following were found to be of most value: Jordan and Evermann ('96), Forbes and Richardson ('08), Bean ('03), and Nash ('08). Many other publications have been consulted but only those containing definite reference to the occurrence of species in Lake Erie are included in the list of literature cited.

The basis of the present list was obtained by reference to two collections from Lake Erie made during the summer of 1920, one by Dr. W. A. Clemens, University of Toronto, and the other by a party from the Royal Ontario Museum of Zoology. Dr. Clemens concerned himself principally with the ciscoes (lake herrings) but he secured specimens of all the species brought in by the fishermen. Most of his specimens, other than ciscoes, were taken at Merlin, Ontario.

The Museum party was stationed at Point Pelee. Their primary object was to secure typical specimens of some of the chief commercial species from which to make casts and colour sketches for permanent museum exhibition specimens. Their specimens were also secured from fishermen.

The species secured by Dr. Clemens were *Ichthyomyzon concolor*, *Acipenser rubicundus*, *Lepisosteus osseus*, *Amia calva*, *Ictalurus punctatus*, *Ameiurus nebulosus*, *Catostomus commersonii*, *Cyprinus carpio*, *Notropis rubrifrons*, *Hybopsis* *storerianus, Hiodon tergisus, Dorosoma cepedianum, Coregonus albus, Leucichthys harengus, Leucichthys sisco huronius, Leucichthys artedi, Leucichthys eriensis, Leucichthys prognathus, Lucius lucius, Pomoxis sparoides, Ambloplites rupestris, Lepomis pallidus, Eupomotis gibbosus, Micropterus salmoides, Stizostedion vitreum, Stizostedion canadense griseum, Perca flavescens, Percina caprodes zebra, Roccus chrysops, Aplodinotus grunniens, Lota maculosa.*

The collection made by the Royal Ontario Museum of Zoology party included *Ichthyomyzon concolor, Lepisosteus osseus, Ictalurus punctatus, Ameiurus natalis, Ameiurus nebulosus, Noturus flavus, Catostomus commersonii, Hybopsis storerianus, Hiodon tergisus, Coregonus albus, Pomoxis sparoides, Stizostedion vitreum, Stizostedion canadense griseum, Roccus chrysops, Aplodinotus grunniens.*

During the spring and summer of 1921 a number of Lake Erie fishermen preserved for the Department of Biology specimens of the fish taken in their nets, especially the less common species. Mr. A. E. Crewe, of Merlin, Ontario, sent *Ichthyomyzon concolor, Petromyzon marinus unicolor, Notropis rubrifrons, Hybopsis storerianus,* and *Cottus ictalops.* Mr. W. D. Bates, of Ridgetown, Ontario, sent the following taken at Rondeau, Lake Erie: *Ichthyomyzon concolor, Catostomus commersonii, Moxostoma breviceps, Moxostoma aureolum, Hybopsis storerianus, Coregonus albus, Salmo gairdneri, Pomoxis sparoides, Stizostedion vitreum, Perca flavescens, Roccus chrysops.* From Mr. A. B. Hoover, of Nanticoke, Ontario, were received *Carpiodes thompsoni, Catostomus commersonii, Moxostoma breviceps, Notropis rubrifrons, Hybopsis storerianus, Hiodon tergisus, Dorosoma cepedianum, Percopsis guttatus, Pomoxis sparoides, Ambloplites rupestris.*

The abbreviations used in the following pages refer uniformly to the following authorities:—

Osburn ('01)	"Fishes of Ohio"
J. & E., Bull. 47 ('96)	"The Fishes of North and Middle America."
Jordan & Evermann ('08)	"American Food and Game Fishes."

Jordan ('82)	"Report on the Fishes of Ohio."
Forbes & Richardson ('08)	"The Fishes of Illinois."
Bean ('03)	"Catalogue of the Fishes of New York."
Nash ('08)	"Vertebrates of Ontario."
Clemens	The collection made by Dr. W. A. Clemens from Lake Erie during the summer of 1920.
R.O.M.Z. Party	The collection made by a party from the Royal Ontario Museum of Zoology stationed at Point Pelee during the summer of 1920.
Crewe	The collection received from Mr. A. E. Crewe as mentioned above.
Bates	The collection received from Mr. W. D. Bates as mentioned above.
Hoover	The collection received from Mr. A. B. Hoover as mentioned above.

The nomenclature adopted is that of Jordan and Evermann ('96) except in the case of Coregonus and Leucicthys, for which their later publication ('11) "Review of the Salmonoid Fishes of the Great Lakes" has been followed.

ANNOTATED LIST OF SPECIES

Ichthyomyzon concolor (Kirtland). Silvery Lamprey

The only species of lamprey previously recorded from Lake Erie. Specimens secured by Clemens and R.O.M.Z. party in 1920, and by Crewe and Bates in 1921. Also recorded by Huntsman ('17) from Lake Erie.

Petromyzon marinus unicolor (De Kay). Lake Lamprey

A specimen, 21 inches long, was taken on November 8th, 1921 in Lake Erie at Merlin, Ontario by Mr. A. E. Crewe.

Polyodon spathula (Walbaum). Paddle-fish

"A single example has been recorded from Lake Erie which it doubtless reached through the Wabash and Erie canal" Jordan and Evermann ('08). Common in the larger streams of the Mississippi valley.

Acipenser rubicundus Le Sueur. Lake Sturgeon

Less abundant than formerly but still of considerable commercial importance.

Lepisosteus osseus (L.).[1] Common Gar Pike

Common.

Lepisosteus platostomus Rafinesque. Short-nosed Gar Pike

Rare. "Sandusky bay, one specimen" Osburn ('01). The specimen described by Bean ('03) is No. 3241 U.S. Nat'l Mus. from Cleveland. Common throughout the Mississippi valley.

Amia calva L..[1] Bowfin; Dogfish

Common. Of little or no value as a food fish.

Ictalurus punctatus (Rafinesque). Spotted Catfish

Taken in larger numbers than any other catfish by the fishermen on the Canadian side of the lake, at least at Merlin and Point Pelee. "Taken most frequently [in our waters] in Lakes Erie and Ontario" Nash ('08). Taken by Clemens and R.O.M.Z. party, 1920. Ranges south through the Mississippi valley and north at least as far as Winnipeg.

Ameiurus lacustris (Walbaum). Great Lake Catfish

"Generally distributed throughout the Great Lakes and in deep rivers, but is more abundant in Lake Erie than any other of our waters" Nash ('08).

Ameiurus natalis (Le Sueur). Yellow Catfish

"In Lakes Ontario, Erie and Huron" Nash ('08). Commonly taken in the nets off Point Pelee (R.O.M.Z. party).

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[1]"The time will doubtless come when thoroughgoing measures will be taken to keep down to the lowest practicable limit the dogfish and the gars—as useless and destructive in our productive waters as wolves and foxes formerly were in our pastures and poultry-yards." Forbes and Richardson ('08).

Ameiurus vulgaris (Thompson). Long-jawed Catfish

"Taken in Lake Erie" Jordan ('82). "Occasionally taken in the Ohio river, but is more abundant in Lake Erie" Bean ('03). "Lower jaw more or less projecting; in other respects scarcely distinct from *A. nebulosus*, with which it may intergrade" J. & E. Bull. 47 ('96).

Ameiurus nebulosus (Le Sueur). Common Bullhead

Commonly taken by fishermen at Merlin (Clemens) and at Point Pelee (R.O.M.Z. party). Said by Bean ('03) to be the most abundant catfish in Lake Erie and its tributaries.

Ameiurus melas (Rafinesque). Black Bullhead

"Sandusky bay at Black Channel" Osburn ('01). "Generally speaking, it is not distributed so far to the northward or eastward as our other abundant bullheads . . . . . through the Great Lakes of Ontario, Erie and Michigan" Forbes and Richardson ('08). "Variable, much resembles *A. nebulosus* but smaller, with shorter, deeper anal and especially shorter pectoral spines" J. &. E. Bull. 47 ('96).

Leptops olivaris (Rafinesque). Mud Cat

Osburn ('01) quotes McCormick of 1892 as follows, referring to the occurrence of this species in Lake Erie, "Quite rare; I have seen but one specimen fresh, though I have noticed heads on the beach." A fish of the Mississippi valley and Gulf States.

Noturus flavus Rafinesque. Stone Cat

"Lake Erie at Sandusky, frequently thrown up dead on the beach by the waves; not noticed in Sandusky bay" Osburn ('01). Secured at Point Pelee by R.O.M.Z. party.

Schilbeodes gyrinus (Mitchill). Tadpole Stone Cat

Osburn ('01) reports having observed it to be common among decaying vegetation in shallow water in Sandusky bay in 1896.

Schilbeodes miurus (Jordan). Mad Tom

"Sandusky bay" Osburn ('01).

Carpiodes thompsoni Agassiz. Drum; Lake Carp

"Lake Erie at Toledo" J. & E. Bull. 47 ('96). "Common in Lake Erie" Nash ('08). Taken by Hoover, 1921.

Catostomus catostomus (Forster). Northern Sucker

"Quite abundant in Lake Erie" Jordan ('82). "Occurs in the Great Lakes and northwest to Alaska in clear, cold waters. It is very common in Lake Erie" Bean ('03).

Catostomus commersonii (Lacépède). Common Sucker

Common at Merlin (Clemens) and Point Pelee (R.O.M.Z. party). Bates and Hoover collections, 1921. "Most abundant of all the suckers in Ontario waters" Nash ('08). Osburn ('01) speaks of it as "one of the commonest species", in Ohio.

Catostomus nigricans Le Sueur. Hog Sucker

Said by Nash ('08) to be found in Lake Erie.

Erimyzon sucetta oblongus (Mitchill). Chub Sucker

"Sandusky bay" Osburn ('01). "Great Lakes region to Maine and the Dakotas, south to Virginia . . . . . . gradually passing southward into the typical *sucetta*" J. & E. Bull. 47 ('96).

Minytrema melanops (Rafinesque). Striped Sucker

"Found in the Great Lakes and south . . . . In Pennsylvania it is limited to Lake Erie and the Ohio valley" Bean ('03). Reported from Lake Erie by Nash ('08).

Moxostoma anisurum (Rafinesque). White-nosed Sucker

Reported by Jordan ('82) from Lake Erie as *M. carpio*. "Great Lakes region; not very common, but widely distributed" J. & E. Bull. 47 ('96).

Moxostoma aureolum (Le Sueur).[1] Common Mullet; Redhorse

"Sandusky bay" Osburn ('01). "Inhabits the Great Lakes and the region northward . . . . common in Lake Erie" Bean ('03). "Formerly abundant in the waters of the Lakes from the St. Lawrence to Lake Superior, but owing to persistent netting during the spawning season it has become comparatively scarce" Nash ('08). Taken by Bates, 1921.

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[1]"Until very recent years this has been recorded as two species, the short-headed, small-mouthed form as *M. aureolum*; and the more ordinary form as *M. macrolepidotum duquesnii* (Le Sueur). This matter is cleared up by Jordan and Evermann (Bull. 47, U. S. Nat. Mus.). It is very probable that some collectors have confused the short-headed form with *M. breviceps* (Cope)." Osburn ('01).

Moxostoma breviceps (Cope). Short-headed Mullet

"Abundant in Lake Erie" J. & E. Bull. 47 ('96). "Seems to be confined entirely to Lake Erie so far as our province is concerned" Nash ('08). Taken by Bates and Hoover, 1921.

Placopharynx duquesnii (Le Sueur)

Osburn ('01) quotes McCormick of 1892 as follows, "Lake Erie, common with other mullets". A southern species.

Cyprinus carpio L. Carp

Very abundant, especially at Rondeau.

Carassius auratus (L.). Goldfish

Found by Turner ('20) along the shore of Middle and South Bass Islands, Lake Erie. Reported by fishermen at Point Pelee, Ontario, but no specimen taken.

Pimephales notatus (Rafinesque). Blunt-nosed Minnow

"Sandusky bay" Osburn ('01). Forbes and Richardson ('08) say this species seems to find a satisfactory place of residence in streams of any size or lakes or ponds of any description.

Semotilus atromaculatus (Mitchill). Creek Chub

Essentially a creek species but recorded by Osburn ('01) from Sandusky bay.

Leuciscus elongatus (Kirtland). Red-sided Shiner

"Generally speaking, a brook species . . . . . . though Dr. Kirtland, who described the species, records it from Lake Erie" Osburn ('01).

Opsopœodus emiliæ Hay

"Lake Erie" J. & E. Bull. 47 ('96). Southern in general range.

Abramis crysoleucas (Mitchill). Golden Shiner

Sandusky bay" Osburn ('01). Frequents sluggish waters.

Notropis anogenus Forbes

Taken at Put-in-Bay by Ward ('19) in connection with a study of fish parasites.

Notropis cayuga Meek

Osburn ('01) reports it as common in Sandusky bay.

Notropis heterodon (Cope)

"Sandusky bay" Osburn ('01).

Notropis blennius (Girard). Straw-coloured Minnow

"Sandusky bay" Osburn ('01).

Notropis hudsonius (DeWitt Clinton). Spawn-eater; Spot-tailed Minnow; Smelt

"Lake Erie, near Sandusky, abundant" Osburn ('01). "Abundant in the Great Lakes" J. & E. Bull. 47 ('96). "Abundant in the Great Lakes and at the mouths of the rivers opening into them" Forbes and Richardson ('08). Essentially a minnow of the larger rivers and lakes.

Notropis whipplii (Girard). Silver-fin

"Sandusky bay" Osburn ('01). Characteristically a minnow of clear streams.

Notropis cornutus (Mitchill). Shiner; Dace

"Sandusky bay" Osburn ('01). "Almost everywhere the most abundant fish in small streams" J. & E. Bull. 47 ('96).

Notropis atherinoides Rafinesque

"Exceedingly common in Lake Erie" Jordan ('82). "Through the Great Lakes . . . . It moves and feeds in large schools, thousands being frequently seen together near the surface" Forbes and Richardson ('08).

Notropis rubrifrons (Cope). Rosy-faced Minnow

"Sandusky bay and Lake Erie at Sandusky" Osburn ('01). Secured by Clemens at Merlin, 1920; also by Crewe and Hoover, 1921. "Delights in the clear waters of rapid streams" Forbes and Richardson ('08).

Rhinichthys cataractæ (Cuvier & Valenciennes). Long-nosed Dace

Although fond of clear, swift waters, Jordan ('82) reports it as found in the tributaries of Lake Erie and even in the lake itself.

Hybopsis dissimilis (Kirtland). Spotted Shiner

"Lake Erie" J. & E. Bull. 47 ('96). Great Lakes region, west and south.

Hybopsis storerianus (Kirtland). Lake Minnow

"Abundant in Lake Erie" Jordan ('82). "Lake Erie near Sandusky" Osburn ('01). Common at Merlin (Clemens) and Point Pelee (R.O.M.Z. party) 1920. Taken by Crewe, Bates and Hoover, 1921. "Lake Erie to Nebraska . . . abundant in the larger streams, especially in Iowa" J. & E. Bull. 47 ('96).

Anguilla chrysypa Rafinesque. American Eel

"According to Kirtland the eel did not formerly inhabit the Lake Erie drainage, but if not, it has found its way there through the canals" Osburn ('01).

Hiodon tergisus Le Sueur. Moon-eye

Taken in considerable numbers in the fishermen's nets. Of little commercial importance. Clemens and R.O.M.Z. party, 1920. Hoover, 1921. "Great Lakes and the Mississippi valley; north to Assiniboine river" J. & E. Bull. 47 ('96).

Dorosoma cepedianum (Le Sueur). Gizzard Shad

Common. "Cape Cod to Mexico; abundant southward . . . . . permanently resident (var. *heterurum*) everywhere in the Mississippi valley in the larger streams; also introduced into Lake Michigan and Lake Erie" J. & E. Bull. 47 ('96). Clemens, 1920. Hoover, 1921.

Pomolobus chrysochloris Rafinesque. Blue Herring; Sawbelly

Originally confined to the Gulf of Mexico and Mississippi valley. "Introduced through the canals into Lake Erie and Lake Michigan" J. & E. Bull. 47 ('96).

Coregonus albus Le Sueur. Lake Erie Whitefish

"This species is the common whitefish of Lake Erie. It is very close to *Coregonus clupeaformis*, the whitefish of the other lakes, differing only in form and colour. Compared with the latter, the Erie whitefish has a smaller head, higher nape, more angular form, and the colour is almost pure olive-white, without dark shades or dark stripes along the back. The flesh is softer, containing more fat. All these differences may be correlated with the fact that Lake Erie is shallow, and its southern shore is fed by warm, shallow, muddy, or milky rivers" Jordan & Evermann ('11).

Leucichthys harengus (Richardson). Georgian Bay Cisco

Clemens ('22) records this species as occurring sparingly in Lake Erie.

Leucichthys cisco huronius (J. & E.). Lake Huron Cisco

"Occasionally enters Lake Erie" Jordan & Evermann ('11). Clemens ('22) found it fairly abundant especially in western portion of the lake.

Leucichthys artedi (Le Sueur). Lake Erie Cisco

"Abounds in Lake Erie especially in its southern parts" Jordan & Evermann ('11). Clemens ('22) reports it as abundant in Canadian waters.

Leucichthys eriensis (J. & E.). Jumbo Cisco

"Inhabits especially the north shore of Lake Erie, where it is extremely abundant" Jordan & Evermann ('11). Clemens ('22) found it very abundant, particularly west of Long Point. On account of its great abundance, size and quality, the most important cisco of Lake Erie.

Leucichthys prognathus (Smith). Lake Ontario Cisco; Longjaw

Clemens ('22) found this species very abundant east of Long Point. Typically inhabits the deep water of the eastern end of the lake.

Leucichthys macropterus Bean

A specimen remarkable for the development of its fins has been described by Bean ('16) as *L. macropterus*.

Salmo gairdneri Richardson. Steelhead Trout

A specimen was taken at Rondeau, Lake Erie, on July 6, 1921, by Mr. W. D. Bates, of Ridgetown, Ontario. This species is propagated by the U.S. Fish Commission and has been introduced into Lake Superior.

Cristivomer namaycush (Walbaum). Great Lake Trout

The Annual Reports of the Department of Game and Fisheries, Province of Ontario, show that approximately two thousand pounds are taken annually from the Canadian waters of Lake Erie. It is found more especially at the eastern end of the lake.

Umbra limi (Kirtland). Mud Minnow

Osburn ('01) found it abundant in the "Black Channel" in Sandusky bay. Usually met with in ponds and creeks with a soft muddy bottom.

Lucius vermiculatus (Le Sueur). Little Pickerel

Taken by Osburn ('01) in Sandusky bay. An inhabitant of the Ohio and Mississippi rivers and streams flowing into Lake Erie and Lake Michigan from the south.

Lucius lucius (L.). Common Pike

Still of considerable commercial importance in Lake Erie, although less abundant than formerly. A cosmopolitan species of the northern hemisphere.

Lucius masquinongy (Mitchill). Maskinonge

Nash ('08) gives the range of this species in Ontario as follows: "In the St. Lawrence about the Thousand Islands, in the waters of the Trent valley, Lake Scugog, Lake Simcoe, and many of our inland lakes, but I have no record of its occurrence in any of the Great Lakes except Lake Erie and the Georgian Bay, where it is quite common."

Fundulus diaphanus menona (Jordan & Copeland). Killifish

Osburn ('01) found it common in Sandusky bay.

Eucalia inconstans (Kirtland). Brook Stickleback

"The Great Lakes from Ontario to Superior" Forbes and Richardson ('08).

Percopsis guttatus Agassiz. Trout Perch

According to Osburn ('01), McCormick of 1892 found this species to be common in Lake Erie. Forbes and Richardson ('08) report it as common in the Great Lakes but rare south of them. Nash ('08) says it ranges all through the Great Lakes and their tributaries north to Hudson Bay. Hoover took it at Nanticoke, 1921.

Aphredoderus sayanus (Gilliams). Pirate Perch

Reported for Lake Erie by Osburn ('01) on the authority of Henshall in 1889. "Occurs in Lake Erie" Bean ('03). "Through the Great Lakes at least as far east as Lake Erie" Forbes and Richardson ('08). Apparently confined to the Great Lakes and southward.

Labidesthes sicculus Cope. Silversides

"Very abundant on sandy bottom in shallow water in Sandusky bay" Osburn ('01). "Found in Lake Ontario, Lake Erie and the Detroit river" Nash ('08). "In all the Great Lakes" Forbes and Richardson ('08). A species of southern distribution.

Pomoxis annularis Rafinesque.[1] Crappie

Jordan ('82) reports it as rarely taken in Lake Erie. "Occurs rarely in Lake Erie" Nash ('08).

Pomoxis sparoides (Lacépède). Calico Bass

"In the Great Lakes in large numbers" Jordan ('82). Taken in 1920 at Point Pelee (R.O.M.Z. party) and at Merlin (Clemens). Bates and Hoover, 1921. See footnote under preceding species.

Ambloplites rupestris (Rafinesque). Rock Bass

"Sandusky bay" Osburn ('01). Forbes and Richardson ('08) state that this species has been taken from Lakes Huron, Erie and Ontario, but that it lives by preference in clear waters flowing over a rock bottom. Clemens, 1920. Hoover, 1921.

Chænobryttus gulosus (Cuvier & Valenciennes). Warmouth

"Lakes Michigan and Erie seem to mark its most northerly distribution . . . . everywhere a fish of the bayous, mud-bottomed ponds, and lakes, and lowland streams" Forbes and Richardson ('08).

Lepomis megalotis (Rafinesque). Long-eared Sunfish

"Sandusky bay" Osburn ('01). "In Lakes Erie, Huron and Michigan" Forbes and Richardson ('08). Abundant southward.

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[1] "It is worthy of note that in Chippewa Lake, which drains into the Ohio river system, this species (*P. annularis*) was found exceedingly abundant, but none of the next species (*P. sparoides*) were taken, while in Summit Lake, with very similar surroundings, but draining into Lake Erie, only *P. sparoides* was taken. These lakes are but a short distance apart, the former being near Medina, the latter at Akron." Osburn ('01).

"A tendency to geographical separation is shown by the fact that *annularis* is the more abundant southward . . . . and *sparoides* northward—the latter, indeed, also ranging somewhat the farther to the north." Forbes and Richardson ('08).

Lepomis pallidus (Mitchill). Blue Sunfish

"Very abundant in Sandusky bay" Osburn ('01)." Occurs abundantly in some parts of Lakes Ontario and Erie" Nash ('08). "In the Great Lakes from Ontario westward, ranging thence to the south and west" Forbes and Richardson ('08). Taken by Clemens at Merlin, 1920. Jordan and Evermann ('08) say that it is *the* sunfish of the lakes, whether large or small, but it is decidedly more abundant in the smaller ones.

Eupomotis gibbosus (L.). Pumpkin Seed

"In Sandusky bay . . . . it is the most abundant sunfish" Osburn ('01). "In Lakes Huron, Erie, Ontario and Champlain" Forbes and Richardson ('08). Clemens took it at Merlin, 1920.

Micropterus dolomieu Lacépède. Small-mouthed Black Bass

"Sandusky bay" Osburn ('01). Less common in Lake Erie than the next species. Prefers running water.

Micropterus salmoides (Lacépède). Large-mouthed Black Bass

"Sandusky bay" Osburn ('01). Clemens took it at Merlin, 1920. "Prefers lakes, bayous and other sluggish waters" Jordan and Evermann ('08).

Stizostedion vitreum (Mitchill). Pike Perch

Very abundant and of great commercial importance. Three colour phases occur and have received distinctive vernacular names, viz. gray pickerel, yellow pickerel and blue pickerel. The significance of these colour phases is not understood.

Stizostedion canadense griseum (DeKay). Sauger

Abundant in Lake Erie; of much less commercial importance than *S. vitreum*.

Perca flavescens (Mitchill). Yellow Perch

Very abundant. One of the most important commercial species in the lake.

Percina caprodes (Rafinesque). Log Perch

"Lake Erie at Sandusky" Osburn ('01). To the northward this species is represented by the following variety.

Percina caprodes zebra (Agassiz). Manitou Darter

Said to be the common form in the Great Lakes. "Lake Erie at Sandusky" Osburn ('01). Clemens took it at Merlin, 1920.

Cottogaster copelandi (Jordan). Copeland's Darter

According to Osburn ('01), Henshall of 1889 took this species in Lake Erie at Put-in-Bay. "Great Lakes region, from Lake Champlain to Lake Huron and south" J. & E. Bull. 47 ('96).

Cottogaster shumardi (Girard)

"It occurs also in the Great Lakes and has been reported from Erie and Michigan" Forbes and Richardson ('08).

Diplesion blennioides (Rafinesque). Green-sided Darter

According to Osburn ('01), McCormick of 1892 found this species to be not uncommon in Sandusky bay. Forbes and Richardson ('08) report it "from Lakes Erie and Ontario" and south.

Boleosoma nigrum (Rafinesque). Johnny Darter

"Sandusky bay" Osburn ('01). Typically a darter of the creeks and small brooks.

Ammocrypta pellucida (Baird). Sand Darter

"Taken also in the lake [Erie"] Osburn ('01). Reported by Jordan and Evermann ('96) from Lake Erie to Minnesota, abounding in clear sandy streams.

Etheostoma flabellare Rafinesque. Fan-tailed Darter

Found by Turner ('20) along the shore of Middle and South Bass Islands, Lake Erie.

Boleichthys fusiformis (Girard)

"Rather common in shallow water in Sandusky bay" Osburn ('01).

Roccus chrysops (Rafinesque). White Bass

Abundant. A commercial species of minor importance.

Aplodinotus grunniens Rafinesque. Sheepshead

Quite an important commercial species, occurring fairly abundantly and growing to a good size.

Cottus ictalops (Rafinesque). Miller's Thumb

Found by Turner ('20) along the shore of Middle and South Bass Islands, Lake Erie. Taken by Crewe at Merlin, 1920.

Lota maculosa (Le Sueur). Burbot; Ling.

Very abundant. In the Great Lakes region it is considered of little value as food. Lake Erie fisherman destroy those taken in the nets because they believe it destructive to other fish. In some places it is esteemed as food.

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UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE

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No. 5

RATES OF GROWTH OF THE BLUE AND YELLOW PIKE PERCH

BY

F. B. Adamstone

of the Department of Biology

University of Toronto

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1922

RATES OF GROWTH OF THE BLUE AND YELLOW PIKE PERCH (*STIZOSTEDION VITREUM*) IN LAKE ERIE

From material obtained during the summer of 1920, at Merlin, Ontario, on Lake Erie, a study has been made, under the direction of Dr. W. A. Clemens, of the rates of growth of the blue and yellow pike perch. These fish, together with the gray pike perch, are described as colour varieties of one species, *Stizostedion vitreum* Mitchell (Jordan and Evermann, 1898, American Fish Manual, 1903). This species is also known as the wall-eyed pike perch, pickerel or doré, the latter being sometimes restricted to the yellow variety.

Apart from their difference in colour, these varieties are also distinguished by their great diversity in size. The blue is apparently the smallest, averaging less than one pound in weight, and occasionally attaining as much as five pounds. The yellow may reach 20 pounds and is often taken weighing from 5 to 10 pounds, and the gray, which is the largest, attains a maximum of 40 pounds, 10 to 20 being common.

The specimens of blue and yellow pike perch obtained at Merlin agree in this divergence in size, but apparently none of the gray variety are caught there by fishermen. Measurements of length, girth, etc., were taken on the specimens of the blue and yellow varieties with a view to the later determination of their respective rates of growth. For this purpose scales from each fish were preserved for the determination of age. The scales were mostly taken from the middle of the sides of the body below the lateral line. In most cases the ear stones were also preserved for use in estimating age.

By microscopic examination of the scales from a fish a fairly accurate estimate of the age can be made. Typical scales of both blue and yellow pike perch are shown in

Figs. 1, 2, 3. From the illustrations it will be seen that the scales are ctenoid; that is, the exposed posterior portion is covered with a number of small spines or teeth. The anterior margin, which is embedded in a pocket of the epidermis and is protected by the overlapping borders of those in front of it, has an entirely different appearance. Instead of being spiny it is fluted and the surface is marked by a large number of fine concentric lines, broken at intervals by radial lines, which pass inward towards the centre from the notches of the scalloped edge. The fine concentric lines are lines of growth, and each represents the addition of a ring

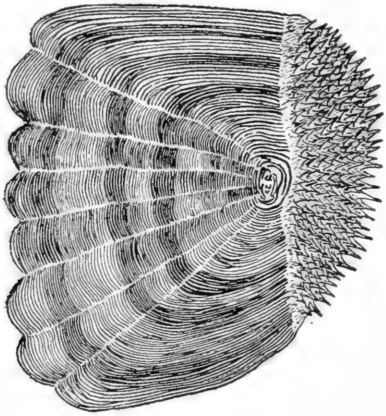

Fig. 1. Scale from a blue pike perch in its fourth summer.

of material to the scale at the border where it is attached to the epidermis.

At regular intervals on the scale the fine lines are laid down alternately closely set and more widely separated. The spacing is wide apart or close together according as the lines were added at a favourable or unfavourable season of the year. This arrangement of lines gives the scale the appearance of having wide light and dark bands when it is examined under the microscope. As shown in Fig. 1 the outer margin is marked by a light band and in the other scales examined a similar area was almost invariably present in this position. This apparently marks a summer's growth since all the specimens were obtained in summer. The central portion of each scale is surrounded by a dark area which must necessarily represent a late summer's growth and the first winter period, since the fish hatch in spring and the central portion of the scale would be formed during the first summer. This is shown by the illustration of the scale of the smallest blue pike perch in Fig. 2.

By counting the number of dark bands present on a scale the age of the fish can be estimated. Thus, if there are three, as shown in Fig. 1, the fish must have lived three years and some fraction of the fourth summer. However,

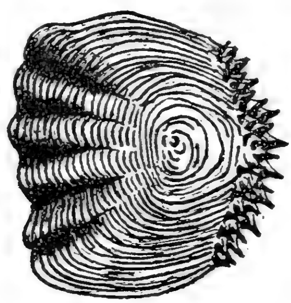

Fig. 2. Scale from a blue pike perch in its first summer.

it is impossible to estimate the fraction of a year with any great degree of accuracy. Accordingly, in the present instance, the number of whole years has been determined and an average fraction added to each. Thus, assuming that in general these fish hatch in May, then fish caught in June of the following year would have completed, on the average, a growth period of one year and one month. Similarly, fish caught in July would have completed one year and two months, and fish caught in August, one year and three months. Therefore, the average growth periods of fish caught in June, July and August would be one year and two months. All the fish considered in this study were obtained during the months of June, July and August, and hence an average of two months has been added to the number of whole years indicated by the scale of any particular fish. Thus the estimated age of the fish whose scale is figured in Fig. 1 is 3 1-6 years and that of the yellow pike perch in Fig. 3 is 2 1-6 years. This arrangement, though quite arbitrary, is justifiable since the measurements of length, weights, etc., must also be averaged in the determination of the rate of growth.

In a great many cases the ear stones of the fish were examined as well as the scales. These also show increase in

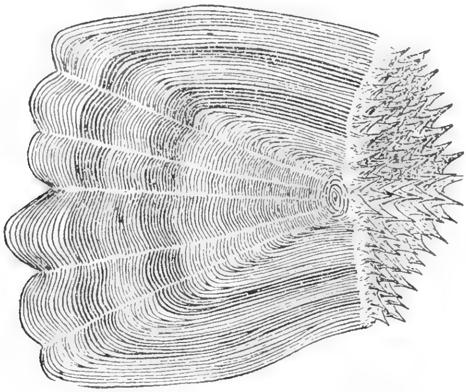

Fig. 3. Scale from a yellow pike perch in its third summer.

size with age and alternate light and dark bands, much like the scales, but they are much more difficult to work with on account of their opacity. However, in a great many cases they could be used to check the results obtained with the scales.

Blue Pike Perch

The data obtained by measurements, and determination of age, of the specimens of the blue pike perch are given in the following table:

No.	Date	Length cm.	Length inches	Age in yrs.	Weight in oz.	Girth in.
52	Oct. 1920	7.4	2.9	½		
11	July 7	15	5.9	2½	2	3½
10	June 25	17	6.7	2½	3	3¾
1	June 24	17.2	6.8	2½	2½	3⅝
17	July 7	18.1	7.1	2½	2½	
28	July 28	19.2	7.5	3⅙	3	4⅛
48	Aug. 16	19.6	7.7	"	3½	4¾
12	July 7	19.6	7.7	"	3	4⅛
15	July 7	19.7	7.7	"	3	
16	July 7	20.4	8	"	3½	
27	July 28	20.4	8	"	4	5
2	June 24	20.6	8.1	"	4	4⅜
8	June 25	20.7	8.1	"	4	4½
18	July 7	20.7	8.1	"	4	4½
13	July 7	21.0	8.3	"	4	4½
44	Aug. 16	21.0	8.3	"	4	4⅝
38	Aug. 13	21.0	8.3	"	5	4⅝
32	July 30	22.0	8.7	"	4	4¾
30	July 28	22.1	8.7	"	5	5⅛
45	Aug. 16	22.2	8.7	"	5	4⅞
46	Aug. 16	22.3	8.8	"	5	4⅛
37	Aug. 13	22.5	8.8	"	6	5
34	July 30	22.8	9	"	5½	5⅛
19	July 7	22.8	9	"	6	5¼
14	July 7	23.2	9.1	"	6	5¼
39	Aug. 14	23.2	9.1	"	7	5¼
33	July 30	23.8	9.4	"	6½	5⅛
29	July 28	23.8	9.1	"	6	5¼
27	Aug. 16	24.5	9.6	"	7	5¼
43	Aug. 16	24.6	9.6	"	8	5⅝
26	July 28	25.2	9.9	"	8	5⅝
31	July 28	25.5	10	4⅙	8	5⅝
40	Aug. 14	25.5	10	"	9	5⅞
20	July 7	26.7	10.5	"	9	5⅞
49	Aug. 16	27.1	10.7	"	11	6⅛
26	Aug. 13	27.7	10.9	"	12	6½
41	Aug. 14	27.6	10.9	"	11	6¼
25	July 28	28.0	11	5⅙	12	6½
21	July 7	28.0	11	"	12	6½
9	June 25	28.6	11.3	"	17	7½
42	Aug. 16	28.7	11.3	"	10	6⅛
4	June 24	29.0	11.4	"	17	7½
51	Aug. 16	29.6	11.7	"	15	6⅞
50	Aug. 16	29.8	11.7	"	14	6⅞
6	June 25	30.2	11.9	6⅙	17	7¾
5	June 24	30.5	12	"	17	7⅜
22	July 7	30.5	12	"	15	7
3	June 24	31.9	12.5	7⅙	17	7½
7	June 25	31.9	12.5	"	17	7½
23	July 7	33.0	13	"	16	7⅛

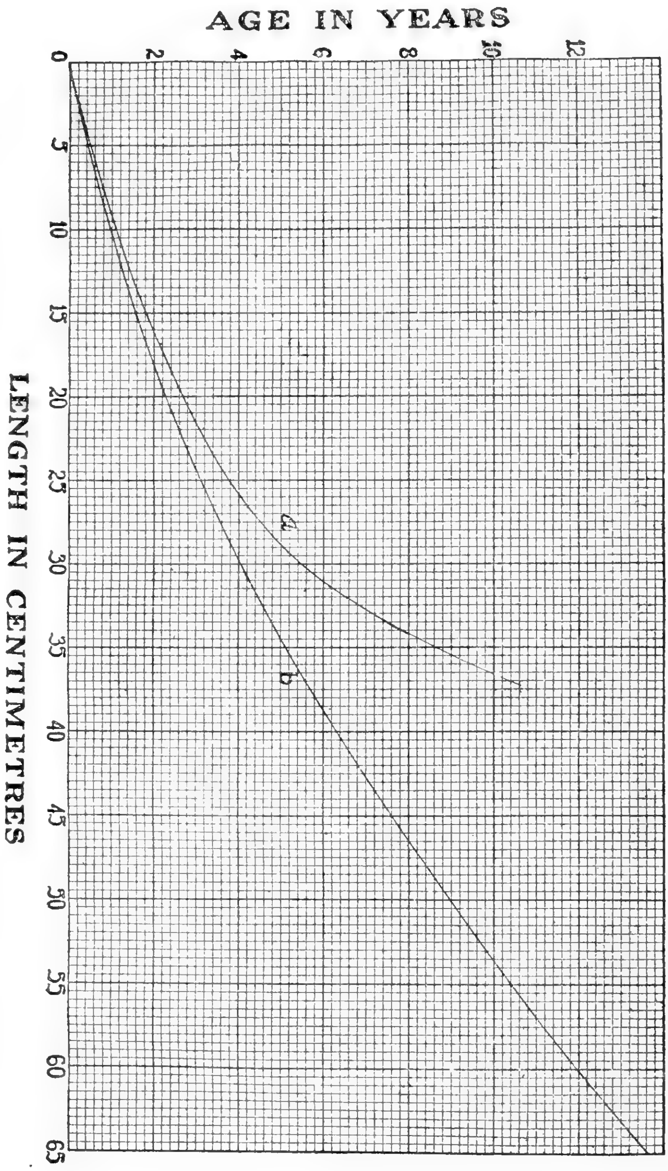

Fig. 4. Graphs showing rates of growth of (*a*) blue pike perch, (*b*) yellowpike perch in Lake Erie.

From the results given above the average length and weight, for each age, have been worked out and are given in the following table:

AGE IN YEARS	LENGTH		WEIGHT IN OZ.
	CENTIMETERS	INCHES	
½	7.4	2.9	
2⅙	16.8	6.6	2½
3⅙	21.9	8.6	5
4⅙	26.4	10.4	10
5⅙	28.8	11.4	14
6⅙	30.4	12.0	16⅓
7⅙	31.9	12.6	16⅔

Using the averages of length and age given in this table, graphs have been drawn (Fig. 4a and 5a) showing the rate of growth of the blue pike perch.

Yellow Pike Perch

A similar determination of the rate of growth of the yellow pike perch has been made from the material collected for the purpose. The results of age determination for these specimens are tabulated below:

No.	Date	Length cm.	Length in.	Age years	Weight oz.	Girth in.
24	Aug. 16	14.7	5.8	2⅙	2	3⅛
20	July 9	15.1	5.9	"	2	
21	" 9	15.1	5.9	"	2	
13	June 25	15.6	6.2	"	2	
12	" 25	16.3	6.4	"	2	3½
1	" 24	16.8	6.6	"	2½	3½
11	" 25	17.8	7.0	"	3	3⅞
2	" 24	18.2	7.3	"	3	3¾
19	July 9	18.8	7.4	"	3	
18	" 9	18.8	7.4	"	3	
23	Aug. 16	21.0	8.3	"	5	4¾
14	June 25	21.0	8.3	"	4½	4¾
9	" 25	21.0	8.3	"	4½	4½
5	" 24	21.0	8.3	"	4½	4½
3	" 24	21.1	8.3	"	4½	4¾
22	Aug. 16	25.0	9.8	3⅙	9½	5⅞
4	June 24	28.6	11.2	"	11	6
7	" 24	30.0	11.8	4⅙	16	6⅞
10	" 25	30.5	12.0	"	14	6½
6	" 24	30.7	12.0	"	14	6½
25	Aug. 18	33.5	13.2	"	1 lb. 6	7⅞
8	June 25	38.7	15.2	6⅙	2 lb. 3	9½
16	" 30	51.5	20.2	9⅙	4 lb. 14	12¼
17	July 5	60.5	23.8	12⅙	8 lb. 14	15½
15	June 30	63.5	25	13⅙	10 lb. 12	16½

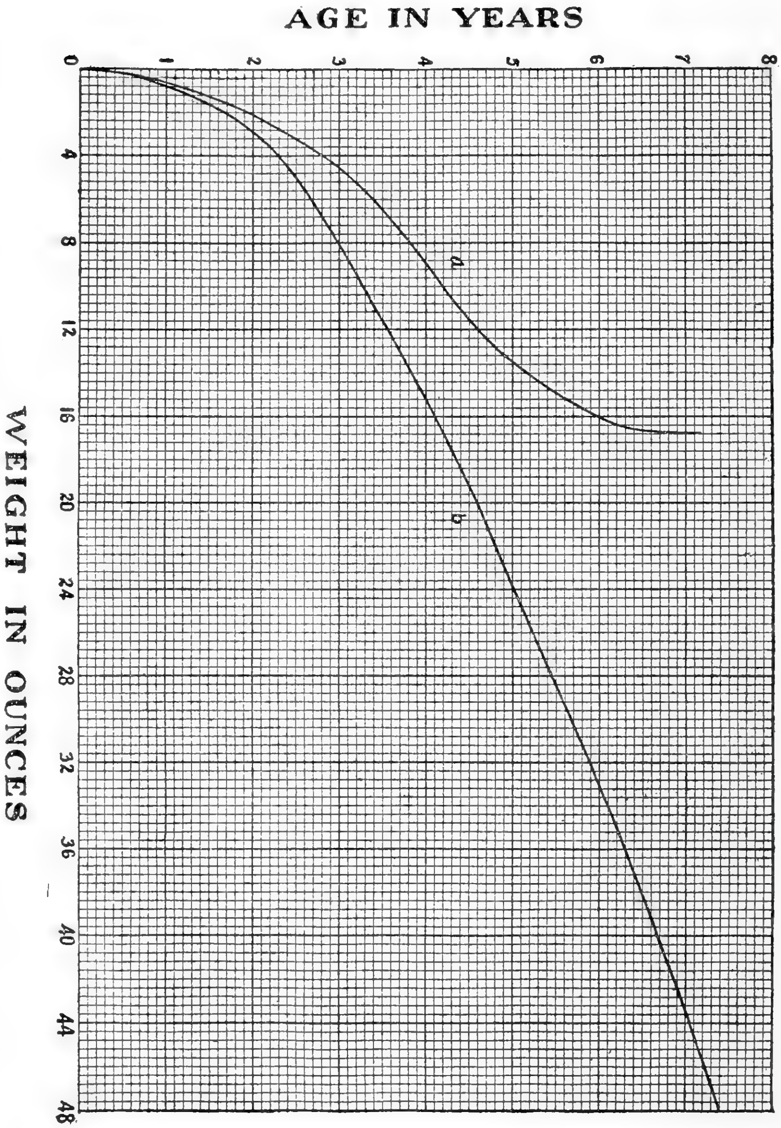

Fig. 5. Graphs showing relation of weight to age, (*a*) blue pike perch, (*b*) yellow pike perch in Lake Erie.

The results given in the preceding table have been used to compute the following table of averages, from which curves illustrating the rate of growth of the yellow pike perch have been drawn in Figs. 4b and 5b.

AGE YEARS	LENGTH CM.	LENGTH INCHES	WEIGHT
2 1/6	18.2	7.4	3 1/6 oz.
3 1/6	26.8	10.6	10 1/4 "
4 1/6	31.2	12.3	16 1/2 "
6 1/6	38.7	15.3	2 lb. 3 oz.
9 1/6	51.5	20.3	4 " 14 "
12 1/6	60.5	24.1	8 " 14 "
13 1/6	63.5	25.1	10 " 12 "

A comparison of the two curves obtained brings out the fact that the rate of growth of the yellow pike perch is fairly uniform, whereas, in the case of the blue variety, there is a decided slowing up of the rate of growth at about the end of the fifth year. In both cases, however, there is a falling off in growth with age. In order to show this the lengths at the ages of 1, 2, 3 years, etc., have been obtained by interpolation on the curves, and from these figures the yearly increase in length is obtained.

Age Years	Blue Pike Perch		Yellow Pike Perch	
	Length cm.	Yearly Increment cm.	Length cm.	Yearly Increment cm.
1	9.3	6.9	10.3	7.7
2	16.2	4.5	18	6.4
3	21.7	4.1	24.4	5.3
4	25.8	3.0	29.7	4.7
5	28.8	2.4	34.4	4.3
6	31.2	1.5	38.7	4.0
7	32.7		42.7	3.8
8			46.5	3.7
9			50.2	3.3
10			53.5	3.4
11			56.9	3.3
12			60.2	2.3
13			62.5	

In the case of the blue pike perch the decrease in rate of growth after the fifth year is not compensated by large increase in weight, as in the case of the yellow variety. Thus, in the fifth summer, the average weight of the blue is 10 oz., which increases to 16 1-3 oz., by the seventh summer, but this increase in weight is accompanied by a very small increase in length.

In the case of the yellow pike perch, on the other hand, the slowing up of growth occurs about the end of the fifth year but the slow growth is more than compensated by the large increase in weight which then begins.

From a consideration of the curves obtained, it would appear that the best time to take the blue pike perch is after the fifth year when they have obtained a length of about 28 to 30 cm. (11 to 12 inches) and weigh 14 to 16 ounces. Since the girth measurement posterior to the gill cover at this age is about 6 inches, this is approximately the size which would be taken in a 3-inch gill net.

With the yellow pike perch, since they increase so rapidly in weight after the sixth year, it would appear that they should not be taken until they have reached a length of at least 15 inches and weigh approximately 2 lbs.

The study of the rates of growth of the blue and yellow pike perch shows that the former do not reach nearly so great a size as the latter, and amply confirms the opinion of fishermen that the blue are much smaller. Moreover, after the fourth year the rate of growth of the blue variety falls off very rapidly, whereas the yellow continue to grow uniformly up to a considerable age. This peculiar difference in the rates of growth possibly indicates some basic physiological distinction between the two varieties which also possibly finds expression in their difference in colour.

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UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE

ONTARIO FISHERIES RESEARCH LABORATORY

No. 6

THE RATE OF GROWTH OF THE YELLOW PERCH (*PERCA FLAVESCENS*) IN LAKE ERIE

BY

W. J. K. HARKNESS

OF THE DEPARTMENT OF BIOLOGY

UNIVERSITY OF TORONTO

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1922

THE RATE OF GROWTH OF THE YELLOW PERCH (*PERCA FLAVESCENS*) IN LAKE ERIE

As shown in the returns given in the annual reports of the Department of Game and Fisheries of the Province of Ontario, the catch of yellow perch (*Perca flavescens* Mitchell) in Canadian waters of Lake Erie has practically doubled in the past ten years. In 1919 the catch amounted to 1,096,935 pounds, valued at $87,755. In view of this increasing value of the yellow perch fishing industry in Lake Erie, it seemed desirable to obtain some definite information as to the rate of growth of this fish.

The study was undertaken at the suggestion of Professor W. A. Clemens, and carried out under his direction. The material was obtained by Dr. Clemens, at the Crewe Bros. Fishery, Merlin, Ontario, during the summer and autumn of the year 1920.

The age of the fish was determined by counting the seasonal growth areas on the scales. The scales found most satisfactory were those from the region about the middle of the body below the lateral line. An examination of a perch scale shows alternating light and dark areas. It has been taken for granted that the light area corresponds to a period of rapid growth which would take place during the summer months, while the darker area, where the lines are more crowded, represents a period of slower growth which no doubt occurs during the winter months. This interpretation of the areas on the scale is supported by the fact that the scales from perch taken in late summer show a distinct light area on the margin, while those from perch taken in early summer show a dark area on the margin. Figure 1 illustrates the characteristics of a perch scale, and the method used in age estimation. Table 1 shows the results of this study coördinated.

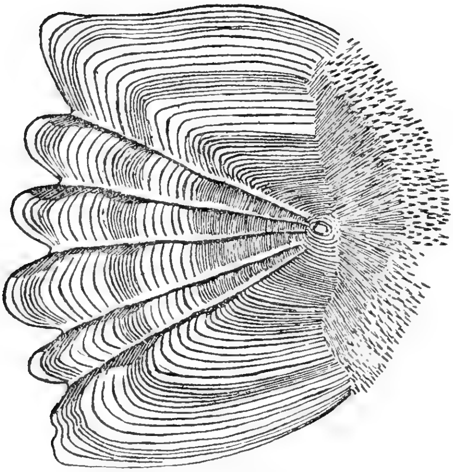

Fig. 1. Scale of a yellow perch at the beginning of its fourth summer.

TABLE 1. DATA ON RATE OF GROWTH OF YELLOW PERCH IN LAKE ERIE.

Age	Number of Fish Examined		Length in cm. to base of caudal fin			Length in inches over all	Girth in inches just posterior to the gills	Weight in Ounces	
	Actual Number	Percentage of Total No.	Average by Measurement	Average by Estimating	Estimated Increase from Year to Year			Average by Observation	Estimated Increase from Year to Year
½ year	1	1.3	4.4	5.0		2			
1½ "	0	0		10.0	5.0				
2½ "	30	40.5	14.4	14.0	4.0	6.6	4.4	2.6	
3½ "	18	24.0	16.8	17.0	3.0	7.7	5.1	4.3	1.7
4½ "	13	18.0	18.7	19.5	2.5	8.5	5.7	5.7	1.4
5½ '	4	5.2	21.7	21.5	2.0	9.9	6.6	9.2	3.5
6½ "	4	5.2	23.4	23.5	2.0	10.8	7.3	11.6	2.4
7½ "	4	5.2	24.4	24.5	1.0	11.0	7.2	12.8	1.2

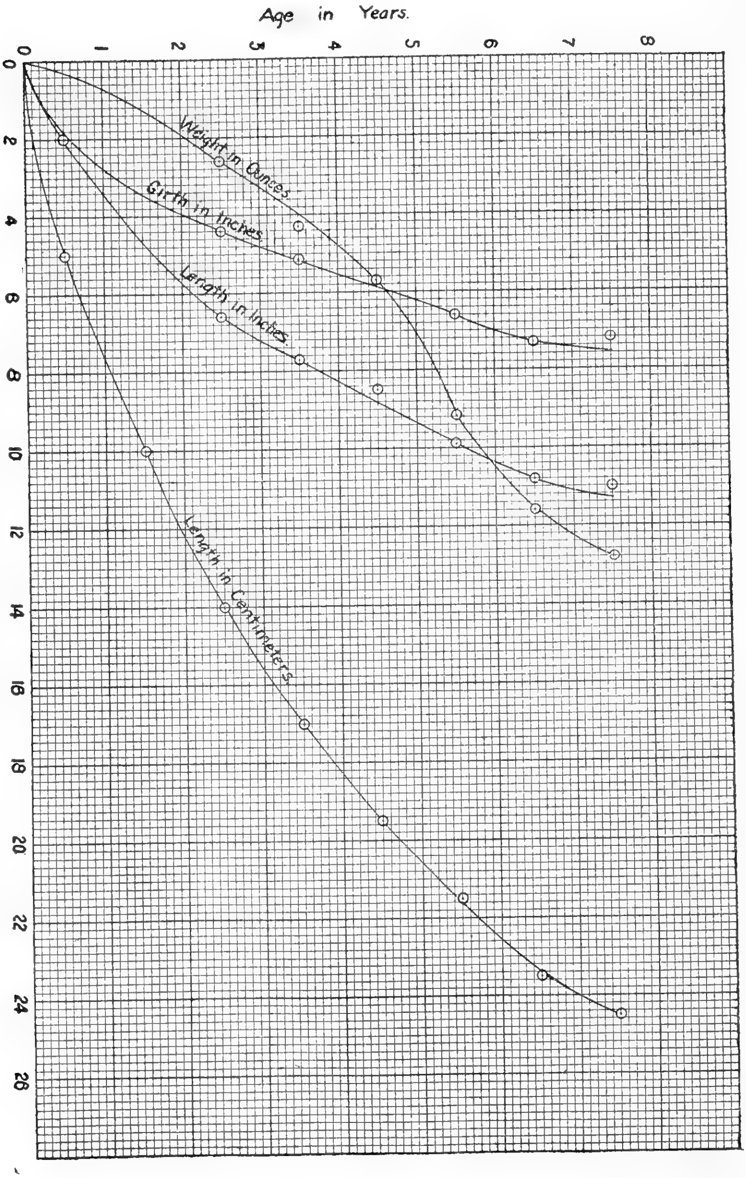

Fig. 2. Graphs showing rate of growth of yellow perch in Lake Erie.

Fig. 2 is a graph showing the relation of age to length in centimeters, length in inches, girth in inches and weight in ounces.

Embody (1915) gives the following table for the growth of yellow perch as compiled from data obtained on the fish growing in natural waters in the vicinity of Ithaca, N.Y.

Age	Length in in. over all	Length in cm. over all	Length in cm. to base of caudal fin
5 months	2–2.5	5–6.5	3.5–5
1 year	3–4	7.5–10	5.5–8
2 years	6–7	15–17.5	13–15.5
Spawn	April		
Advanced fry	May–June		
Fingerlings	September		

The measurements given by Embody have been reduced to centimeters, and the last column shows the approximate lengths of these fish to the base of the caudal fin. These figures agree very closely with the data compiled from fish growing in Lake Erie as do also those of Pearse and Achtenberg (1920) who give the lengths of yellow perch taken in Lake Mendota, Wis., in the first summer as 2.9 cm. on July 7 to 6.1 cm. on August 24.

If the fish are taken before they reach maturity and are thus prevented from spawning, the supply of that species will soon become depleted. This is amply exemplified by the disappearance of the trout from many of the Ontario streams, and the bass from the lakes.

It is believed that the fish studied are a fair average of the total catch. By a study of table 1 and Fig. 2 it is seen that approximately

40 per cent. of all the perch caught were 2½ years old averaging 14.0 cm. (6.6 in.) in length, 4.4 inches in girth and 2.6 ounces in weight.

24 per cent. of all the perch caught were 3½ years old averaging 17.0 cm. (7.7 in.) in length, 5.1 inches in girth and 4.3 ounces in weight, an increase of 1.7 ounces over the 2½ year old perch.

18 per cent. of all the perch caught were 4½ years old averaging 19.5 cm. (8.5 in.) in length, 5.7 inches in girth and 5.7 ounces in weight, an increase of 3.1 ounces over the 2½ year perch, and only

5.2 per cent. of all the perch caught were 5½ years old averaging 21.5 cm. (9.9 in.) in length, 6.6 inches in girth and 9.2 ounces in weight, an increase of 6.6 ounces over the 2½ year old perch.

Pearse and Achtenberg (1920), judging by the measurements made on individuals from a school of young perch which remained near the base of Picnic Point, Lake Mendota, during the summer of 1916, and by observations of the gonads of half grown perch at various seasons, believe that perch may become sexually mature in Lake Mendota at the end of two years of growth. No information was obtained as to the age when the yellow perch first spawns in Lake Erie waters, but it probably is the end of the third year.

Yellow perch increase most rapidly in weight between the age of 3½ and 5½ years (Fig. 2). During these two years the perch in Lake Erie increase on an average about 5 ounces, which is more than their weight at 3½ years of age (Fig. 2).

It would appear from the data at hand, that no yellow perch should be caught which are less than 4½ years old. In other words from the standpoints of conservation and of monetary returns this fish should be taken when about 8 to 10 inches in length. This would allow the fish to spawn at least twice, and this would tend to ensure an inexhaustible supply. This would also give the fisherman a larger supply of a much more satisfactorily marketable fish. Unless some protection is given there is danger of the yellow perch fishery in Lake Erie becoming depleted in a few years if the rate of increase in the amount of catch during past few years is maintained.

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UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 7

THE RATE OF GROWTH OF THE WHITE FISH (*COREGONUS ALBUS*) IN LAKE ERIE

BY

JOHN H. COUCH

OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

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THE RATE OF GROWTH OF THE WHITE FISH (*COREGONUS ALBUS*) IN LAKE ERIE

The purpose of this investigation has been to obtain some definite information concerning the rate of growth of whitefish in Lake Erie. The study was undertaken at the suggestion of Dr. W. A. Clemens to whom the writer desires to express his appreciation of the kind assistance given.

The specimens were procured from points along the north shore of Lake Erie (Kingsville, Merlin, Ridgetown and Nanticoke) through the kindness of Messrs. B. Wescott, A. E. Crewe, W. D. Bates and A. B. Hoover. For purposes of comparison eight specimens of whitefish were obtained from Port Credit on Lake Ontario and two from Hudson Bay. The latter were collected by Rev. W. G. Walton on July 22, 1919, at Great Whale river.

Identification

The fish from Lake Erie are here referred to the species *C. albus* Le Sueur, while those from Lake Ontario to *C. clupeaformis* (Mitchell) following Jordan and Evermann (1911). By way of comparison detailed measurements were taken of three specimens from Lake Erie, numbers 101, 102 and 105; three from Lake Ontario, numbers 66, 67 and 68; and the two from Hudson Bay, numbers 131 and 132. All the specimens had been preserved in formalin and alcohol some time previous to the time the measurements were made. The results are shown in the following table:

	LAKE ERIE				LAKE ONTARIO				HUDSON BAY		
SpecimenNo.	102	103	105	Av.	66	67	68	Av.	131	132	Av.
Body length (mm.)	558	428	382		462	350	418		302	234	
Dorsal rays	13	11	12		13	11	11		14	13	
Anal rays	13	14	13		11	12	13		13	13	
Scales	85	81	85		84	87	84		78	79	
Gill rakers	22	25	28		25	26	25		26	25	
*Head	.20	.21	.19	.20	.21	.22	.21	.21	.235	.22	.23
Body depth	.29	.34	.29	.31	.28	.24	.23	.25	.275	.27	.27
C.P. length	.07	.09	.08	.08	.11	.09	.10	.10	.11	.11	.11
C.P. depth	.09	.10	.08	.09	.08	.08	.07	.08	.09	.09	.09
Eye	.03	.04	.03	.03	.035	.04	.04	.04	.05	.05	.05
Maxilla	.05	.05	.05	.05	.05	.05	.055	.05	.07	.07	.07
Pectoral length	.16	.17	.16	.16	.18	.17	.17	.17	.19	.17	.18
Pelvic length	.15	.15	.14	.15	.17	.16	.165	.165	.17	.18	.175
Dorsal height	.16	.17	.17	.17	.18	.18	.18	.18	.19	.21	.20
Anal length	.13	.13	.105	.12	.13	.14	.13	.13	.13	.11	.12

*Measurements given as decimal fractions of body length.

The results for the Lake Erie and Lake Ontario fish agree closely with those given by Jordan and Evermann (*loc. cit.*) and Bensley (1915). For the Hudson Bay fish several slight though interesting variations appear. The caudal peduncle appears to be longer; the diameter of the eye greater; the length of the maxilla greater; the height of the dorsal greater; the lengths of the pectoral and pelvic fins greater, and the scales on the lateral line fewer. In spite of these differences there is a close resemblance to the Lake Ontario whitefish and it seems advisable for the present to refer these two fish to the species *C. clupeaformis*.

Rates of Growth

The rate of growth was determined by plotting curves between the age ascertained from the scales and the length and weight determined by direct measurement. The scales for determining the age were taken from the side of the fish, some from just below the anterior part of the dorsal fin, some near and including the lateral line, and some from just before the pelvic fin where the scales are large. The round even scales from the dorso-lateral region were found to be more satisfactory than those from the ventro-lateral region. The latter were larger but had radiate markings and ridges on them and the summer and winter areas were not so well defined. The vertebrae and otoliths of some specimens were preserved as a secondary means of determining the age but they were found to be much less reliable beyond three years of age. The method of determining the age from the scales is illustrated in figure 1. It is assumed that the areas with widely separated lines represent spring and summer periods when growth conditions are at their best. Conversely the closely spaced areas represent the winter months. In Fig. 1 the upper two scales (A and B) are from whitefish from Lake Erie aged two and five years respectively. The lower two (C and D) are from the whitefish from Hudson Bay, aged five and ten years respectively. All scales are enlarged to the same degree, i.e. fifteen diameters. The scales and likewise the fish themselves from Hudson Bay are smaller than those from Lake Erie, although the former are much older. This apparently furnishes a striking illustration of the effect of cold water on the growth of these fish.

The rates of growth of the fish examined are shown in Fig. 2. The results indicate that during the first two or

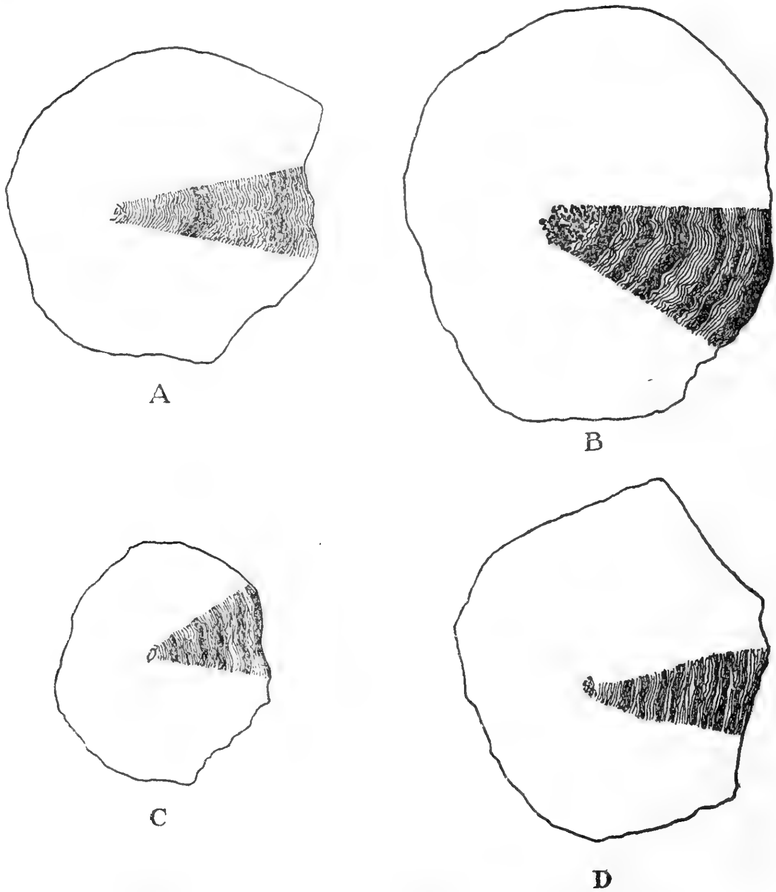

Fig. 1. Scales from whitefish from Lake Erie and Hudson Bay.
A and B from Lake Erie, third and sixth summers respectively.
C and D from Hudson Bay, sixth and eleventh summers respectively.

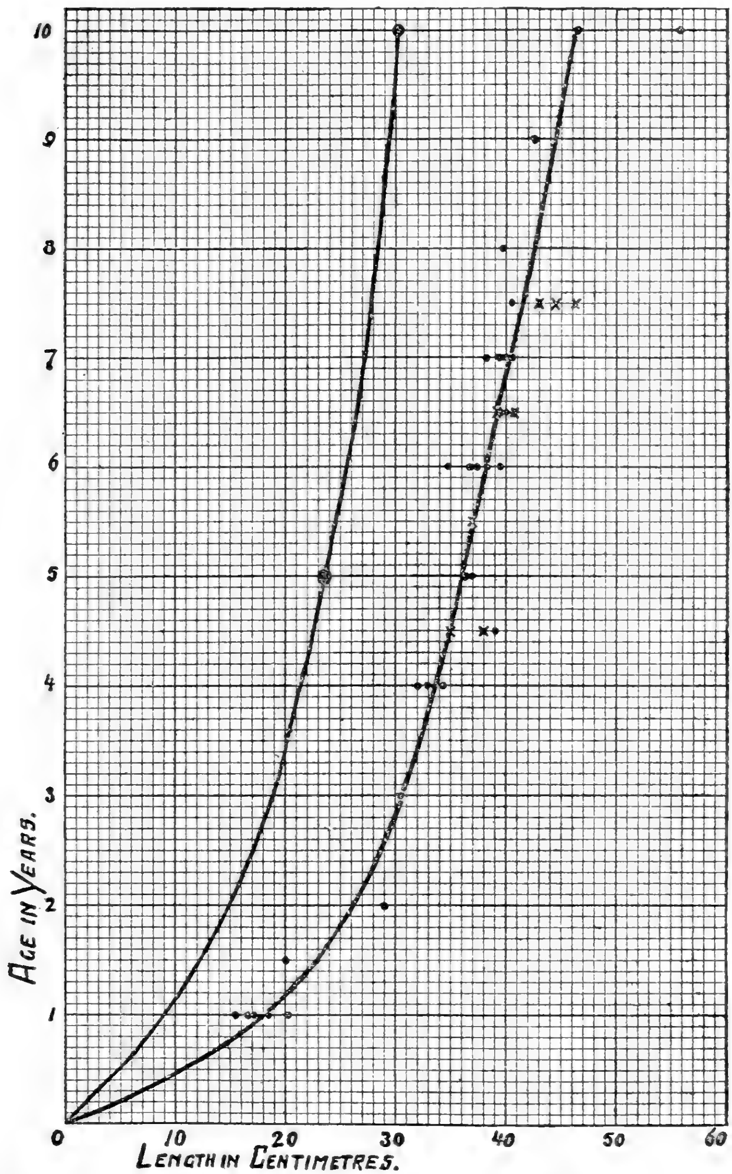

Fig. 2. Graphs illustrating rates of growth of whitefish from Lake Erie and Hudson Bay.

O, whitefish from Hudson Bay.
o, " " Lake Erie.
X, " " Lake Ontario.

three years the fish grow quite rapidly in length, then gradually the rate of growth lessens and the increase in length with age is much less noticeable. They do however, continue to increase in length until ten or twelve years of age and probably throughout their entire lives. The eight specimens from Lake Ontario are also shown on the graph although the number is too small to warrant a curve. However, they appear to have a rate of growth somewhat similar to that

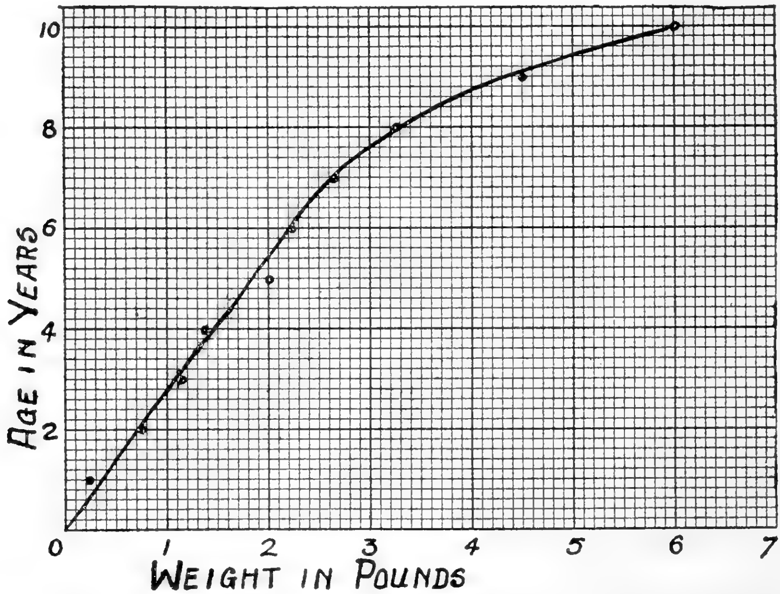

Fig. 3. Graph showing rate of increase in weight with age, whitefish, Lake Erie.

of the Lake Erie fish. The two from Husdon Bay are also shown and an approximate curve projected through them. Here also it is strikingly demonstrated that the rate of growth in cold water is much slower than in such waters as Lake Erie. Since a fish is a "cold-blooded" animal its body temperature in cold water is low, and it follows directly that its metabolic reactions are all depressed and hence that growth is retarded.

The fish were weighed at the same time that the scales were removed and the lengths determined. It is interesting to compare the rate of increase of length with age (Fig. 2) and the rate of increase of weight with age (Fig. 3).

Since the conditions of the fish, such as the amount of fat and the development of the gonads, result in considerable differences in weight, the average of all the fish in each year was taken and this is used in this curve. It indicates that

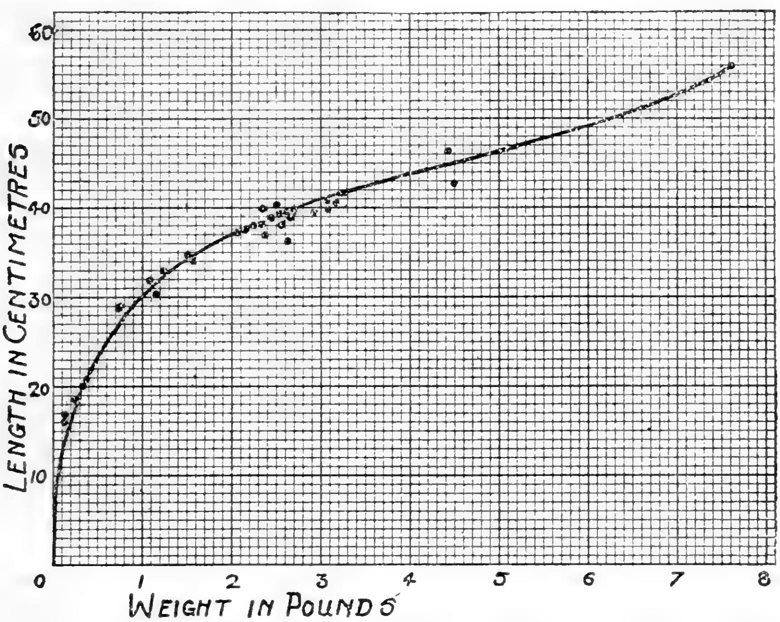

Fig. 4. Graph showing relation between length and weight, whitefish, Lake Erie.

the fish increase quite uniformly in weight up to four or six years of age, after which they increase rapidly relative to age and also to length. This is of the utmost importance from a commercial standpoint as the weight obviously bears a direct relation to food value. If left to the age of seven to ten years (40-50 cm.) the fish would have passed through that period when there is the greatest relative increase in weight. The wisdom of such a course is obvious. Another phase of this matter has been illustrated in Fig. 4 where weight and length have been plotted. In this graph each individual fish was recorded. It shows that at first the fish develops rapidly in length for a small increase in weight. Then at about 35 cms. the rate of growth in length decreases and the fish begins to increase in weight. This rapid increase in weight and comparatively slow increase in length continues at least up to ten years of age though probably soon after this age the rate of increase in weight falls off again. The curve corroborates the deductions drawn from Figs. 2 and 3.

DATA—*COREGONUS ALBUS*—LAKE ERIE

Specimen No.	Date	Length cm.	Girth cm.	Weight lb. oz.	Age Years	Sex
1	May 1919	32.0		1 lb. 1 oz.	4	
2	"	29.0		0 " 12 "	2	
3	"	20.0		0 " 5 "	1½	
25	June 6	37.0		2 " 6 "	5	♀ very fat
26	"	46.5		4 " 7 "	10+	♀ fat
27	"	33.0		1 " 4 "	4	♀
28	"	34.3		1 " 9 "	4	♂ fat
29	"	30.3		1 " 2 "	3	♂
30	"	34.8		1 " 8 "	6	♂
31	"	18.5	10.1		1	
32	"	17.1	9.5		1	
33	"	15.7	8.8		1	
34	"	15.6	8.8		1	
50	June 25/20	16.8	10.1	0 " 2 "	1	
51	"	18.5	12.6	0 " 4 "	1	
52	July 5	20.3	14.5	0 " 5 "	1	
53	" 6	16.1	11.0	0 " 2 "	1	
54	" 13	36.5	39.8	2 " 10 "	5	
100	Dec. 6	39.6		2 " 15 "	6½	♀ large eggs
101	"	42.8		4 " 8 "	9	♀ " "
102	"	55.8		7 " 10 "	10	♀ spent
103	"	40 0		3 " 2 "	6½	♀ large eggs
104	"	40.5		2 " 8 "	7	♀ spent
105	"	38.2		2 " 5 "	6	♀ large eggs
106	"	39.3		2 " 7 "	7	♂ large testes
107	"	40.6		3 " 2 "	7	♂ partly spent
108	"	39.6		2 " 9 "	6	♂ " "
109	"	37.3		2 " 1 "	6	♂ " "
110	"	40.5		3 " 3 "	7½	♀ large eggs
111	"	38.1		2 " 9 "	7	♂ fat
112	"	39.9		2 " 11 "	8	♂ partly spent
113	"	41.8		3 " 4 "	6½	♀ large eggs
114	"	37.8		2 " 2 "	6	♀ partly spent
115	"	39.0		2 " 10 "	4½	♀ " "
116	"	39.7		2 " 10 "	7	♀ entirely "
117	"	40.3		2 " 8 "	7	♀ " "
118	"	38.1		2 " 4 "	6	♂ partly spent
119	"	39.4		2 " 11 "	6	♀ large eggs
120	"	40.0		2 " 5 "	7	♀ spent

DATA—*COREGONUS CLUPEAFORMIS*—LAKE ONTARIO

No.	Date	Length cm.	Weight	Age Years
61	Dec. 2, 1920	44.5	2¾ lb.	7½
62	"	38.0	1¾ "	4½
63	"	39.3	2¼ "	6½
64	"	37.0	1⅝ "	5½
65	"	43.0	2¾ "	7½
66	"	46.2	3 lb. 13 oz.	7½
67	"	35.0	1 " 6 "	4½
68	"	41.8	2 " 7 "	6½

DATA—*COREGONUS CLUPEAFORMIS*—HUDSON BAY

No.	Date	Length cm.	Age Years	
131	July 22 1919	30.2	10	Great Whale River
132	"	23.4	5	" " "

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UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE

ONTARIO FISHERIES RESEARCH LABORATORY

No. 8

REPRESENTATIVE *CLADOCERA* OF SOUTH-WESTERN ONTARIO

BY

N. K. BIGELOW

OF THE DEPARTMENT OF BIOLOGY

UNIVERSITY OF TORONTO

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1922

REPRESENTATIVE *CLADOCERA* OF SOUTH-WESTERN ONTARIO

During the past two years the author of this paper has made a special study of the *Cladocera* in various parts of the Province of Ontario. In view of their common occurrence in practically all bodies of water and their fundamental economic importance, it is surprising that but little attention has heretofore been given to this interesting group in our province. Sars (1916) lists nine species found in samples of surface plankton collected during the summer of 1907 in the Go Home Bay region of Georgian Bay and submitted to him for examination by Professor E. M. Walker. The *Cladocera* of that list are as follows:—

Holopedium gibberum Zaddack

Sida crystallina (Müll.)

Daphniella brachyura Liéven = (*Diaphanasoma brachyurum*)

Daphnia hyalina var. *oxycephala* Sars = (*Daphnia longispina* var. *hyalina*)

Hyalodaphnia retrocurva var. *intexta* Forbes (*Hyalodaphnia* = *Daphnia*)

Ceriodaphnia scitula Forbes (probably = *C. quadrangula* Müll.)

Bosmina longirostris (Müll.)

Polyphemus pediculus (L.)

Leptodora hyalina Lilljeb. = (*L. kindtii* Focke)

Birge (1918) mentions *Chydorus latus* Sars as "rare, Canada, near Lake Erie". Birge (1894) lists a number of *Cladocera* taken in the American waters of Lake St. Clair, Detroit River and the western end of Lake Erie. No doubt these species also occur in the Canadian waters of these regions.*

In the present paper the occurrence of forty-nine species of *Cladocera* is recorded. The classification and arrangement of these is based on Birge (1918). The material studied came from the following localities, which are indicated on the accompanying map (Fig. 1).

1. Georgian Bay. Several hundred samples of plankton collected during the years 1903, 1905 and 1907 from eight stations in the Go Home Bay region in the south-eastern part of Georgian Bay under the direction of Professor B. A. Bensley and Professor E. M. Walker were kindly placed at the writer's disposal for examination. Also the stomach contents of 19 ciscoes (*Leucichthys harengus*) taken in the south-western part of Georgian Bay have been examined. These were obtained in November 1920 from Wiarton by Professor W. A. Clemens. In the locality records in the following part of the paper, Georgian Bay, unless otherwise stated, refers to the Go Home Bay region.

2. Port Sydney. This small village is situated on Lake Mary about 15 miles from the town of Huntsville in the Muskoka District. In the summer of 1919 plankton collections were made in various small lakes, ponds and pools within a radius of four miles of this village and also in the north branch of the Muskoka River.

3. Toronto. Plankton collections were made in Grenadier Pond, in the lagoons on Toronto Island and in various small ponds and pools in the immediate vicinity of this city. These collections were made mostly in the spring and autumn of 1919 and the spring of 1920.

4. Lake Ontario. The stomach contents of seven ciscoes (*L. ontariensis*) obtained by Professor W. A. Clemens at Port Credit in November, 1920, have been examined.

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*Since the above was written an article has appeared entitled "Notes on Canadian Entomostraca," by A. Brooker Klugh, in the Canadian Field Naturalist, vol. XXXV, No. 4, pp. 72-73, 1921. In this paper twelve species of *Cladocera* are recorded from four localities in Ontario, all of which localities are other than those mentioned in the present paper.

5. Bond Lake and Wilcox Lake. These two small lakes are situated about 20 miles north of Toronto. During the spring and autumn of 1919 and the spring of 1920 plankton hauls were made in these lakes as well as in several small ponds and pools in their immediate vicinity.

6. Lake Erie. The alimentary tracts of approximately 200 ciscoes from Lake Erie have been examined. Four species were represented, namely *L. eriensis*, *L. artedi*, *L. sisco huronius* and *L. prognathus*, and were obtained by Professor W. A. Clemens from various points along the north shore of Lake Erie in the spring of 1919 and the summer and autumn of 1920. Since ciscoes are pre-eminently plankton feeders, much interesting information concerning the distribution of *Cladocera* was gained from this source.

7. Point Pelee. Samples of plankton were taken during the summer of 1920 from various types of permanent and temporary ponds and pools on this point of land, the southernmost point of Canadian soil.

The drawings with which this paper is illustrated were all made from specimens collected in the various localities mentioned above.

SIDIDAE

Sida crystallina (Müller)

Georgian Bay, Lake Erie, Point Pelee. This species appears to seek the shallower water close to shore especially in the vicinity of aquatic plants and was not found in small ponds or pools unless they were immediately adjacent to larger bodies of water. It is a rather important form from the standpoint of fish food since it ranked third in the list of organisms most commonly found in cisco stomachs, *Daphnia* and *Leptodora* respectively exceeding it in frequency. Forty-eight jumbo ciscoes taken from June 1 to August 2, 1920, at Merlin chiefly, but also at Rondeau, Lake Erie, had eaten it in considerable numbers.

Latonopsis occidentalis Birge

Point Pelee. Fairly common June 18, 1920, in a small weedy pond near Lake Pond.

Latona setifera (Müller)

Georgian Bay, Point Pelee (Lake Pond). Apparently uncommon in Georgian Bay since only a single specimen was taken. Five specimens were found in July and August in plankton swept from aquatic vegetation in Lake Pond (Point Pelee).

Diaphanosoma brachyurum (Liéven)

Georgian Bay, Lake Erie, Point Pelee. In some samples of plankton this species was fairly common and a few specimens were observed in two cisco stomachs (*L. eriensis*) from Merlin in July and August 1920.

Diaphanosoma leuchtenbergianum Fischer

Georgian Bay, Point Pelee. Less common than the preceding species.

HOLOPEDIDAE

Holopedium gibberum Zaddach

Georgian Bay, Lake Erie. This species occurred very abundantly in most of the open water plankton from Go Home Bay and a few were taken from a cisco stomach (*L. eriensis*) from Lake Erie, July 1920.

DAPHNIDAE

Of the members of this family the genus *Daphnia* is the most widely distributed and the most abundant in point of individuals. Their immense numbers, their great economic importance as fish food and their amazing variations among individuals of the same species can only be fully appreciated by those who have made a study of fresh water plankton and the contents of fish stomachs. In a great many ciscoes examined the entire alimentary tracts were found to be literally crammed with the remains of countless thousands of *Daphnia*. Of 205 of these fish examined 160 had eaten *Daphnia* to a greater or less extent. In the majority, *Daphnia* were by far the most abundant food organisms present and in 26 formed the entire food material. The only ciscoes which had not fed largely on *Daphnia* were some taken in the spring of 1919 when *Ephemeridae* formed the bulk of the food material, and a few others taken in the deep open waters where *Mysis relicta* and *Limnocalanus macrurus* were the dominant crustaceans.

Daphnia pulex (de Geer)

Port Sydney, Toronto, Lake Ontario, Bond Lake, Lake Erie, Point Pelee. Generally common everywhere in bodies of water of all sizes from large lakes to small temporary pools. However it was not found in the Georgian Bay plankton which is surprising in view of the large numbers of samples taken. Neither was it found in any of the cisco stomachs from the eastern portion of Lake Erie. It appears to be the commonest species in the western part of this lake, however, and apparently forms the bulk of the food of the ciscoes there during summer and autumn at least. The majority of the jumbo ciscoes (*L. eriensis*) taken during the summer and autumn of 1920 had eaten this species together with some *Daphnia retrocurva* which may be only a form of *D. pulex*, and all the individuals of this species taken during November 1920 had eaten *D. pulex* only.

Daphnia retrocurva Forbes

Georgian Bay, Lake Ontario, Lake Erie. Abundant in the plankton from Georgian Bay and very abundant in the cisco stomachs from Lake Erie. It appears to be a summer form in Lake Erie as ciscoes taken at Rondeau in June 1919 had eaten almost as many individuals of this species as of *D. pulex*. Many of these specimens showed astonishing variations in the shape and extent of the cephalic crest as shown in Figs. 1-4. One individual with a pronounced *retrocurva* crest had the same type of pecten on the claws of the post abdomen as is found in typical *D. pulex.* Forms approaching the *D. arcuata* type were also found. In spite of the amazing differences between typical specimens of *D. retrocurva* and *D. pulex* the indications point strongly to the conclusion that the two forms may be extreme variations of one species. It is not improbable that a careful study of these forms at Rondeau during the month of June might establish their identity.

Daphnia longispina (Müller)

Georgian Bay, Toronto, Lake Ontario, Bond Lake, Lake Erie. Very abundant, ranking next to *D. pulex* in numbers. It is an exceedingly polymorphic species. In the smaller lakes and larger ponds var. *hyalina* form *typica* was the most common phase. Form *typica* was found in Bond Lake and Grenadier Pond (Toronto), but in the latter body of water two remarkable variations occurred in May 14, 1920, as shown in Figs. 5 and 6. One had a protuberance over the region of the heart as is found in *D. pulex* var. *minnehaha,* while the other had a minute downward projecting crest on the head. In any large collection of *Daphnia longispina* it has been found that variations in form are not uncommon.

In the larger lakes form *galeata* seems to be the prevailing form of this species. In his list of the *Entomostraca* of Georgian Bay, Sars mentions the *Daphnia* from Go Home Bay region as *D. hyalina* var. *oxycephala* although at first inclined to consider it as *D. galeata.* The results of the present studies would indicate that the form he was dealing with was *D. longispina* var. *hyalina* form *galeata* according to the generally accepted nomenclature of the present time. It is much the commonest species in the southern part of Georgian Bay in the plankton and cisco stomachs examined. It occurred in nearly all of the plankton samples in varying numbers and abundantly in all of the stomachs of the nineteen Georgian Bay ciscoes (*L. harengus*) examined, along with *Diaptomus* and *Epischura.* Five out of seven Lake Ontario ciscoes (*L. ontariensis*) taken at Port

Credit in November 1920 had eaten this species almost entirely. In Lake Erie form *galeata* of *D. longispina* is the prevailing form but is much less abundant than either *D. pulex* or *D. retrocurva.* Jumbo ciscoes from Merlin, Ontario, taken during July and early August 1920 had eaten this species almost entirely.

In Figs. 7, 8 and 9 are shown some extreme variations such as are occasionally found scattered among ordinary specimens of this species.

Simocephalus vetulus (Müller)

Toronto (Grenadier Pond), Bond Lake, Point Pelee. Fairly common in the above mentioned localities among aquatic vegetation and doubtless widely distributed.

Scapholeberis mucronata (Müller)

Toronto, Lake Wilcox, Port Sydney. Commonest in small pools in these localities but also found in shallow water along the margins of lakes.

Scapholeberis aurita (Fischer)

Point Pelee. Found only about the middle of July 1920 in a small muddy pool in a pasture where it occurred sparingly in a plankton composed mostly of *Ceriodaphnia reticulata* and *Moina affinis* (Fig. 10).

Ceriodaphnia reticulata (Jurine)

Toronto, Bond Lake, Point Pelee. Only found in small pools or ponds but very abundant when found (Fig. 11).

Ceriodaphnia lacustris Birge

Georgian Bay, Toronto (Lagoon on Toronto Island). Not common.

Ceriodaphnia quadrangula (Müller)

Georgian Bay, Point Pelee (Lake Pond). This is probably the *Ceriodaphnia scitula* mentioned by Sars in his list of *Entomostraca* from Georgian Bay.

Ceriodaphnia pulchella Sars

Point Pelee. Taken during the months of July and August 1920 in some rather large ponds.

Moina affinis Birge

Point Pelee. This cladoceran was very common during the month of July 1920 in a small muddy pool in a pasture, along with *Ceriodaphnia reticulata* and a few *Scapholeberis aurita*. Most of the specimens were covered with a minute unicellular organism, a few of which are shown attached to the post abdomen in Fig. 12. This species also occurred in a few temporary rain pools along a roadway.

BOSMINIDAE

Bosmina longirostris (Müller)

Georgian Bay, Toronto (Grenadier Pond), Bond Lake, Wilcox Lake, Lake Erie, Point Pelee. This is one of the most widely distributed of all our *Cladocera*. Some specimens from Go Home Bay appear to have the spine on the posterior ventral extremity of the valves longer than is usual in this species. This fact was noted also by Professor G. O. Sars in his examination of Go Home plankton collected in 1907.

Bosmina longispina Leydig

Port Sydney. The only specimens identified with certainty as belonging to this species were two taken June 18, 1919, from the north branch of the Muskoka River. Eventually this species may prove to be but an extreme variation of the preceding one as some specimens of *Bosmina* from Go Home Bay have been found to be intermediate in many respects between the two.

MACROTHRICIDAE

Macrothrix rosea (Jurine)

Point Pelee (Lake Pond). A few specimens were taken in plankton swept from among weeds, August 22, 1920.

Illiocryptus spinifer Herrrick

Toronto. Two brilliant red specimens of this species were found in December, 1918, creeping about among a thick growth of *Chara* in a small stream near Grenadier Pond, Toronto.

Illiocryptus sordidus (Liéven)

Point Pelee (Lake Pond). Common in August, 1920, in plankton swept from aquatic vegetation. The post abdomen of one of these specimens is shown in Fig. 13. Some individuals were very light yellow in colour and others were quite transparent.

Acantholeberis curvirostris (Müller)

Georgian Bay, Port Sydney. Occurred sparingly in plankton collected from the shallower parts of Go Home Bay, but very abundantly in a small pond in the middle of a sphagnum bog situated about four miles south of Port Sydney.

Drepanothrix dentata (Eurén)

Georgian Bay. Apparently rare since it occurred in only a few of the many samples (Figs. 15-16).

Streblocerus serricaudatus (Fischer)

Bond Lake. Only one small specimen taken in plankton, November 9, 1919.

Ophryoxus gracilis Sars

Georgian Bay. Not uncommon in plankton collected from shallow waters (Fig. 14).

CHYDORIDAE

Eurycercus lamellatus (Müller)

Georgian Bay, Toronto (Grenadier Pond), Bond Lake, Lake Erie, Point Pelee. Common in the weedy parts of ponds and lakes.

Camptocercus rectirostris Schoedler

Georgian Bay, Bond Lake, Point Pelee (Lake Pond). Very common, November, 1919, in Bond Lake.

Kurzia latissima (Kurz)

Georgian Bay, Toronto (Grenadier Pond), Point Pelee. Only a few specimens were taken in each of these localities.

Acroperus harpae Baird

Bond Lake, Point Pelee. Especially common in November, 1919, in Bond Lake.

Acroperus angustatus Sars

Bond Lake. Apparently this species is only a form of the preceding species since many forms intermediate between the two were taken on November 9 and 15, 1919, in Bond Lake.

Leydigea quadrangularis (Leydig)

Georgian Bay, Toronto (Grenadier Pond), Point Pelee. Only one or two specimens were found in each of these localities (Fig. 17).

Alona guttata Sars

Toronto (Grenadier Pond and also in smaller ponds and pools), Bond Lake, Point Pelee. Very abundant.

Alona affinis (Leydig)

Georgian Bay, Bond Lake, Point Pelee (Lake Pond). Occurred most abundantly in the plankton from the shallow weedy parts of Go Home Bay.

Graptoleberis testudinaria (Fischer)

Georgian Bay, Toronto (Grenadier Pond), Bond Lake, Point Pelee. Only a few specimens were found in each of these places.

Pleuroxus denticulatus Birge

Port Sydney, Toronto, Bond Lake, Point Pelee. Never found in open water plankton.

Pleuroxus trigonellus (Müller)

Port Sydney, Toronto (Grenadier Pond), Bond Lake, Point Pelee (Lake Pond). Several specimens were taken in November, 1919, in Bond Lake, but only one or two in each of the other localities. It appears to be an uncommon though widely distributed species (Figs. 18-19).

Pleuroxus striatus Schoedler

Point Pelee. Not uncommon during the summer of 1920 in certain ponds.

Pleuroxus procurvatus Birge

Toronto (Grenadier Pond and also smaller ponds and pools), Bond Lake, Wilcox Lake, Point Pelee. The only plankton in which this species was abundant was swept on June 1, 1919, from very shallow water along the margin of Wilcox Lake.

Chydorus globosus Baird

Georgian Bay, Toronto (Lagoon on Island), Point Pelee (Lake Pond). Only a single specimen was found in each of these localities (Figs. 20-21).

Chydorus sphaericus (Müller)

Georgian Bay, Port Sydney, Toronto, Bond Lake, Wilcox Lake, Point Pelee. Most numerous in small weedy pools near Toronto. Variety *punctatus* was the only form of this species present in some plankton taken April 17, 1920, in Bond Lake.

Chydorus faviformis Birge

Georgian Bay, Bond Lake, Point Pelee (Lake Pond). Most abundant at Point Pelee, but only a few specimens were found in any of these localities (Fig. 22).

Chydorus barroisi ? (Richard)

Toronto. Although this is supposed to be a southern species, a *Chydorus* which must be either this or an undescribed species closely related was taken on October 19, 1919, in a small weedy pool near Bloor Street and Clendenan Avenue, Toronto. It showed the sharp teeth on the keel of the labrum distinctly but apparently lacked the spine on the postero-ventral margin of the shell. It appeared in company with a great many typical *Chydorus sphaericus* and a careful search not only through this sample of plankton but through collections made from the same pool many times since has failed to disclose another individual (Fig. 27).

Anchistropus minor Birge

Georgian Bay. Four specimens of this peculiar Cladoceran were found in some plankton taken in August, 1905, in weedy shallow water (Figs. 23-24).

Monospilus dispar Sars

Georgian Bay, Point Pelee (Lake Pond). Occurred only in plankton swept from among weeds and not very abundantly (Figs. 25-26).

Alonella excisa (Fischer)

Port Sydney, Bond Lake, Point Pelee. Not very common.

Alonella nana (Baird)

Port Sydney, Bond Lake, Point Pelee. This beautiful striated species was even less common than the preceding one.

POLYPHEMIDAE

Polyphemus pediculus (L.)

Georgian Bay, Port Sydney (Muskoka River), Point Pelee. Fairly common. The specimens taken in June, 1919, from the north branch of the Muskoka River had a peculiar coloration. The tips of the last two pairs of legs as well as the ventral side of the caudal process were of a deep brilliant blue which contrasted strongly with the extreme transparency of the rest of the body.

LEPTODORIDAE

Leptodora kindtii Focke

Georgian Bay, Lake Erie. Common enough in Lake Erie to constitute a most important item of food of ciscoes. Forty-three jumbo ciscoes (*L. eriensis*) taken from July 6 to August 2, 1920, had eaten *Leptodora* very largely along with a few *Daphnia* and *Sida*. In Georgian Bay *Leptodora* occurred in plankton from the deep open water. Some specimens taken September 12, 1905, contained the immature stages of some Trematode. In each case the parasites were quite conspicuous as they were in the very transparent part of the creature's body lying alongside of the digestive tract where they contrasted strongly with their surroundings. It may well be that they were the early stages of a cisco parasite.

The table that follows summarizes the distribution of the Cladocera as given in the preceding pages.

It is evident from this table that the Cladoceran fauna as herein recorded is far from exhaustive for any of the localities studied but taken as a whole it may be considered representative of the south-western portion of Ontario. It is seen to be identical or nearly so with that of the northern portion of the United States as might be expected from the similarity of conditions in the two regions.

During the course of these studies many puzzling forms were encountered especially in the family *Chydoridae*. For example, forms related to *Chydorus*, *Alona*, *Alonella* and *Pleuroxus* combining characters found in the anatomy of two or more of these genera were occasionally seen and the writer feels convinced that many surprises await the future student of these *Cladocera*.

	Georgian Bay	Port Sydney	Toronto	L. Ontario	Bond L. Wilcox L.	L. Erie	Point Pelee
Sida crystallina	+					+	+
Latonopsis occidentalis							+
Latona setifera	+						+
Diaphanosoma brachyurum	+					+	+
" *leuchtenbergianum*	+						+
Holopedium gibberum	+					+	
Daphnia pulex		+	+	+	+	+	+
" *retrocurva*	+			+		+	
" *longispina*	+		+	+	+	+	
Simocephalus vetulus			+		+		+
Scapholeberis mucronata		+	+		+		
Scapholeberis aurita							+
Ceriodaphnia reticulata			+		+		+
" *lacustris*	+		+				
" *quadrangula*	+						+
" *pulchella*							+
Moina affinis							+
Bosmina longirostris	+		+		+	+	+
" *longispina*		+					
Macrothrix rosea							+
Illiocryptus spinifer			+				
" *sordidus*							+
Acantholeberis curvirostris	+	+					
Drepanothrix dentata	+						
Streblocerus serricaudatus					+		
Ophryoxus gracilis	+						
Eurycercus lamellatus	+		+		+	+	+
Camptocercus rectirostris	+				+		+
Kurzia latissima	+		+				+
Acroperus harpae					+		+
" *angustatus*					+		
Leydigea quadrangularis	+		+				+
Alona guttata			+		+		+
" *affinis*	+				+		+
Graptoleberis testudinaria	+		+		+		+
Pleuroxus denticulatus		+	+		+		+
" *trigonellus*		+	+		+		+
" *striatus*							+
" *procurvatus*			+		+		+
Chydorus globosus	+		+				+
" *sphaericus*	+	+	+		+		+
" *faviformis*	+				+		+
" *latus**							
" *barroisi?*			+				
Anchistropus minor	+						
Monospilus dispar	+						+
Alonella excisa		+			+		+
" *nana*		+			+		+
Polyphemus pediculus	+	+					+
Leptodora kindtii	+					+	

*Recorded by Birge "near Lake Erie."

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Fig. 1. Map of southwestern Ontario, showing localities from which *Cladocera* were obtained.

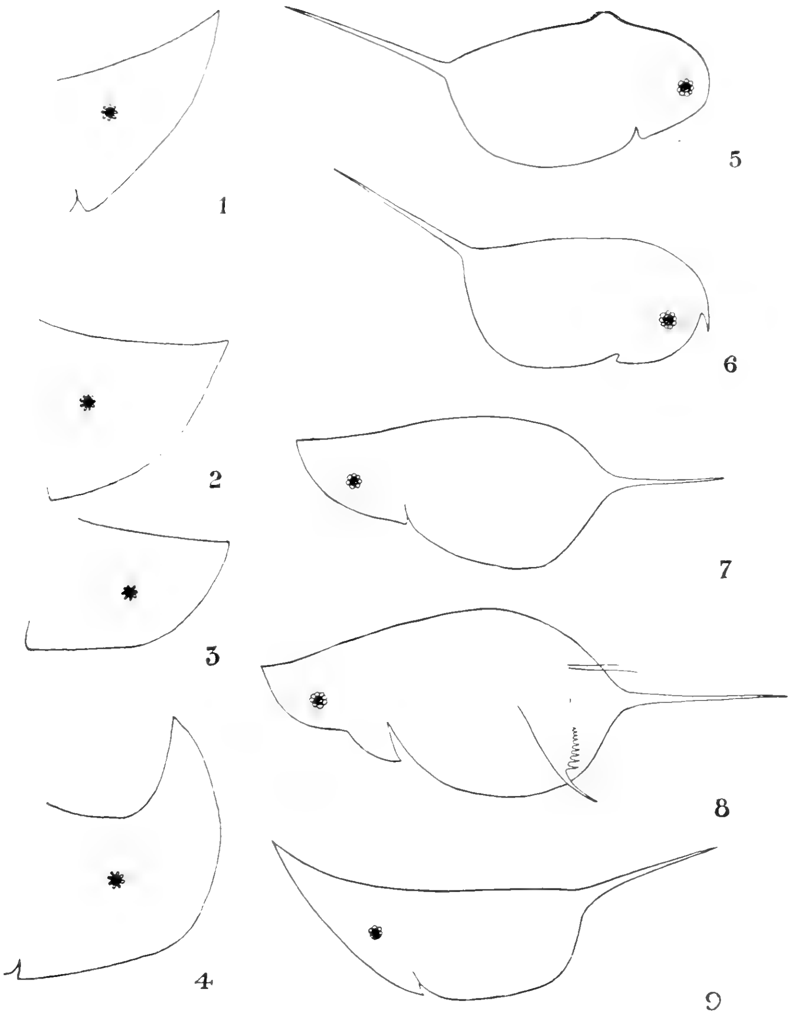

Plate I. Cladocera, Ontario

Figs. 1-4. *Daphnia retrocurva*, Rondeau, Lake Erie, June, 1919; variations in cephalic crest.

Figs. 5-6. *D. longispina* var. *hyalina* form *typica*, Grenadier Pond, Toronto; peculiar variations.

Figs. 7-9. *D. longispina* var. *hyalina* form *galeata*, Georgian Bay; some extreme variations.

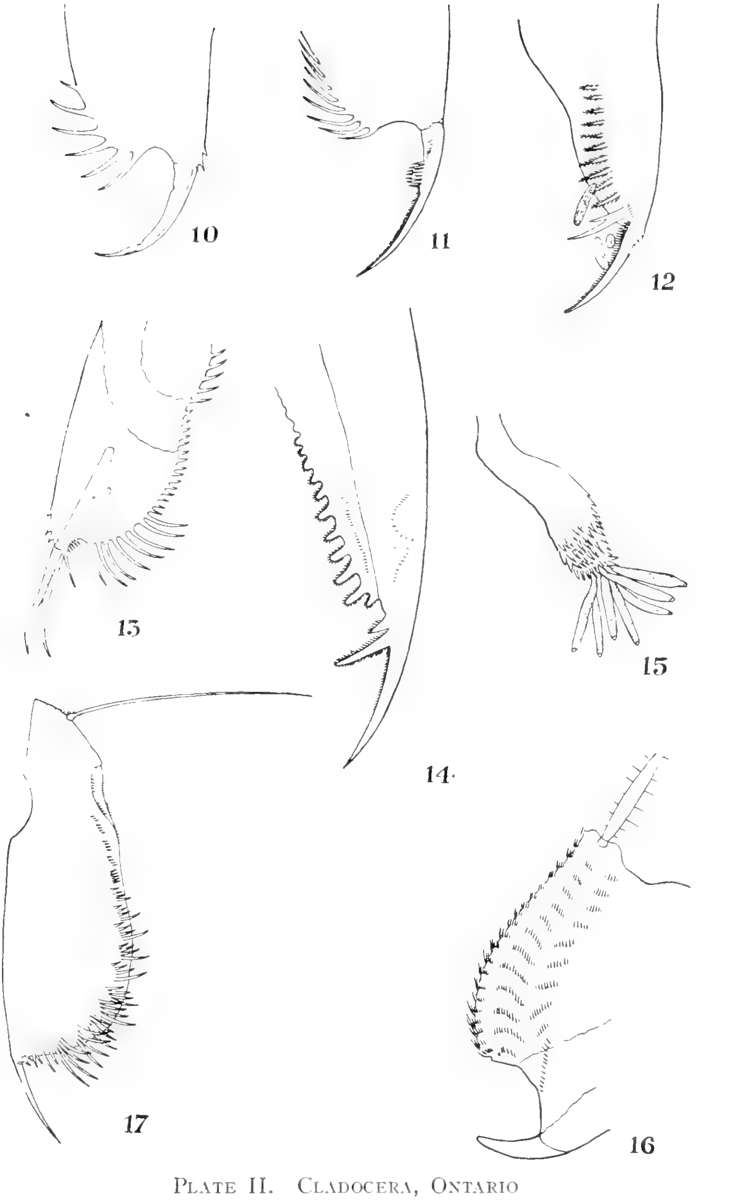

Plate II. Cladocera, Ontario

Fig. 10. *Scapholeberis aurita*, end of post-abdomen; Fig. 11, *Ceriodaphnia reticulata*, end of post-abdomen; Fig. 12, *Moina affinis*, end of post-abdomen; Fig. 13, *Illiocryptus sordidus*, post-abdomen; Fig. 14, *Ophryoxus gracilis*, post-abdomen; Fig. 15, *Drepanothrix dentata*, antennule female; Fig. 16, *Drepanothrix dentata*, post-abdomen; Fig. 17, *Leydigea quadrangularis*, post-abdomen.

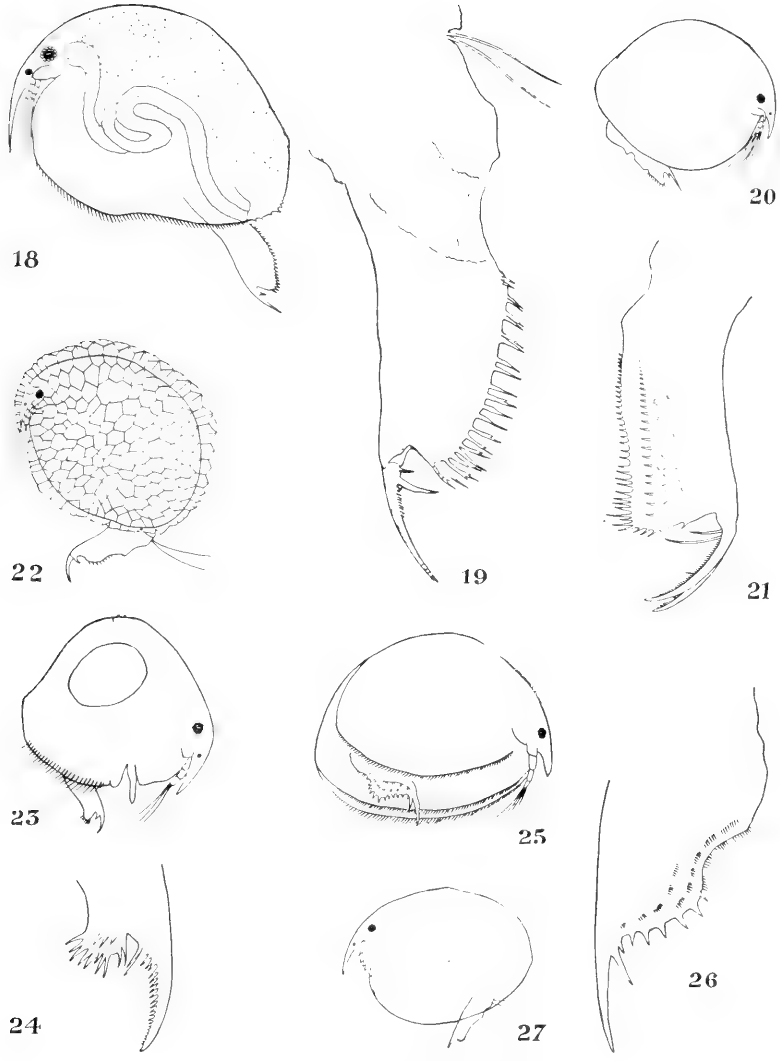

Plate III. Cladocera, Ontario

Fig. 18, *Pleuroxus trigonellus*; Fig. 19, *Pleuroxus trigonellus*, post-abdomen; Fig. 20, *Chydorus globosus*; Fig. 21, *Chydorus globosus*, post-abdomen; Fig. 22, *Chydorus faviformis*; Fig. 23, *Anchistropus minor*; Fig. 24, *Anchistropus minor*, end of post-abdomen; Fig. 25, *Monospilus dispar*; Fig. 26, *Monospilus dispar*, end of post-abdomen; Fig. 27, *Chydorus barroisi?*

UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 9

BREEDING HABITS OF THE LAND-LOCKED SEA LAMPREY

(*PETROMYZON MARINUS* var. *DORSATUS* WILDER)

BY

A. F. Coventry

of the Department of Biology
University of Toronto

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1922

BREEDING HABITS OF THE LAND-LOCKED SEA LAMPREY

(*PETROMYZON MARINUS* VAR. *DORSATUS* WILDER)

Nearly all that has been recorded concerning the life-history of the land-locked sea lamprey (*Petromyzon marinus dorsatus* Wilder) refers to the earlier description of Jordan and Fordice (1885) and the very inclusive study by Gage (1893) and his associates of the variety as it occurs in Cayuga and similar lakes of northern New York. For many years it has been known locally that a lamprey occurs in Lake Ontario at least some miles east and west of Toronto, where it is sometimes greatly in evidence, attaching itself temporarily to boats in motion or more especially to food-fishes and thus brought up by fishermen operating gill nets for whitefish and lake trout in the open waters. This lamprey has been confused to some extent with the silver lamprey (*Ichthyomyzon bdellium* Jordan). Its identity with *P. marinus dorsatus s. unicolor* was suggested by Bensley (1915), as a result of studies of the animal and of the surface wounds on fishes in relation to reports of fishermen as to occasional lamprey marks on whitefish in Georgian Bay; and confirmed by Huntsman (1917) as a result of a systematic review of the known records of lampreys from Ontario waters. So far as the writer is aware no young have been recorded hitherto from the Toronto area, though there is a single metamorphosed specimen of 13.5 cm. taken in a swamp near Whitby in the university collection.

While it is evident from what is known of the glacial history of the Great Lakes Basin that a community of conditions is to be expected as between the New York lakes and Lake Ontario, and also between both and the Gulf of St. Lawrence, the relative isolation of the habitat previously described lends interest to its more open occurrences in

Lake Ontario and also to the comparison of its breeding habits and development with that of the Cayuga lamprey. At the same time it will be recognized that the term "land-locked" as applied to the animal is largely a matter of descriptive convenience. The case is analogous in some respects to that of the land-locked sea salmon in its original occurrence in Lake Ontario. Of these and other species of fishes related as respectively fresh water and marine we know neither the nature of the original medium nor the environmental factors associated with their varietal and specific differences.

On Friday, May 27, 1921, Mr. J. R. Dymond of the Department of Biology reported that large numbers of land-locked sea lampreys were in the Humber river, just west of the city of Toronto. The vast majority of those he saw, and they numbered hundreds, were in a small rocky pool immediately below the Lambton weir; many were swimming about, others hung on to the rocks from which they could be picked by hand. They appeared to be blocked in their ascent of the stream by the weir, which is about three feet high. Mr. Dymond did not see any nests on this date. It was then decided to attempt to follow the progress of the breeding season, and with this object in view frequent visits were made to the river during June.

The stretch of the river in which nests were found is about three-quarters of a mile long and terminated upstream by the weir already mentioned; no nests or adults were seen above this in spite of careful search. Downstream, nests were not discovered below the rapids at the Old Mill Bridge, below which point the river becomes deep with a muddy bottom for the rest of its course to Lake Ontario, a distance of about two miles. Between the weir and the bridge the river averages about thirty yards in width and two feet in depth at this season of the year, with occasional holes as much as six feet deep. The river bed is composed of clean gravel or shingle interrupted here and there by large flat slabs of solid rock, and the stream is broken up by frequent rapids, none steep enough to make real 'white water', although the larger are difficult enough to wade against. The general direction of the stream is from north to south and the valley is so wide that in spite of the high banks (80-100 feet) the sun reached the water by 8 o'clock in the morning (standard time).

As was subsequently found during repeated wanderings along this stretch of the river, nests were excavated only in the more rapid regions and indeed only in the shallower parts of these. The majority were in not more than a foot of water and none were seen at a greater depth than two feet. Large stretches of gravel of apparently exactly the same physical qualities as in the rapids, but covered instead by comparatively slowly moving water, were completely neglected, while a few yards up or down stream nests were abundant.

The nests are shallow depressions in the bed of the stream usually oval in outline, with the long axis in the direction of flow. They vary considerably in size, from about 12 inches by 18 inches to 24 inches by 30 inches. They are constructed usually by a pair of lampreys, but single animals have been seen working, and in one case at least two pairs occupied one large nest, all four individuals moving stones.

The stones moved are in general not larger than an inch in diameter, and most of them are smaller than this; occasionally, and with great effort, stones as big as two inches across are dragged from the excavation. In no case were two animals seen combining to move one stone, although in a number of cases this would have enabled them to make a much more convenient nest; if a stone too large to be moved by individual effort lies within the ambit of the nest, it remains. The material is deposited on the downstream side of the nest so as to form a kind of parapet of which the curve conforms to that of the oval hollow. An animal, having attached itself to a stone, allows itself to drift tail first with the current, until its mouth is over the downstream edge of the nest, it then brings itself to a halt with a sharp movement of its tail and at once drops the stone in position. While choosing stones the animal's movements are rather indeterminate; it will often lift and drop immediately a number of pebbles before carrying one clear, and often it will remain stationary in the nest for minutes on end, either adhering to a large stone or lying at rest in the still pocket of water caused by the parapet. At the upstream edge of the nest there is nearly always a stone of markedly large size. No factor determining the site of the nest could be discovered other than the general ones of gravel of the right degree of coarseness and a sufficiently rapid current; given these, nests seemed to be impartially distributed in mid-stream or near the banks, at the upper edge of a rapid or down its full extent; in places they were so numerous as to suggest aeroplane photographs of heavily shelled fields.

The actual process of laying was watched a number of times. The two animals concerned cease carrying stones and take up a position with their heads at the upper edge of the nest; this is achieved in one of two ways; either both attach themselves to the large stone already mentioned, or the female alone takes this position, the male clinging to the top of her head; at once after this the posterior halves of their bodies twist together for about a complete turn and simultaneously make very rapid flapping movements, so fast, indeed, as to be almost vibrations. During this process, which lasts only a few seconds, eggs may be seen pouring from the female as a number of small white specks, which become mixed with the very small stones and sand stirred up by the agitation of the parents' bodies. As soon as this movement ceases eggs and sand together settle down at the bottom of the nest. The male and female then separate and resume their stone-hauling, often moving stones from points a foot outside the nests and placing them on the parapet, but after a few minutes the laying process is repeated; how often this interruption and resumption of laying may occur was not determined, but certainly as many as four.

In the large nest already mentioned as being the work of four animals one and the same male was seen to pair with each of two females, eggs from different mothers being mixed in the nest.

The eggs when they are first laid stick so firmly to stones that any attempt to detach them usually destroys them; after about fifteen minutes, however, they do not adhere at all so closely and may be washed off with a gentle stream of water from a pipette; in the course of a day or two they lie loose among the pebbles.

During the period over which nesting was watched the temperature of the water varied from 18° C. on June 4th, to 23° C. on June 21st and 27th, the temperature being taken between 8 and 9 o'clock a.m., standard time.

The nesting season lasted approximately a month. As already noted abundant adults were seen on May 27th, but no nests. On June 1st nests were found in a rapid stretch about six hundred yards below the weir; the animals had apparently relinquished the attempt to go higher upstream, since on this date none were seen in the pool, nor were any seen subsequently this far up. The nest of June 1st had probably been provided with eggs the previous day, as those from which samples were taken all showed segmentation stages. The last nestings observed were on June 21st and no adults were seen later than June 22nd.

As to whether the parents die after spawning I cannot make a definite statement. I have, however, a strong feeling that they do not, and this opinion is based on the very small number of dead lampreys as compared with the abundance of the living seen during the nesting season. During June not more than a dozen or a dozen and a half dead were seen either in the nesting reach itself or in the slower stretch of water between this and Lake Ontario, while in the course of a few hours 150 living individuals were taken from the pool below the weir at the beginning of the season. If, then, the parents die at the end of the breeding season, they appear to return first to the lake, for it is hardly imaginable that so many individuals dying in so short a space of time and in so limited an extent of water should leave so slight a trace of the event.

An attempt was made to determine the time that elapses before the young leave the nest, and although the data are not quite conclusive, a probable estimate can be made.

There are two sources of possible error, first the necessity of disturbing the pebbles at the bottom of the nest among which the larvae are developing. The young after hatching are found one to two inches below the surface and in the undisturbed nest have presumably reached a position in which they are not affected by the flow of the stream; to get samples the overlying stones have to be turned gently aside with the point of a pipette until the larvae appear, when they are at once sucked up. In this process a number are inevitably dislodged from their crannies among the pebbles and swept away by the current, and it is not improbable that during the readjustment which must follow any such violent invasion of the colony new circulations of water are established, carrying still more of the young prematurely from the nest, which will thus be empty before its normal time. This error involves probably not more than two or three days.

The other complication is the difficulty of deciding when a nest is quite empty. The larvae are often distributed in patches over different parts of the nest, and while the greater part of the nest may not reveal a single larva, finally a thickly populated area may be touched by the pipette. The danger lies in overlooking such spots, and this is the greater since thoroughly to search a nest is a tiring procedure, the most practicable way being to kneel by it and, using a water-glass for clearer observation, bend close over it while turning the stones. With practice, however, likely spots are soon recognized, and in this case again the total inaccuracy is probably not large, almost certainly within the limits of variation due to changes in temperature. The two errors, further, tend to balance one another.

A nest called No. 3 may be taken as typical. It was first observed on June 1st, and the eggs were within a few hours of laying; on June 22nd no more larvae could be found in it. It should be mentioned here that specimens collected from this nest at various times and allowed to develop in the laboratory had by this time become quite transparent owing to the gradual disappearance of the shining white yolk, that they were taking solid food from the mud provided, that they could swim powerfully and fast, and that they always made vigorous efforts to get under small stones or into the mud in the vessel. They were thus properly equipped to start the new phase of their existence. It is certain that these laboratory-bred animals were normal since they were compared time and again with specimens brought freshly from the nest, and no difference could be found; they could be used, therefore, as a sort of indirect check on the likelihood of the nest's being fully vacated.

The young, therefore, left the nest after about three weeks: this result is confirmed by observations on other nests and may be accepted as the average length of time for such conditions as prevailed during the breeding season of 1921. That the young leave the nest voluntarily and by their own exertions can, I think, hardly be doubted, since during the breeding season no rain fell after June 4th, and the stream became steadily lower and consequently the current less likely to disturb the nests. The young hatch out of the egg in seven or eight days.

I have not yet been able to discover where the next stage of life is spent despite careful examination of many samples of mud collected below the spawning reach at all depths down to 4 feet.

It is worth remark that in all the nests examined a number of eggs failed to develop; the percentage was not accurately determined, but is estimated at 10 to 20 per cent. of the total. These eggs become a light brown colour and may be found in the nest throughout the whole period of 'incubation.' On examination they prove to be covered with a delicate felt-work of almost colourless fungal hyphae, and if any of these infected eggs are by accident introduced into a dish in which larvae are developing there is formed on the floor of the vessel a strong growth of fungus, in which the larvae, as they become active and attempt to burrow, entangle themselves and perish. The causes of this non-development were not discovered, but three possibilities seem available; (1) that some eggs are incapable of fertilization, (2) that the rather haphazard method of fertilization fails to ensure that a sperm reaches every egg, (3) that the eggs begin to develop, but owing to some weakness are at an early stage invaded by the fungal parasite. Further research is required to clear up this point.

Finally it seems worth while to call attention to the combination of unattached eggs with the position of the nest in the fastest accessible water, a condition that would hardly be, *a priori*, expected. It is true that for the first few minutes of their free existence the eggs are attached, apparently just long enough for the stones to which they adhere to settle into a permanent arrangement under the current conditions obtaining in the nest; subsequently they lie scattered loosely among the pebbles. The parapet on the downstream side of the nest certainly creates an eddy of comparatively still water in the nest, but a very slight disarrangement destroys the effect of this, as many experiences while collecting have shown. The aetiology of so curious a laying habit presents some interesting problems.

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Fig. 1. The weir at Lambton.

Fig. 2. A typical rapid, the site of a number of nests.

Fig. 3. A characteristic reach of the R. Humber, showing a succession of rapids and the nature of the banks.

UNIVERSITY OF TORONTO STUDIES

BIOLOGICAL SERIES

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No. 10

GLACIAL AND POST-GLACIAL LAKES IN ONTARIO

BY

A. P. COLEMAN

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LIST OF ILLUSTRATIONS

GLACIAL AND POST-GLACIAL LAKES IN ONTARIO

Introduction

The following paper has been prepared in collaboration with the Department of Biology of the University of Toronto, members of the staff of which are now engaged on a plan of investigation of the economic fishery problems of Ontario waters.

Present conditions relating to the existence and distribution of the fishes and other aquatic organisms obviously depend upon the succession of physical changes which have taken place during the past, but in the case of the Great Lakes and related waters the transition is especially important, not only because of the enormous area affected but also because the most significant changes took place in the period immediately preceding the present one, and, centering in the northern continental region, involved great extremes of both temperature and physical modification of the land surface. It is intended to bring together scattered materials on the subject and to put on record a number of observations thus far unpublished; but in the main to outline the Pleistocene history of the lakes as worked out by previous writers such as Gilbert, Spencer, Fairchild, Taylor, Goldthwait, and Johnston. The account of Lakes Iroquois and Ojibway will be taken chiefly from the present writer's previous publications. References will be made to climatic conditions and to the life in the waters and on the shores of these ancient lakes in so far as the evidence permits; and special attention will be given to the comparatively little known lacustrine features of northern Ontario. The southern shores of most of these extinct lakes are almost as well known as those of the existing Great Lakes, but the north-eastern parts, where their waters met the waning ice sheet, are still only imperfectly worked out, largely because the region is sparsely settled and to a great extent covered with forests.

The writer has been greatly aided in his work by Professors Bensley, Huntsman, and Clemens, as well as others of the staff in Biology, and wishes to express his appreciation of their assistance. The revision of the names of mollusca mentioned in this report is mainly due to Dr. Frank C. Baker of Urbana, Ill., to whom thanks are due for bringing the nomenclature up to date. Professor A. D. Robertson of the Western University, London, Ontario, also assisted in this respect.

Early Conditions in the Great Lakes Region

The region of the Great Lakes in early Palaeozoic times was a shallow marginal sea skirting the south side of the Canadian Shield where sediments of varying kinds were being deposited. The bottom was gradually sinking, about as fast as the deposits were formed, so that the water remained shallow throughout vast periods of time, including the Cambrian, the Ordovician, and the Silurian. The sediments laid down varied much in character, most of them consisting of mud, a portion of sand and gravel, and another portion, probably formed when the water was deepest, of calcareous materials. When consolidated, the mud formed shale, an easily crumbling rock; the sand turned to sandstone of moderate solidity; and the calcareous matter, shells, corals, etc., gave rise to compact and durable limestones, the thickest being the Niagara or Lockport limestone. Sometime during the later Palaeozoic the region fringing the Precambrian continent ceased to sink, and at length was raised above the sea as a plain gently sloping southwestwards. From that time onward most of the Great Lakes region remained a land surface, only a small part of its eastern side having been briefly submerged at the close of the Ice Age.

During the many millions of years since its elevation above the sea, the Archaean hills to the north and the sedimentary rocks to the south of this region have been ceaselessly attacked by weathering, changes of temperature,

2. Escarpment at Hamilton

and running waters. The crystalline Precambrian rocks have in general resisted these attacks best, and the thick beds of shale have suffered most. The result has been that the sedimentary rocks, which once encroached much farther northwards upon the granites and gneisses of the old Precambrian continent, have, except where protected in some cavity of the ancient surface, been stripped off for a long distance south of the latest shore of the Palaeozoic sea. In this process the shales were removed most rapidly and the limestones resisted best, so that ultimately a broad unsymmetrical trough was carved out with a gently sloping surface of Archaean toward the north and an irregular set of cliffs of the strong Niagara limestone toward the south. The wall was by no means straight, and in places there were two or three lower lines of cliffs between the main elevation and the northern slope of granite and gneiss. This row of

1. Section across the Palaeozoic Boundary

cliffs facing the old land has played an important part in directing the drainage of the region and is still a marked physiographic feature, called in southern Ontario the Niagara escarpment. As the surface above the escarpment follows the gentle dip of the strata southwestward, the arrangement is sometimes called the Niagara Cuesta. The eating back of the sedimentary rocks must not be thought of as due to direct river action but rather to the slow decay of the shales under atmospheric attack, resulting in the undercutting of the cliffs, allowing slices of the overlying limestone to fall, the fragments being removed gradually by solution due to carbonic acid brought down by rain. The escarpment has been caused, then, by differential weathering.

Some time before the beginning of the Glacial period the Great Lakes region stood much higher above the sea than at present, probably at least 1,800 feet. This must have had important effects upon the drainage, steepening the grade of the rivers; and if the uplift was greater in one direction than another, possibly turning the drainage into new directions. There were probably no lakes at this time, the valleys having slope enough to allow all the water to run off; but the directions of flow are not always very certain, and different writers have expressed quite opposite views in regard to the matter.

The Laurentian River

J. W. Spencer, one of the first to discuss the Preglacial rivers, came to the conclusion that the whole region, except the Superior basin, was drained by a predecessor of the St. Lawrence, which he called the Laurentian river, because it flowed on or near the edge of the ancient Laurentian continental mass, reaching the ocean through what is now Cabot straits between Newfoundland and Nova Scotia.[1] Some American writers, on the other hand, consider that the elevation was more to the northeast and that the rivers crossed the escarpment by one or more gaps and joined the Mississippi, finally reaching the Gulf of Mexico. The latter idea has been worked out in detail by Grabau,[2] who thinks the main stream flowed southwestward, crossing the escarpment by a channel at Dundas. Since Grabau's work was done, evidence in the way of well records has been obtained showing that a channel connecting the Upper Lakes with Ontario extends at least to sea level. This and the great depth of the Ontario basin, reaching nearly 500 feet below sea level near its east end, strongly support Spencer's theory, which will be outlined here.

In Preglacial times eastern Canada extended to the edge of the continental shelf, 140 miles beyond the present

[1]Evolution of the Falls of Niagara, Geol. Sur. Can., 1907, pp. 289, etc.
[2]Bull., N.Y. State Museum, No. 45, Vol. 9, 1901, pp. 37, etc.

southeastern coast of Nova Scotia, and Newfoundland was a part of the mainland. The old river channel then excavated can be followed by soundings to the edge of the enlarged continent, where the shallow water ends, and the bottom descends toward the depths of the sea. By the kindness of Dr. Huntsman the soundings on the chart have been examined, and it is found that the deepest point reaches 335 fathoms and the next deepest, farther up near Bird rock (Magdalen islands), 313 fathoms. The old river valley extended 840 miles beyond Quebec and at the edge of the continent is now from 1,878 feet to 2,010 feet below the sea level. Dr. Spencer made the depth 3,660 feet (611 fathoms), but this sounding is on the slope toward deep water and there are no shallower soundings on each side, so that his interpretation is probably a mistake.

The rest of the great river channel, as given by Dr. Spencer, is mostly above sea level. It begins on his map in the deeper parts of the basins of Lake Michigan and Lake Huron, turns north from about the middle of Lake Huron to Georgian Bay and then bends southeastward along the foot of the escarpment to Barrie. A buried channel extends from Barrie to Toronto, after which the river kept to the deeper south side of the Ontario basin, and finally turned northeast along the present St. Lawrence valley. The buried channel between Georgian Bay and Lake Ontario was inferred by Spencer from wells sunk in drift for a town water supply at Barrie (280 feet) and at Richmond Hill (400 feet). Since his results were published the inference he made has been confirmed and strengthened by several other wells, one at Newmarket reaching 265 feet, another at Bradford reaching 330 feet before striking rock and one on Mr. Page's farm two miles west of Thornhill, where 650 feet of glacial and interglacial materials were passed through before rock was encountered. The well was finally sunk to 1,203 feet in solid rock, ending in Laurentian granite. As the Page well was drilled at a point about 650 feet above the sea, the old channel extends 246 feet below Lake Ontario to present sea level. It is perhaps worth mentioning that

Spencer described this channel as entering the Ontario basin twenty miles east of Toronto, where the Admiralty chart showed a depth of 474 feet, with soundings of no more than 200 feet on each side.[1] This appeared so interesting that some years ago I spent an afternoon sounding across the supposed channel but found no depression in the lake bottom. The sounding of 474 feet was apparently an error for 174 feet. In reality the buried channel comes out to the Ontario basin under the city of Toronto, where drift deposits near the mouth of the Don have been found for a depth of nearly 100 feet below the level of the lake. It is probable that a still deeper drift-filled valley exists to the west to correspond to the sea-level depth of the drift near Thornhill.

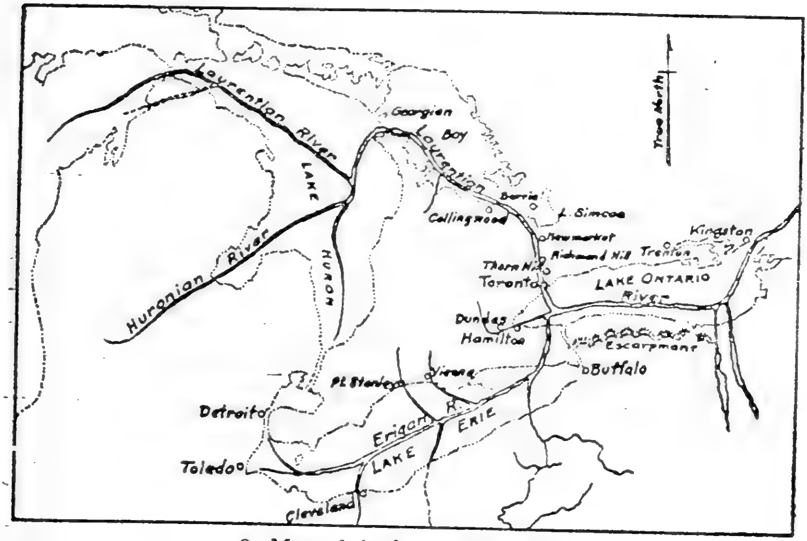
Below Lake Ontario the old channel is lost for a time, since at the present outlet through the Thousand Islands, where for a short distance Archaean rock is encountered connecting the Adirondacks with the old continent, there are no signs of a valley cut into the solid rock such as one would expect a great river to carve in the long Preglacial ages. Probably the original channel is to the southeast of the Thousand Islands and has been overlooked because filled with drift. That the old river flowed to the south of the present St. Lawrence at one place is shown by the fact that water drawn off artificially from the river furnishes an important source of power with a drop of 30 feet at Massena, N.Y. This water is afterward returned to the St. Lawrence at Lake St. Francis, ten miles down stream, and one may suppose that the Preglacial river followed this lower route, avoiding the present Long Sault rapids near Cornwall.

From this point the Laurentian river seems to have occupied the present river valley to Quebec; below which a submerged channel may be traced by soundings, as is mentioned above, till it reaches the edge of the continental platform beyond Cabot straits.

The length of the Laurentian river, as mapped by Spencer, was 1,740 miles.

[1]Evolution of the Falls of Niagara, p. 394.

Since four of the present Great Lakes have depths reaching below sea-level, and three of them are included in the supposed ancient river channel, one must suppose that an important amount of differential warping of the earth's crust has occurred since these basins and their drift-filled connections supplied a continuous grade from the interior highlands to the sea. There are difficulties in accounting for these anomalies, but no better theory has thus far been suggested.



3. Map of the Laurentian River

Tributaries of the Laurentian River

If we assume that the Laurentian river existed, and that it threaded several now distinct basins, it is evident that there must have been numerous tributaries joining it. Spencer has indicated several of them on his map, the first being the Huronian river, formed of two branches, one coming from the depression of Saginaw bay, and the other running north from the southern portion of Lake Huron. In the Ontario basin he maps two tributaries, the small

Dundas river and the large and important Erigan river draining the Erie basin and a considerable area to the south. This he indicates as entering the Ontario basin by a buried channel crossing the Niagara escarpment just west of DeCew falls, three or four miles south of St. Catharines. A number of wells show that this valley was deep enough, or almost deep enough, to drain the Erie basin completely.[1] Grabau completely reverses this conclusion, however, and believes that a great river, roughly corresponding to the upper part of Spencer's Laurentian river, flowed southwest through the Dundas valley and the basin of Lake Erie. At the time he wrote the DeCew channel was unknown, or he would perhaps have chosen it as the course of the main drainage system.[2] Spencer's map shows three tributaries of the Erigan river coming in from Ohio and even from Pennsylvania to the south, one of them including the upper part of the Ohio river reversed in direction; so that the two writers seem entirely at cross purposes.

If we admit that Spencer's river system is not improbable, there are still some parts of the basins of the Great Lakes left unprovided for. Lake Superior is not included in his map; but Leverett reports a "buried channel leading southward from the east end of the basin to the head of Lake Huron some distance west of the present line of discharge through St. Mary's river;"[3] which may indicate a connection with the Laurentian river. On the other hand, it has been suggested that Lake Superior drained toward the southwest; and buried southward-pointing outlets have been reported near Chicago and near Cleveland, indicating the drainage of the Michigan and Erie basins into the Mississippi. At present the evidence does not seem decisive as to the direction of drainage of the westward and southward parts of the basins.

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[1]*Ibid.*, pp. 418-428.

[2]Bull., N.Y. State Mus., No. 45, Vol 9, p. 42-5.

[3]Outline, Hist. of Great Lakes, 12th Rep., Mich. Acad. Sc., 1910, p. 21.

Origin of the Lake Basins

All of the basins of the Great Lakes except that of Lake Erie reach below sea level. Lake Superior, with its average surface 602 feet above the sea, has soundings of 1,008 feet; Lake Huron, 578 feet above sea, has a depth of 700 feet; and Lake Michigan of 870 feet; while Lake Ontario, with a water level 246 feet above the sea, has a depth of 738 feet. Lake Erie, 571 feet above the sea, reaches a depth of only 204 feet. It is evident that there must have been great changes in the relative levels of different portions of the region to account for the great depths of the lakes just mentioned.

The dip of the Keeweenawan rocks surrounding Lake Superior is always lakewards, as if the basin had been formed by a downward bending of the sedimentary strata and the beds of lava found so extensively on its shores and islands. The shape of the lake suggests a syncline with a sharp northward bend in the middle. Some believe that the synclinal shape has been produced by lateral thrusts of a mountain-building character; but it is more probably the result of the removal from a central hearth of the vast quantities of lava piled up on its shores, thus allowing the surface beds to collapse. The much shallower basin of Lake Nipigon, which may be considered the first of the chain of lakes, seems to have been formed in the same way. It is improbable, however, that the basin of Superior could have remained unfilled during the enormous time since the latest Precambrian, so that here too one must suppose that it was for long a river valley draining west or south by a drift-filled outlet still undiscovered.

Lake Huron and Georgian bay occupy basins partly due to warping of the earth's crust, but largely caused by an immense dam of Pleistocene drift materials, glacial and interglacial, piled up to a height of 942 or even 1,200 feet above sea level, thus turning the drainage which once followed the Preglacial Laurentian river into the St. Clair, Detroit, and Niagara rivers.

The Lake Michigan valley probably drained partly into the Mississippi under Preglacial conditions; but the southward outlet is now blocked by drift of much less thickness than that between Georgian bay and Lake Ontario.

Lake Erie owes its shallow basin partly to the filling with drift of an old outlet toward Lake Ontario, but largely to differential uplift of its northeastern end.

Lake Ontario, also, probably has a drift-filled outlet toward the east, but has been greatly deepened by differential raising of the outlet at the Thousand Islands. The two lower lakes illustrate more distinctly than the others the formation of basins from river valleys by the elevation of the outlets. They have been formed mainly by the action of epeirogenic forces, and damming has been of minor importance, while Lakes Huron and Michigan are held up by dams of drift materials.

Precursors of the Great Glacial Lakes

The glacial lakes of Ontario and the adjoining states, as generally defined, include only those bodies of water formed during the retreat of the last, or Wisconsin, ice sheet, but it is evident that each of the earlier sheets which has covered the region must have dammed back the northward or northeastward flowing waters in a similar way, and, in fact, that each ice advance must have formed lakes which gradually diminished in area as the ice front moved southwards until the whole of their basins was occupied; and afterwards a series of lakes expanding as the ice sheet retreated when the climate became temperate again.

How often the Great Lakes region was invaded by ice is not entirely certain, though the geologists who have studied the drift of Iowa distinguish five successive ice sheets as having covered parts of that state; while each of four interglacial intervals indicates a great retreat of the ice, if not its complete removal, before the following sheet advanced. In Ontario there is positive evidence of one interglacial period of milder climate than the present, when

no ice sheet could have survived, and of another great retreat of the ice when the Ontario basin at least was set free. These earlier glacial lakes, whether formed by an advancing or a retreating ice sheet, have left only very fragmentary evidence of their existence, and any attempt to map their boundaries is out of the question, though there can be no doubt of their existence. Later ice advances have in most cases completely buried or removed the proofs of such bodies of water.

During the Toronto interglacial period there was a lake in the Ontario basin which stood at first 60 feet above the present lake, and later rose to about 150 feet. An interglacial successor of the Laurentian river drained the Huronian valley into the lake just mentioned, forming a great delta at Toronto covering more than 100 square miles with sediments having a thickness at Scarborough Heights of 190 feet. As the climate for part of this interglacial period was distinctly warmer than that of Toronto at present, as is shown by the trees of the time, ice cannot have served as a dam, and one must suppose that the waters were held up by a differential elevation of the outlet near the present Thousand Islands. Later the barrier was removed and the water fell to 40 feet below the present lake, as is shown by old valleys carved to that depth and then buried under the next boulder clay. This level may correspond to the supposed drift-filled outlet southeast of the Thousand Islands. The lake of the Toronto Formation had a rich fauna, including 41 species of shellfish, of which ten or eleven are unios, mostly forms now living in the Mississippi.[1] Fish remains occur also, the only certain species being a large catfish, as determined by Professor Bensley from a spine. The evidence as to climate furnished by the aquatic life corroborates the conclusions drawn from the trees, suggesting temperatures corresponding to points 4 or 5 degrees farther south at the present time. No interlobate moraine had been deposited across the Preglacial channel before the Toronto Formation,

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[1]Guide book, No. 6, Geol. Congr. Tor., pp. 17-18.

so that the St. Clair, Detroit, Niagara outlet had not yet come into existence.

During the advance of the ice sheet which followed the Toronto interglacial time, a lake must have been formed in the Ontario basin, but no certain deposits belonging to it have been found. During the retreat of this ice sheet, which extended beyond Newcastle, fifty miles to the east, the glacial lake reached a level of 204 feet; and later the process was repeated twice more, as shown by beds of stratified sand and clay 25 and 36 feet thick respectively, between sheets of boulder clay, implying water levels 238 and 306 feet above Lake Ontario. A few small shells have been obtained from the second interglacial beds, belonging to species still living in the region; but the two upper sands seem to have been deposited in lifeless waters, probably with the ice front not many miles to the northeast. What took place in the basins of the other Great Lakes can in most cases only be inferred from our general knowledge of the advance and retreat of the great ice sheets which passed over the region; since lake deposits belonging to the successive interglacial intervals have not been certainly identified.

Lake Agassiz

The earliest of the glacial lakes, as usually defined, lay to the west of the region here specially considered and will be mentioned only briefly. Lake Agassiz, as it has been called, occupied parts of Saskatchewan, Manitoba, and Ontario in Canada, and parts of Minnesota and North Dakota in the United States. When at its greatest dimensions it covered 110,000 square miles between the watershed to the south and the retreating Keewatin and Labrador ice sheets, its northern shore being the margin of the Keewatin sheet and its eastern that of the Labrador sheet. It was a comparatively shallow lake which drained southeastwards by what has been called the Warren river into Minnesota river, a tributary of the Mississippi. When the two confluent ice sheets melted so far as to separate, a

readily accounted for. The climate of Manitoba at the time was probably not much more rigorous than now, since the buffalo lived on the shores of the lake; and the fish and molluscs could not have multiplied as they did unless its waters were unfrozen for several months in the year.

Early Glacial Lakes in the Basins of the St. Lawrence System

Probably before Lake Agassiz was drained, the basins of the upper lakes of the St. Lawrence system began to be set free by the melting of the southern end of the ice lobes that occupied them. The evidences of this are found mostly in the states to the south of the province of Ontario, so that it will not be necessary to describe in detail these early glacial lakes. They have been mapped by Leverett, Taylor, Goldthwait, and others in the United States, and to a minor extent by Spencer in southern Ontario. A full and excellent account of them is given by Taylor in Monograph LIII of the United States Geological Survey, to which those specially interested in the matter are referred.

Numerous early stages of water have been recognized and more or less completely mapped in each of the three upper lake basins, but only the most long lived of them need be mentioned here. In the Superior basin Lake Duluth followed up the shrinking ice lobe and ultimately occupied about half of the present basin as well as flooding a strip of the present shores. It drained southwestward through the St. Croix river valley into the Mississippi.[1] This lake, when at its greatest extent, covered part of the Thunder Bay region in Ontario.

The southern half of Lake Michigan was occupied at first by a crescent-shaped lake which expanded northwards, and has been called Lake Chicago. It emptied toward the southwest by the valley of Desplaines river, a tributary of the Mississippi.

The southern end of Lake Huron and the basin of Lake Erie had a very complicated history and numerous names

[1]U.S. Mon. LIII, p. 328, map op. p. 400.

have been given to bodies of water following up the ice. Only one of these, Lake Warren, will be mentioned. Its beaches extend into the province of Ontario and were studied first by Spencer.[1] He supposed that the region was covered by an arm of the sea and named this extension of the Gulf of St. Lawrence the "Warren Water." Later it was recognized that it was a glacial lake having an outlet through what is now Saginaw bay into Lake Chicago. Spencer believed that this body of water extended far to the north and included the upper beaches around Lake Superior. He was followed in this by Lawson, who measured many beaches north of Lake Superior; and by the present writer in the same region and farther east. The more recent and more detailed work of Taylor and others in the United States has cut down greatly the dimensions of this lake, and the high beaches to the north are now known to belong to Lake Algonquin.[2]

At a later stage the waters of the Huron-Erie basin sank below the level of the outlet to Lake Chicago, and Lake Lundy took the place of Lake Warren. Some of its beaches are found in southern Ontario. It is supposed that Lake Lundy emptied toward the east through the state of New York and the Hudson valley.[3]

Lake Algonquin—Its Outlets

The various lobes of the Labrador ice sheet were gradually shrinking, though with some halts and even re-advances, marked by the building of moraines, and at length the basins of the Upper Lakes were almost completely free, though to the north and northeast, beyond the present boundaries of Lakes Superior and Huron, ice still formed a part of the shore. At first all outlets toward the northeast were blocked, but the basins of the three great Upper Lakes were in communication, forming what was called by Spencer Lake

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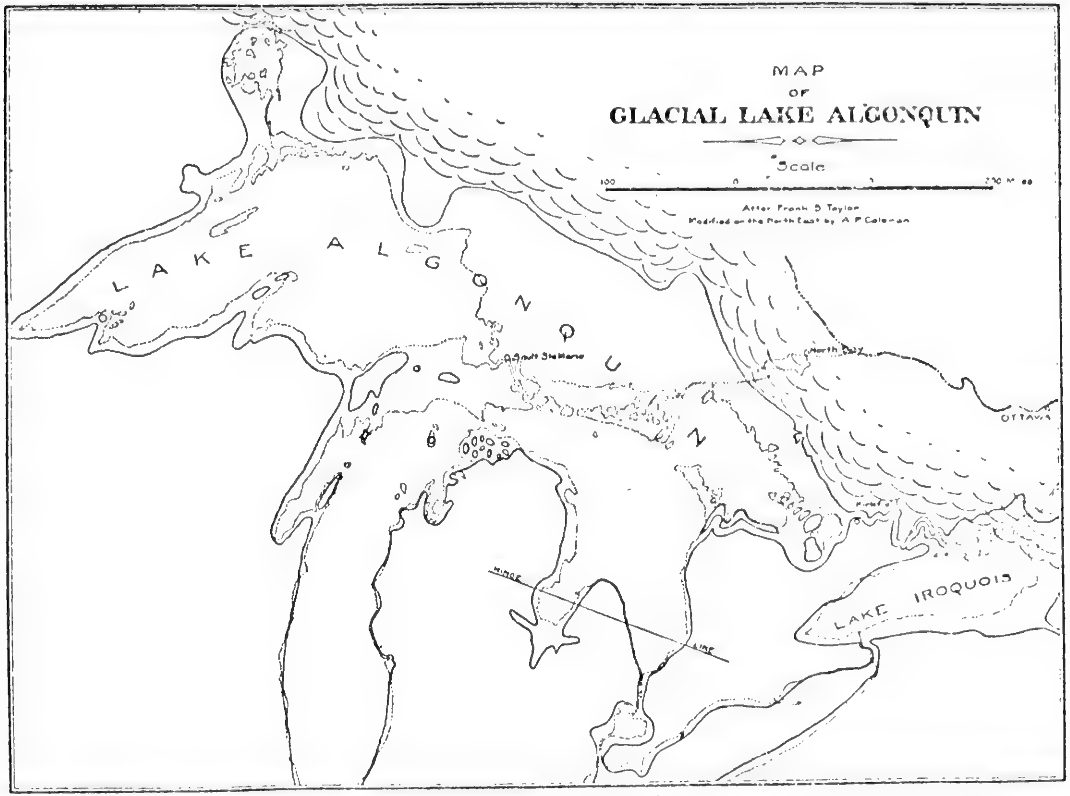
[1]Falls of Niagara, G.S.C., p. 287.
[2]U.S. Mon. LIII, pp. 392, 398.
[3]*Ibid.*, pp. 399-406.

Algonquin, and probably drained for a short time past Chicago into the Mississippi. Lake Erie was no longer dammed by the ice front and became partly a river valley, and partly a separate lake, through which for a time Lake Algonquin emptied into the Ontario basin. It may be that both of these channels functioned for a short time until the ice so far withdrew from the Georgian bay region as to allow a lower outlet past Kirkfield into the Trent valley.

Affairs were in a very unstable condition with regard to outlets, and also as to the area and shape of Lake Algonquin. When the Kirkfield outlet was opened, the land in that region stood lower than either the Chicago or St. Clair channels, and the great lake must have been lowered to correspond, leaving the earlier channels dry. As the load of ice was removed by thawing toward the northeast, the land beneath the thinning ice sheet rose to correspond to the relief, and at length the Kirkfield or Trent outlet reached a level when the St. Clair channel and perhaps also the Chicago channel were occupied once more. There was a long continued two-outlet or three-outlet stage during which a substantial beach was built round the whole shore. Ultimately, the northeastward elevation closed the Kirkfield outlet, and the reinforced St. Clair river lowered its bed in drift deposits so far that the Chicago outlet, limited by a sill of rock, ran dry, and the whole drainage of Lake Algonquin passed through the Erie valley and over Niagara Falls.[1]

During the two- or three-outlet stage of Lake Algonquin, there seems to have been a long halt in the retreat of the ice and also in the elevation of the region toward the north. In the southern parts of the basins, although the shore stood higher than at present, the area occupied followed pretty closely the boundaries of the present lakes. Toward the north, northeast and east, however, Lake Algonquin extended much beyond the present limits, a northern bay even including the basin of Lake Nipigon. Much of the land north of the Sault Ste. Marie and northeast of Georgian

[1] *Ibid.*, pp. 407, etc.



4. Map of Lake Algonquin

bay was flooded; so that the lake covered considerably more space than the three Upper Lakes. It had an area of perhaps 100,000 square miles, coming next to Lake Agassiz in dimensions and far surpassing it in volume of water, since parts of its basin had a depth of from 1,200 to 1,500 feet.

The southwestern shores of Lake Algonquin have been carefully mapped, but the northern and northeastern are still only imperfectly known, since the region is largely forest-covered and roadless.

Present Altitude of the Shore of Lake Algonquin

A detailed account of the southern shores of Lake Algonquin, accompanied by an excellent map, is to be found in Taylor's description of the Post-glacial lakes.[1] It has been determined that along the southern half of Lake Michigan and the lower ends of Saginaw bay and Lake Huron the old shore is horizontal and rises 607 feet above the sea or 26 feet above the present lakes. The horizontal portion ends at what is called a "hinge line" crossing the lakes in a direction about 20° south of east and entering the province of Ontario at the village of Grand Bend, northwest of London. Beyond the hinge the shore rises as one goes north. At Kirkfield, for a long time on the main outlet of the lake, the shore is 883 feet above the sea, showing a deformation in the distance of 276 feet, about two feet per mile in the direction of tilt. The highest beach rises more rapidly farther north, reaching 1,007 feet at Huntsville, as determined by Goldthwait, and 1,015 feet at Root river, six miles north of the Sault Ste. Marie, according to Leverett.[2] Up to these points the position and elevation of the highest shore is considered to be somewhat definitely fixed. A number of shore deposits probably belonging to it are known still farther north, however. At Heyden station on the Algoma Central Railway, 13.3 miles north of the Sault, there is a gravel plain 1,082 feet above the sea, which almost

[1] *Ibid.*, pp. 409-438.
[2] *Ibid.*, p. 435.

certainly belongs to Lake Algonquin; and Goldthwait has found a probable Algonquin beach at Trout Creek, 54 miles north of Huntsville and 1,221 feet above the sea, representing a rise of about four feet per mile between the two places. Northward of the hinge line the beach is split up into groups of successive beaches, showing that elevation was progressing during the lifetime of the lake.

The northeast shore of Lake Algonquin has never been traced continuously, though at many localities lake deposits or old beaches have been found which probably represent Algonquin water levels, a few of them belonging to the highest beach, but most of them corresponding to lower stages of the lake, after the Kirkfield or Trent outlet had been abandoned and the drainage followed the St. Clair river toward Niagara Falls. A number of these points are along railways, since the location engineer is much attracted by flat plains or level beaches; and many of the divisional stations, where yard facilities are required, have been located on lake deposits. In these cases the levels are definitely known. In other cases the old lake deposits have been measured by aneroid during canoe trips or walks across country, and the elevations are much less certain. As it will probably be many years before the wild region north of the lakes is carefully surveyed, it is thought advisable to give these aneroid determinations in spite of their possible want of accuracy. It is not thought necessary, however, to give aneroid levels of old beaches near points where Wye level surveys have been made by Lawson and others, though many such determinations were made.

Water Levels in the Sudbury and Sault Districts

Lake deposits are widespread in the Sudbury District, about 90 miles a little north of west from North Bay and 150 miles northwest of Kirkfield. The deposits include plains of stratified clay, mostly in the interior of the nickel basin, running from 820 feet at Coniston to 889 at Chelmsford (both railway levels), indicating moderately deep water

conditions in a bay of Lake Algonquin. To the north sand plains occur at Hanmer (968) and Capreol (1,003) stations, and there is a gravel terrace five feet above the track at Selwood Junction (1,089). Along the main line of the Canadian Pacific Railway northwest from the Sudbury basin there are sand plains, succeeded by gravel plains at Windy Lake (1,221) and at Cartier (1,378). The last is a divisional station with many switches and tracks laid out on a gravel flat, which probably belongs to the highest Algonquin beach. All these figures are from railway levels, and are accurate. The highest sand and gravel plain observed in the district is at Meteor lake about 50 miles north of Chelmsford and 45 miles in a direction about 20° east of north from Cartier. Aneroid readings make the level 1,420 feet, which would give a rise of one foot per mile from Cartier, probably under the true rate of change. The Meteor lake region is a pitted plain enclosing steep-walled kettles which were formed by the slow thawing of ice masses buried under lake shore deposits, at the margin of the retreating ice sheet.

Although no continuous shore has been traced in the Sudbury District the widespread character of the lake deposits and their position rising gradually to the north of Lake Huron, make it certain that Lake Algonquin when at or near its highest level extended at least 50 miles and probably 90 miles from the present coast of Lake Huron.

On a former page reference was made to high level sand and gravel terraces along the Algoma Central Railway, extending for thirteen miles north of the Sault Ste. Marie. Many old lake beds have been found farther to the north, partly along the shore of Lake Superior on the route to Michipicoten, and partly inland beyond Michipicoten bay.

The first point measured (by aneroid) is on the northeast side of Batchewana bay, thirty miles north of the Sault, where three terraces stand at 967, 1,047, and 1,152 feet respectively. The highest terrace is 70 feet above the highest one near the Sault, giving a rise of two and a half feet per mile.

The next measurements were made near Brulé harbour,

92 miles in a direction a little west of north from the Sault. Here, on a path from Brulé harbour to the mouth of Old Woman bay a wonderful succession of bars is found having the following elevations:

867 feet	Algonquin beaches
858 "	
842 "	
823 "	
814 "	
750 "	
734 "	
724 "	
706 "	
658 feet	Nipissing beaches.
636 "	
623 "	
612 "	

The elevations up to 734 feet were determined by hand-level, the higher ones by aneroid. The beaches are practically continuous from 814 to 823, and from 842 to 867 feet. In fact there are only two wide gaps in the succession, one above what are considered Nipissing levels and one between 750 feet and 814. The levels given were measured from Brulé harbour up to a col between granite hills at 867 feet, but a similar succession goes down to Old Woman bay on the other side. They are all gravel or boulder beaches, and are very recent-looking up to 56 feet above Lake Superior, being free from trees or bushes, though covered with lichen.

Twelve miles northeast of Brulé a branch of the Algoma Central railway runs from Michipicoten harbour to the Helen mine, its route being mainly over great delta plains of sand and gravel deposited by Michipicoten river in Lake Algonquin and later bodies of water. Somewhat east of the harbour, on a road leading from the Mission to Wawa lake, ten terraces or beach ridges were hand-levelled, run-

ning from 623 to 810 feet. One at 681 feet is a broad sand terrace, perhaps the highest Nipissing beach, though the greatest break, of thirty feet, is just above 702 feet.

Brient Station on the railway is on a terrace of stratified sand at 759 feet and Wawa Station, on a gravel terrace, is at 960 feet, while Wawa lake is at 938 feet. The lake is dammed by a bar at the railway level (960 feet), and was a bay of Lake Algonquin cut off by wave action.

Higher beaches reach 1,042, 1,088, and 1,140 feet, as determined by aneroid. At Goudreau lake, twenty-eight miles northeast of Michipicoten harbour, a distinct bar was hand-levelled from a bench mark on a railway "try line," working out at 1,330 feet above sea level.[1]

Thirty miles northwest of the harbour a beach was found at 1,382 feet on Obatonga lake, and about ten miles farther northwest, on Pokay lake, there is a beach at 1,445 feet (both aneroid levels). This is the highest water level observed in the region, but at several C.P.R. railway stations east of Michipicoten there are lake deposits at about the same level. Pardee, 60 miles east, is on a sand plain (1,524 feet), and Chapleau, a divisional point 70 miles east, is on a sand plain (1,412), with a higher terrace including glacial kettles between it and Poulin station (1,499). Eighty miles east, at Nemegos (1,421), there is a sand plain, and near Winnebago, 100 miles east, there is a gravel plain and railway ballast pit at 1,447 feet.

Winnebago is 80 miles northwest of Cartier and north of the Sault; and it is evident that, as usual, the railway has chosen for its route the sand and gravel plains and terraces of the old shore. The position of the railway roughly outlines this part of Lake Algonquin at its highest stage.

Algonquin Beaches Northeast of Michipicoten Bay

The shore of Lake Superior between Michipicoten harbour and Heron bay, where the C.P.R. reaches it, is comparatively

[1]This beach was first put at 1,430 feet, but later it was found that the bench-marks were adjusted to 100 feet below the level of Lake Superior so as to allow for under-water work at the harbour.

little known, since it is not touched by any travelled route and can be studied only by using fishing boats. At the mouth of Dog river, fifteen miles west of Michipicoten harbour, beaches have been measured by aneroid at 721, 851 and 962 feet; probably all belonging to Lake Algonquin. Farther to the west the shore is mountainous and too rocky and precipitous to provide much beach material, and the same is true of the shore bending northwest toward Heron bay. At Kilkenny, a small fishing harbour just at the bend, excellent gravel beaches were hand-levelled at 610, 618, and 644 feet, the highest one probably belonging to the Nipissing beaches. As the highest mountains in Ontario rise within a few miles of the shore (Tip-top, 2,120 feet, is the culminating point), it is evident that there must have been a large promontory or island here in Algonquin times.

The railway levels on the C.P.R. between Pardee and Heron bay are mostly below 1,200 feet, though some "summits" reach nearly 1,500 feet; but no well defined water levels have been observed, except possibly the flat on which White river (1,225 feet), a divisional point, is located. It is possible that the ice front remained for a long time in contact with the mass of high land between Michipicoten and Heron bays. The region deserves a much more careful study than has yet been devoted to it.

Michipicoten island, forty miles southwest of Michipicoten harbour, displays, as might be expected, a fine series of beaches, which fall into distinct sets; the lowest from 617 to 624, the next from 667 running to 680, and a third from 730 to 780 feet. At 806 feet there is a well-marked gravel beach and a lake dammed by beach materials. There is a wide terrace at 835 feet including a lake, and a highest terrace at 897 feet.[1] The beaches above 680 feet may be reckoned as belonging to the Algonquin series, which, however, is not complete, the highest members being lacking. The measurements were by aneroid.

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[1]Bur. Mines, Vol. 8, 1899, pp. 154-5.

Where the shore of Lake Superior turns from northwest to due west, at Peninsula, the following beach levels have been measured by aneroid:

980 feet	687 feet
959 "	669 "
732 "	647 "

Of these the levels above 687 come within the Algonquin limits. Forty miles east of Peninsula a sand plain at Bremner station (1,132) probably represents an Algonquin water level. This point is twenty-two miles northwest of Pokay lake, previously mentioned as showing one of the highest beaches recorded.

To the northeast of Peninsula, Pic river has piled up widespread delta materials, and sand terraces rise to levels of 757, 820, and 895 feet, representing low stages of Lake Algonquin. West of Peninsula, terraces were measured at several places, but Lawson's work, done with a Wye level, is more accurate, and only terraces above his determinations will be given.

At Jackfish bay Lawson records beaches running from 721 to 1,020 feet; and at the well named station, Terrace, there are terraces at 830, 845, 920, 974, and 994 feet. At Schreiber, a divisional station, Lawson gives a lake level at 993 feet, and one and a half miles west I have found one at 1,037 feet (aneroid). At Winstons, eight miles west, he mentions only one beach level, at 812 feet, but my aneroid readings show terraces of Lake Algonquin at 832, 890, 931, 967, and 985 feet also. Where the C.P.R. crosses Nipigon river Lawson gives seven terraces, of which only the highest, at 734 feet, can be considered to belong to Lake Algonquin.[1]

Beaches in the Nipigon Region

Besides the water levels at the mouth of Nipigon river a number of terraces occur farther north, showing that Lake Algonquin included most or all of the Nipigon basin. Twenty-four miles northwest, on Nonwatin lake, a sand

[1]Geol. and Nat. Hist. Survey of Minnesota, 20th An. Rep., 1891, Table, p. 280.

plain occurs at 917 feet (aneroid); and still further in that direction, on Black Sturgeon lake, there is a terrace at 660 feet (railway try line) and another at 963 feet (aneroid), the lowest one belonging to the Nipissing levels.

The Pleistocene features of the west side of Lake Nipigon have, so far as I am aware, not been studied; but on the east side there are broad sand plains at Poplar Lodge and for thirty miles to the east.

Lake Nipigon, the first of the chain of Great Lakes, is 852 feet above the sea or 250 feet above Lake Superior. By hand level and aneroid sand plains and terraces have been measured at 907, 930, 947, 987, and 1,020 feet within a few miles of the lake near Poplar Lodge. Farther east there are higher plains at 1,060 and 1,070 feet (aneroid) and at Kinghorne station on the Canadian Northern railway at 1,090 feet.

Poplar Lodge is 46 miles in a direction 5° east of north of the mouth of Nipigon river. Twenty miles farther north, near Red Paint river, there is a sand plain 922 feet above the sea, as determined by hand level from Lake Nipigon. A few miles to the northeast a moraine forms the watershed toward James bay (1,065 feet). Moraines cover much of the watershed north and northeast of Lake Nipigon and thus far no lake deposits have been recognized there.

It is probable that during most of the life of Lake Algonquin the shore in this region was of ice. As the highest Algonquin levels should reach above 1,500 feet in the northern part of the Nipigon area one may reasonably conclude that during the earliest stages of the lake most of the Nipigon basin was still ice-filled. In the later stages, with water levels of from 900 to 1,090 feet, the Nipigon bay of Lake Algonquin must have been about the size of Georgian bay, and with its numerous Archaean islands must have considerably resembled the latter.

Lake deposits are widespread to the southwest of Nipigon river and their elevations have been determined at a number of points on the C. P. Railway. Lawson records terraces in several places on or near Thunder bay, many of them

reaching the Algonquin level; the same is true along the coast of Minnesota to the southwest.

The old lake Kaministiquia described by Taylor from deposits west of Fort William was probably a part of the highest Algonquin waters, which attained from 1,400 to 1,500 feet above sea level.[1]

Whether this stage extended across the watershed between the Great Lakes and the waters draining into Lake Winnipeg is not certain. The elevations of the railway summits beyond Lake Superior are 1,568 feet for the Canadian Pacific near Martin station and 1,580 feet for the Canadian Northern at Huronian station. It is doubtful if the highest Algonquin waters ever connected with those of Lake Agassiz across this watershed. The greatest elevation of lake deposits observed by myself west of the watershed is at Ignace, forty miles beyond the summit (at Martin), where a gravel terrace used for railway ballast rises seven or eight feet above the track, which is 1,486 feet above the sea. The gravel terrace reaches about 15 feet above the track somewhat to the east of the station, *i.e.*, 1,501 feet, considerably below the watershed.

The highest Agassiz beach reported by Johnston in western Ontario is only 1,200 feet above sea level,[2] and it seems improbable that the two greatest glacial lakes ever mingled their waters. The only certain connection between them is through the rivers which drained them into the Mississippi. This connection is long and round-about and it is not probable that the two lakes drained into the great river contemporaneously.

Algonquin River

Although neither the earliest nor the latest effluent of Lake Algonquin, the Kirkfield or Trent channel is the most interesting of its outlets and probably functioned for a longer time than any of the others, though toward the end the

[1]Am. Geol., Vol. XVII, 1896, p. 254.

[2]G.S.C., Mem. 82, Rainy River Dist., p. 59.

waters of the lake were divided between the Algonquin and the St. Clair rivers and finally passed entirely into the latter. The most careful study of the outlet has been made by Johnston,[1] though it had previously been observed and described by Gilbert, Taylor and others.[2]

The route followed by the river was in the main that of the Trent Valley canal. A bay of Lake Algonquin, covering the present lakes Couchiching and Simcoe, extended eastward from Kirkfield to Fenelon Falls, where the Algonquin river began. It flowed through the basins of Sturgeon, Pigeon, Buckhorn and Stony lakes and then followed either the Otonabee or the Indian river valley to Rice Lake, at that time a bay of Lake Iroquois, which will be mentioned later. The old channel has been traced down the Trent valley to the Bay of Quinté and Lake Ontario, showing that Lake Algonquin survived Lake Iroquois for a period of time long enough to excavate a wide and deep channel to the present level of Lake Ontario if not below it. The present Trent river is far too small to have carved out the valley it occupies.

The puzzling feature of this continuation of the Algonquin river channel so far below the level of Lake Ontario lies in the fact that between the draining of Lake Iroquois and the formation of Lake Ontario there came the marine episode when the basin of Ontario was invaded by an arm of the sea, which stood in the Bay of Quinté region seventy-eight feet above the present Lake Ontario.

The solution of the problem is probably to be found in the fact that when Lake Iroquois ended the sea was much lower than now, since a part of the water of the globe remained stored in the great ice sheets still remaining on the continents. If we suppose that only half of the world's ice caps had melted when the glacial tongue which held up Lake Iroquois at the Thousand Islands disappeared, the sea was

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[1]G.S.C., Mus. Bull., No. 23, The Trent Valley Outlet of Lake Algonquin.
[2]U.S. Mon. LIII, pp. 410, etc.

80 or 100 feet lower than now, according to computations which will be mentioned later.

For most of its existence, according to Johnston, Algonquin river flowed through the Indian river channel, one of the present connections between Stony lake and Rice lake. He infers this from the magnitude of the delta built at its mouth in the Rice lake bay of Lake Iroquois.[1] Ultimately the northward elevation of the region turned the water into the Otonabee channel, when an important delta was made in old Lake Peterboro, a little above Rice lake.[2] The low marine stage probably occurred while the latter channel was in use, when the Algonquin river flowed down the Trent valley to the level of Lake Ontario.

Life and Climate of Lake Algonquin

At Tolleston near Chicago, in beds probably belonging to one of the earlier glacial lakes, many shellfish occur and also bones of several species of fish and of a duck, as well as leaves of oak (*Quercus marceyana*) and cones of spruce (*Picea evanstoni = canadensis?*). The middle Tolleston, which F. C. Baker considers to correspond to the Algonquin beach, also contains fifteen species of molluscs. Another stage includes eleven species of heavy unios characteristic of the Mississippi, among them five which occur in the Toronto interglacial beds on the Don. Except the spruce, which does not grow so far south as Chicago, all the species inhabit the same region now and indicate a climate like the present. One or two of the molluscs even suggest a climate warmer than the present.[3]

The Tolleston deposits were formed at or near the old outlet of Lakes Chicago and Algonquin in shallow water more than 400 miles south of the northern shore of ice, so the evidence is not conclusive as to temperatures in the lake as a whole.

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[1]G.S.C., Mus. Bull., No. 23, pp. 11, etc.

[2]Bull. Geol. Soc. Am., Vol. 15, 1904, pp. 357-8.

[3]Ill. Acad. Sc., Vol. IV, 1911, Post-glacial Life of Wilmette Bay, Glacial Lake Chicago.

In the Algonquin beach near Jackson point on the shore of Lake Simcoe, Johnston has found fresh water shells including *Lymnaea palustris*, *L. decollata* and *Sphaerium rhomboideum*;[1] all still living in Georgian Bay. He has found them also at Roche's point and Wilfred, and says: "The occurrence in the deposits of the highest shore-line of Lake Algonquin of fossil shells of mollusca similar to those living in Georgian Bay, and the fact that the fossil shells are only slightly reduced in size show that the temperature conditions of the water could not have been much more severe than at present. This is also borne out by the general absence of ice 'ramparts' on the abandoned shores of Lake Algonquin and the rare occurrence of boulders in the lacustrine deposits of the lake."

In my own work fossils have been found in Algonquin sands 810 feet (aneroid) above the sea on Pic river, 35 miles above the C.P.R. at Heron bay, including fragments of *Unio* or *Anodon*, *Sphaerium*, *Pisidium*, *Goniobasis*, *Lymnaea*, *Planorbis*, *Amnicola*, *Succinea*, *Valvata*, and probably two or three other genera. Unfortunately the species were not determined, but all the genera still live in Lake Superior.[2]

Many years ago Robert Bell reported shells from Pic river 30 feet above the water and the same distance below the top of the bank, but it is uncertain whether the deposits belong to Lake Algonquin or the Nipissing Great Lakes. They include two *Unios*, an *Anodon*, and a *Margaritana*, with species of *Lymnaea*, *Planorbis*, *Valvata*, and *Amnicola*; "the whole being of a more southern type than the mollusca at present inhabiting the rivers and lakes of the neighbourhood."[3]

Three miles above the Mission on Michipicoten river near its mouth there is a deposit of peat and logs six or eight feet above the water. An expert lumberman has recognized white pine, jack pine, white and black spruce, balsam, cedar,

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[1]G.S.C., Mus. Bull., No. 23, pp. 15 and 16.
[2]Bur. Mines, Ont., Vol. 18, 1909, p. 153.
[3]G.S.C. An. Rep., 1870-71, p. 328.

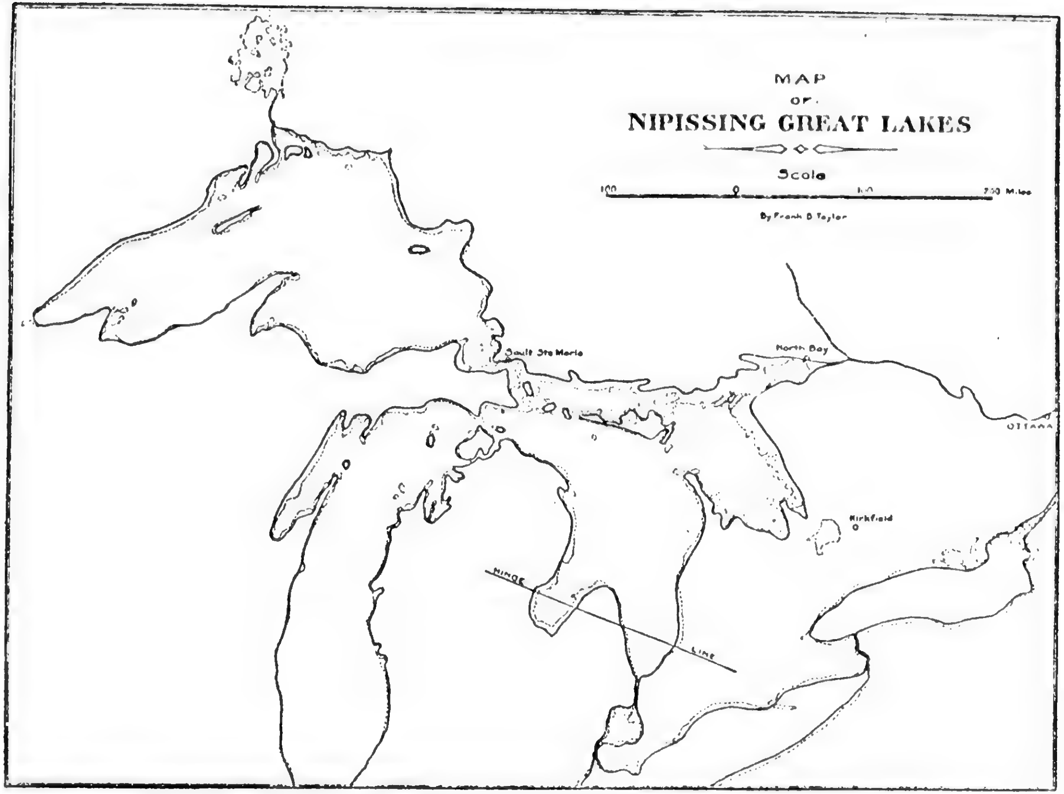
and poplar among the logs and fragments of wood; and in the peaty matter there are leaves of deciduous trees and of cedar and spruce, scales of pine cones, and some mosses. The age of the bed of clay in which they occur is uncertain, but it is older than the sand and gravel terraces which overlie it. These are beach deposits of the Nipissing Great Lakes. The peaty clay with wood was probably formed in moderately deep water at a low stage of Lake Algonquin.

It is notable that none of the shellfish or trees observed in Algonquin beds suggest a subarctic climate, such as might have been expected in connection with a lake whose shore was partly formed by the ice front. All the plants and animals still live in the waters or on the shores of Lakes Superior and Huron; so that there is no evidence that the climate was colder than at present. It may be that the slowly melting edge of the ice was largely buried under morainic materials on which trees could grow, as on the Malaspina piedmont glacier in Alaska.

At present the temperature of the water of Lake Superior is about that of greatest density, 39.2° Fahr.; and it is not unlikely that Lake Algonquin had the same temperature, while the shallow water of its southern temporary outlet near Chicago must have been much warmer to permit the life of so many Mississippi shellfish as have been found in the Tolleston beds.

The Nipissing Great Lakes

The final removal of the ice from the northeastern edge of the Algonquin basin opened a new outlet, at that time lower than the one by St. Clair river, through Lake Nipissing and the Mattawa valley to the Ottawa. The waters of the Upper Lakes were lowered to correspond and what has been called by Taylor the Nipissing Great Lakes resulted, the basins of Lakes Superior, Michigan and Huron being at the same level and communicating by straits so that St. Mary's river did not yet exist.



5. Map of Nipissing Great Lakes

The Nipissing Great Lakes lasted long and formed a pronounced beach which has been traced almost all the way round their shores. In area they were only slightly larger than the present lakes, though there was an extension toward the east covering the valley of French river and Lake Nipissing and ending at North Bay, where the outlet river began. A detailed and excellent account of these lakes and their shores has been given by Taylor,[1] and it is not necessary here to give more than an outline of their history.

Rise of the land toward the northeast gradually restored the use of the St. Clair channel and during most of their history the Nipissing Great Lakes had two outlets. Finally the rise toward the northeast turned all the water southwards, the North Bay channel went dry and the present lakes came into existence.

South of the "hinge line" mentioned on an earlier page the Nipissing beach is horizontal, ten or twelve feet lower than the Algonquin beach, and about 15 feet above the present Lakes Huron and Michigan. North of the hinge the Nipissing shore is split up into a series of beaches closely following one another.

At the North Bay outlet the highest Nipissing beach has been fixed at 698 feet by Goldthwait,[2] and to the south it becomes lower until at Sarnia near the hinge line it is only 597 feet. At Sault Ste. Marie it is 651 feet above sea level and on the north shore of Lake Superior it rises to its highest levels, given by Taylor as 703 feet at Jackfish bay and 710 (aneroid) at Peninsula harbour,[3] the point farthest from the hinge line and a little north of the isobase of North Bay. Probably the lower terraces along Pic river represent the highest known portion of the Nipissing shore. Delta materials are widely spread along the river valley; and one sand and gravel terrace twelve miles above the railway bridge and eight miles from Peninsula is at 718 feet (aneroid),

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[1]U.S. Mon. LIII, pp. 447-462.
[2]*Ibid.*, p. 459.
[3]*Ibid.*, p. 460.

6. Nipissing Beaches at Brulé

and no doubt belongs to the Nipissing shore,[1] while others a few miles up the river, somewhat higher though not measured, probably represent a continuation of it.

A few other localities on the northeast shore of Lake Superior may be added to those mentioned by Taylor. The highest point after Pic river is probably at the Mission near the mouth of Michipicoten river, where terraces were measured by hand level, beginning at 623 feet above the sea (21 above Lake Superior) and continuing with comparatively small gaps up to 702. An interval of thirty feet separates this series from the next, which may be considered to belong to the Algonquin set of beaches. According to the isobases shown on Taylor's map, 702 feet is six or seven feet above the proper level. On the other hand, a broad sand terrace at 681 feet seems too low as compared with the isobases. Which should be taken as the highest Nipissing beach is uncertain, though the 702 feet level seems to the writer the more probable one.

Near Brulé harbour, ten miles south of Michipicoten, very well formed beaches were hand-levelled with only small gaps from the present lake level up to 658 feet, which may be considered the highest Nipissing terrace.

On Michipicoten island, just touched on the north by Taylor's isobase of 676, aneroid readings show a first series of beach ridges up to 22 feet, where there is a sea cave, a second series up to 65 feet, where a terrace affords space for several houses, and above this a succession of faint stages up to 78 feet, followed by a gap before the next water level at 128 feet. Probably the beaches at 667 and 680 feet belong to the Nipissing set and the higher ones to Lake Algonquin.

Life and Climate of the Nipissing Great Lakes

Shells have been found in Nipissing beach gravels at various places. Taylor mentions *Unio luteolus*, (=*Lampsilis luteola*), *Sphaerium Striatinum*, *Lymnaea elodes*, and *Gonio-*

[1]Bur. Mines, Ont., Vol. 18, 1909, p. 153.

basis depygis as occurring near Cheboygan, Mich.[1] These are common forms in the Great Lakes at present.

Many years ago Dr. Chapman, professor of Geology in the University of Toronto, described shells from deposits on the banks of Nottawasaga river near Georgian Bay. At Angus on the west bank of the river 30 or 40 feet above Lake Huron he collected *Unio* (=*Elliptio*) *complanatus*, *Cyclas similis* (=*Sphaerium sulcatum*), *C. dubia* (=*Pisidium virginicum*), *Amnicola porata*, *Valvata tricarinata*, *V. piscinalis*, *Planorbis trivolvus*, *P. campanulatus*, *P. bicarinatus* (=*antrosus*), *Lymnaea palustris*, and *Physa ancillaria*. This point is about 20 miles from Georgian Bay. About twelve miles from the mouth of the river Dr. Bigsby found two layers from four to six inches thick closely packed with unios. He adds *Melania* (=*Goniobasis*) and *Paludina* (=*Campeloma*) to the list just given.[2] Probably shells and wood found at Owen Sound belong to beach deposits of Nipissing waters also.[3]

To the species secured by these older geologists may be added the following shellfish obtained by the present writer from the banks of Nottawasaga river: *Sphaerium rhomboideum*, *S. sulcatum*, *Pisidium noraboracense*; *Valvata sincera*, *Amnicola limosa*, *Goniobasis livescens*, *Lymnaea desidiosa*, *Planorbis deflectus*, *P. parvus*, *Succinea avara*, *Polygyra monodon*, and *Helix* (=*Polygyra*) *tridentata*. The collection includes nineteen species, seven of them mentioned in former lists. All of the species referred to above are still inhabitants of Lake Huron and suggest a climate similar to that of the present.

A very interesting set of river deposits along the Niagara, from Queen Victoria Park and Goat Island to about the Whirlpool, is probably of the same age as the Nipissing Great Lakes at their latest stage when the drainage was partly through the St. Clair, Detroit, and Niagara channels.

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[1]U.S. Mon. LIII, p. 452.
[2]G.S.C., Geol. Can., 1863, p. 910.
[3]*Ibid.*, p. 912.

These are mentioned in the *Geology of Canada* (1863) as containing *Planorbis bicarinatus* (=*antrosus*), *Physa heterostropha*, *Lymnaea caperata*, *L. stagnalis*, *Melania* (=*Goniobasis*) *Niagarensis*, *M. conica*, *M. acuta*, *Paludina decisa* (=*Campeloma decisum*), *Amnicola limosa porata*, *Unio* (=*Elliptio*) *gibbosus*, *U.* (=*E.*) *complanatus*, *U.*(=*Obovaria*) *ellipsis*, *U. rectus* (=*Eurynia recta*), *Margaritana* (=*Alasmidonta*) *marginata*, *Cyclas similis* (=*Sphaerium sulcatum*) and a land snail *Helix* (=*Polygyra*) *albolabris?*[1]

Miss E. J. Letson, in 1901, published a list of 31 shells from Goat Island with a description and figure of each species. Of these 24 are in addition to the species given above. They include *Pleurocera subulare* (=*acuta*), *Goniobasis livescens*, *G. haldemani*, *Amnicola limosa*, *A. letsoni*, *Bythinella obtusa* (=*Amnicola emarginata*), *Pomatiopsis lapidaria*, *Valvata tricarinata*, *V. sincera*, *Campeloma decisum*, *Sphaerium striatinum*, *S. stamineum*, *Pisidium virginicum*, *P. compressum*, *P. abditum*, *P. ultramontanum*, *P. scutellatum*, *Alasmidonta calceola*, *Quadrula solida* (=*Pleurobema solidum*), *Q. coccinea* (=*P. coccineum*).[2]

The present writer collected fourteen species of shells in Queen Victoria Park, a number of years ago. Of these five species are not included in the foregoing lists—*Sphaerium solidulum*, *Unio luteolus* (=*Lampsilis luteola*), *U. clavus*, (=*Pleurobema clavum*), *U. occidens* (=*Lampsilis ventricosa*) and *Margaritana* (=*Alasmidonta*) *marginata*. In addition cyprids and chara may be mentioned as well as bones of mammoth found by Hall many years ago.

In all 36 species of shellfish have been obtained from the river sands and gravels near the Falls. Most of them still live in the river, but four of the species, *Lampsilis ventricosa*, *Pleurobema solidum*, *P. clavum* and *Alasmidonta marginata*, it is stated, are not found in the lakes but are Mississippi forms.[3] They must have reached Niagara river in a round-

[1] G.S.C., 1863, pp. 913-14.

[2] Bull. N.Y. State Mus., No. 45, Vol. 9, 1901, pp. 238-252.

[3] Stockholm Geol. Congr., Changes of Climate since the last Glaciation, pp. 386-7.

about way going north from the Chicago outlet, when it was in operation, through Lake Michigan and then south through Lake Huron, St. Clair river, etc., to Niagara Falls.

Whether the Mississippi shellfish should be held to imply a milder climate than the present is uncertain. The three unios mentioned and four others occur in the Toronto interglacial beds associated with trees now growing in Pennsylvania and Ohio, suggesting a climate 4° or 5° warmer than the present.[1] Twenty-one out of the forty interglacial molluscs occur also in the lists from Niagara.

As the last remnant of the Labrador ice sheet had disappeared from Ontario south of the Hudson bay watershed it is very probable that the Nipissing climate was as warm as the present, and it may have been warmer, as suggested by the unios.

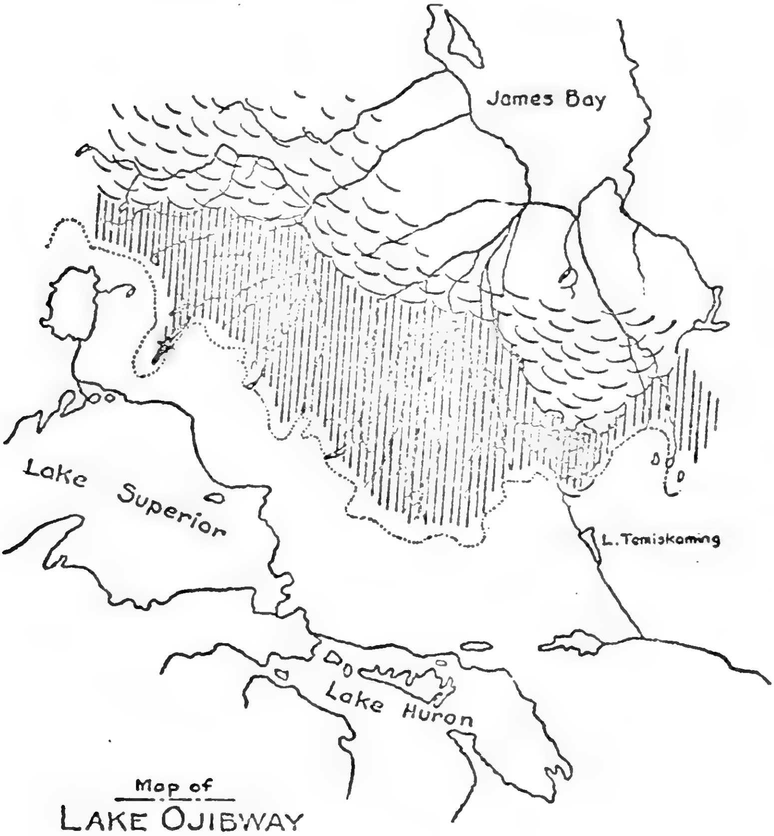
Lake Ojibway

The earliest and highest levels of Lake Algonquin reached 1,400 or 1,500 feet north and northeast of Lake Superior, as shown on previous pages; and it is known that there are at least three passes across the watershed toward Hudson bay which are very much lower than this. From west to east these are the passes at the head of Paint river, northeast of Lake Nipigon, at 1,046 feet (railway level); at Long Lake 22 miles from the north shore of Lake Superior, at 1,040 feet (aneroid); and at Missinaibi 45 miles northeast of Michipicoten bay, at 1,090 feet. It is evident that without some barrier Lake Algonquin at its highest stage would have extended indefinitely north of the watershed. This was prevented by the position of the ice front which stood at the divide or somewhat to the south of it, when Lake Algonquin began. Pitted plains in several places show the junction of ice and water.

As the ice retreated the land rose toward the northeast, but not rapidly enough to prevent Lake Algonquin, when

[1]Geol. Congr. Mexico, 1906, Interglacial Periods in Canada, pp. 15, 16; also Geol. Congr., Toronto, 1913, Guidebook No. 6, pp. 15-18.

its waters stood at about 1,100 feet, from extending bays across the lowest portions of the watershed. These bays seem to have been of short duration, since no well-defined



7. Map of Lake Ojibway

shore forms extend northward from the Algonquin beaches at these points. This was demonstrated for the Missinaibi col by Taylor, who decided, from lack of beaches north of the divide, that the Algonquin water, as it had been named

by Spencer, was not a part of the sea but a separate ice-dammed lake.[1]

The northward rise of the land presently lowered the Algonquin shore to 1,000 feet or less and the northern bays were cut off from the parent lake. Probably they formed small lakes between the retreating front of the ice and the watershed, and ultimately merged into a large body of water which the present writer has named Lake Ojibway, from the Indian tribe occupying the region.[2]

The presence of a great body of fresh water in the position just suggested for Lake Ojibway is undoubted, since its deposits form the wide "clay belt" of northern Ontario, covering, according to explorations carried out for the Government of Ontario, an area of 25,000 square miles. The clay belt shows in many places beautifully stratified clay in annual layers from a half inch to an inch or two in thickness. The clay deposits have an undefined limit toward the north, but on the south pass into sandy shallow water materials and sometimes show beach gravels indicating the shore of the lake. Unfortunately, the region i still only imperfectly explored and is largely forest-covered, so that up to the present the exact boundaries of the lake have not been mapped, and it may be long before this work is undertaken. Toward the west the clay belt ends northeast of Lake Nipigon; and toward the east extends far into the province of Quebec. Whether the whole area of clay should be included in Lake Ojibway is doubtful. M. E. Wilson thinks that the Quebec clays were laid down in a separate body of water, which he names Lake Barlow.[3] He is probably correct in supposing that a lobe of ice occupying the depression of Lake Timiskaming separated the two bodies of water, at least for a part of their existence, and whether they united for a time when this ice lobe was melted remains uncertain. It is very desirable that some one should go over the ground more thoroughly than has yet been attempted, particularly

[1] Am. Geol., Vol. XVII, 1896, p. 255.

[2] Bur. Mines, Ont., Vol. 18, 1909, pp. 284-293.

[3] G.S.C., Mem. 103, 1918, pp. 140-145.

in the Timiskaming region, where a number of problems remain to be solved.

The point of outlet of Lake Ojibway is not certainly known. It was believed by the writer, when the name was given to the lake, that the outlet was by the valley of Lake Timiskaming into the Ottawa, but if this lowest part of the southern edge of the clay belt was filled with ice some other channel must be sought for. The waters may have escaped southward along the edge of the ice, in which case the channel would be a shifting one, moving from west to east; or the outlet may even have been over the ice, at least for a time, so that no direct evidence of it would be left.

Stratified clay is found on both sides of Lake Timiskaming toward its northern end, reaching levels of 642 to 776 feet near Haileybury, New Liskeard, and Uno Park, and of 648 to 796 feet at Baie des Pères on the Quebec side. Farther south near the mouth of Montreal river sand and clay terraces were measured from 624 to 811 feet. The measurements were made partly with a hand level but mainly with an aneroid.[1] The clay beds were laid down probably in moderately deep water, but they are south of the watershed, which is at 935 or 940 feet, and cannot be considered as belonging to Lake Ojibway, though they are just like the Ojibway clays. It seemed probable at first that they were deposited in an extension of the Nipissing Great Lakes, whose outlet is only about fifty miles south of Montreal river where it enters Lake Timiskaming; but the finding by Gilbert, Taylor, and others of a channel draining the Nipissing Great Lakes into the Ottawa river at Mattawa, only 488 feet above the sea, seems to make this impossible.[2]

Johnston, repeating a measurement made by De Geer, puts the highest marine beach at 690 feet, near Kingsmere, eight miles northwest of the city of Ottawa, and suggests that a narrow arm of the sea extended to the head of Lake

[1]Bur. Mines, Ont., Vol. 9, 1900, pp. 177-8.
[2]U.S. Mon. LIII, p. 448.

Timiskaming; so that the clays were probably laid down in a northern fiord of the Champlain sea. There is no evidence that the water was salt, since marine shells have not been found in the Timiskaming region.

In accounting for the clay terraces above 690 feet it is necessary to recall the fact that the marine water level rises toward the north at the rate of three feet per mile.

The suggestion just mentioned does not solve all the problems of the relations between Lake Ojibway and the Nipissing Great Lakes, for the North Bay outlet of the latter lake is given by Taylor as 698 or 700 feet, and since it is 50 miles north of the Kingsmere parallel, differential elevation would carry the marine level 140 feet above it. Apparently the North Bay outlet must have been opened considerably later than the highest marine stage at Ottawa, when elevation of the land had proceeded to the extent of more than 140 feet; and we must assume that ice still occupied the Nipissing-Timiskaming region when the highest marine level occurred at Ottawa.

To return to Lake Ojibway, the retreat of the ice on the north of the watershed at length gave an escape for its waters toward Hudson bay, and the lake came to an end. It was probably the most variable and short lived of the glacial lakes of Ontario. When it ended Hudson bay reached much farther south than at present, at one point coming within 150 miles of Lake Superior, but there is no evidence that salt water encroached on the lake deposits.

Estimates have been made of the time covered by Lake Ojibway by determining the annual layers of clay in its deposits. Baker states that the clay reaches twenty-six feet in a railway cutting near Ground Hog river and that the layers are from a half inch to occasionally three inches in thickness;[1] while M. E. Wilson estimates the clay beds of Lake Barlow as averaging less than twenty-five feet thick, and gives the maximum number of beds counted as 250. He suggests that this represents the number of years

[1]Bur. Mines, Ont., Vol. 20, 1911, pp. 231-2.

during which a given point was covered by the lake.[1] W. A. Parks found a thickness of 40 or 50 feet on the shores of Night Hawk lake;[2] and the present writer estimated the thickness near Matheson at about 50 feet. Railway engineers report a still greater thickness found in bridge work near Cochrane. If the layers average an inch in thickness, fifty feet would mean 600 years as the minimum duration of the lake.

The fauna of Lake Ojibway must have been acquired from the bays of Lake Algonquin, which crossed the watershed toward the end of the history of the latter lake and the beginning of the former. Only one record is available as to its character. M. B. Baker reports *Amnicola porata, Lymnaea elodes, L. pallida, L. umbilicus, Planorbis bicarinata, Succinea obliqua, Valvata tricarinata,* and a land snail, *Helix striatella;* but does not mention the locality where they were found.[3]

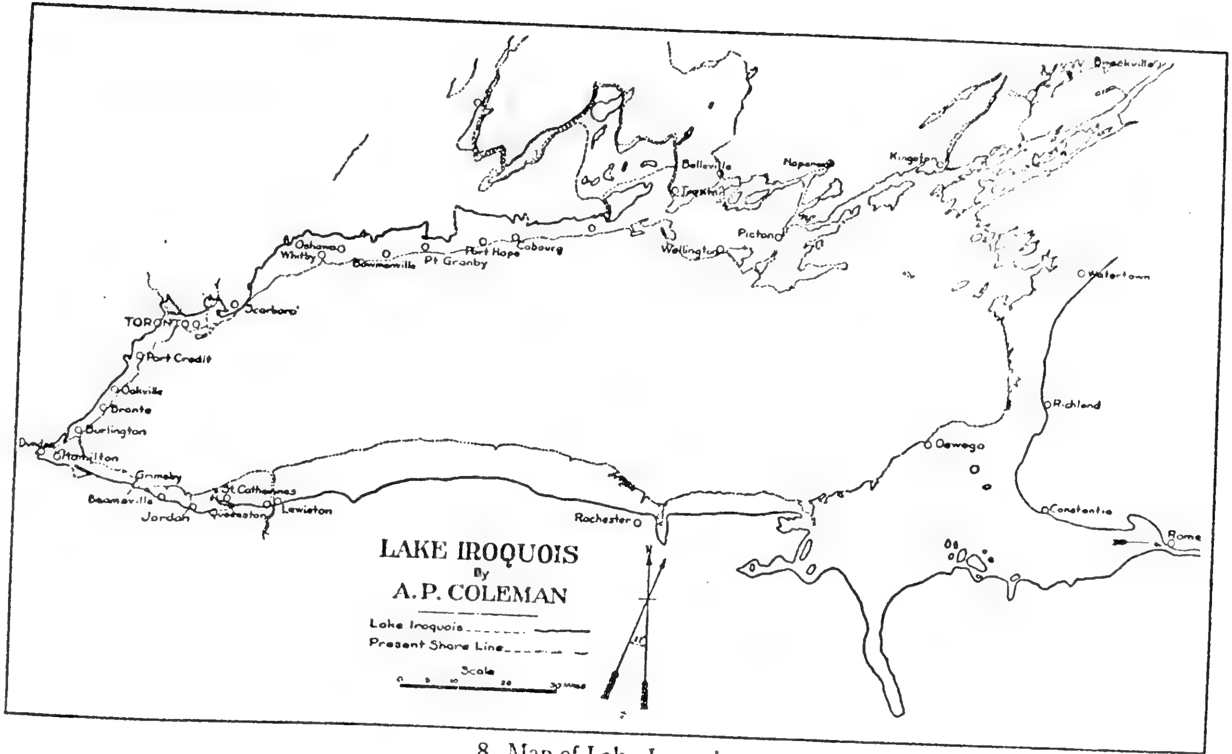
In all probability the Abitibi lakes and other smaller sheets of water which have succeeded Lake Ojibway inherited their inhabitants from it and ultimately from Lake Algonquin.

The shellfish listed above do not indicate more severe conditions than the present. The northern shore of melting ice was perhaps largely covered with débris and seems to have had little effect in chilling the water of the lake, especially on its shallow southern side.

Waters of the Ontario Basin

Lake Warren, one of the earlier stages of water, occupied the southern part of the Huron basin, the whole of the Erie basin, and extended along the south side of the Ontario basin; though most of the actual area of Lake Ontario was still filled with ice. The outlet of Lake Warren is considered to have been across Michigan to Lake Chicago and ulti-

[1] G.S.C., Mem. 103, 1918, pp. 141-5.
[2] Bur. Mines, Vol. 8, 1899, p. 175.
[3] *Ibid.*, Vol. 20, 1911, p. 233.



8. Map of Lake Iroquois

9. Iroquois Shore, Scarborough

mately to the Mississippi. As the Ontario lobe of ice withdrew, lower outlets were opened toward the east, at what has been called the Lake Dana stage, and drainage through the Mohawk valley to the Hudson began. Finally the waters were lowered still further and Lake Iroquois came into existence. An elaborate series of beaches and outlets has been worked out in the state of New York, especially by Fairchild, and those interested in the matter will find reports and maps of the different stages in Bulletins of the State of New York.[1]

Lake Iroquois

Much the most long-lived and interesting of the bodies of water occupying a part or the whole of the Ontario basin is Lake Iroquois, first described by Gilbert in New York and by Spencer in Ontario, the appropriate name having been given by the latter writer. This was the first of the glacial lakes to be defined, and it has furnished the criteria by which the others have been studied. The abandoned shores of Lake Iroquois were the first on which the differential elevation of the beaches toward the north was demonstrated.[2] The shore of Lake Iroquois has been more completely and certainly worked out and mapped than that of most of the other glacial lakes, and the part within the province of Ontario has been studied in detail by the present writer.[3]

Lake Iroquois began as a narrow strip of water to the west and south of the ice lobe, but rapidly increased in area as melting proceeded until the whole Ontario basin was set free, when a considerably larger area was occupied than that of the present lake. The west half of Lake Iroquois follows closely the outline of Lake Ontario, but usually at a distance of from two to ten miles from the present shore.

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[1]Bull. 106, 1907, Glacial Waters in the Lake Erie Basin; and Bull. 127, Glacial Waters in Central New York.

[2]Falls of Niagara, G.S.C., pp. 277, etc.

[3]Bur. Mines, Ont., 13th An. Rep., 1904, pp. 225-244; also Bull. Geol. Soc. Am., Vol. 15, 1914, Iroquois Beach in Ontario, pp. 347-369.

At Scarborough Heights the Iroquois beach has been cut away for half a mile by the present lake. At Trenton in Ontario and at Sodus, New York, Lake Iroquois spread to the north and south far beyond the Ontario limits and reached a width of nearly 100 miles from the northwest to southeast. At the east end of the basin the northern shore is wanting for a distance of about 70 miles, where the ice barrier stood.

With the exceptions just stated, the Iroquois beach is as complete as that of Ontario, though cut through at various places by rivers. From Quay's Siding, about seven miles north of Port Hope, to Hamilton, and on the south side to Rome, N.Y., the beach is continuous, but to the northeast of these points it is split up into several strands which tend to spread apart toward the north. In reality the line from Quay's to Rome is a pivot about which the water level swung, rising in a direction N. 20° E. and sinking in the opposite direction. To the southwest of Quay's the earlier beach levels are buried more and more deeply under later beach deposits. This is shown at the reservoir park in Toronto, where beach materials go down 70 feet, and still better at the Desjardins canal cut near Hamilton, where undoubted beach deposits reach a depth of 83 feet.

It is evident that an important change of level was going on throughout the life of Lake Iroquois, the northeastern end rising either continuously or at frequent intervals. The differential elevation of the northeastern end of the beach as compared with the southwestern amounts in Ontario to 460 feet. At Hamilton, the lowest point of the latest stage of the beach, the present level is 362 feet above the sea, and at an old island near West Huntingdon, about twenty-seven miles north of Belleville, the beach is more than 744 feet above sea level.

Climate and Life of Lake Iroquois

The beaches of Lake Iroquois have proved fossiliferous near Hamilton and at Toronto. The splendid gravel bar extending north from Hamilton toward Burlington has supplied many animal remains including mammoth, wapiti,

10. Iroquois Gravel Bar, East Toronto

buffalo, and beaver.[1] Mammoth ivory and bones are frequently found in gravel pits and brickyards west of the bar also. Fragments of wood determined by Penhallow as *Larix americana* and *Picea* (probably *nigra*) have been found 30 feet below the surface in Hamilton, suggesting a cooler climate than the present.[2]

At Toronto many horns of caribou and a few bones of elephants including a mammoth tooth have been found in gravel bars; and also a number of shellfish—*Campeloma decisum*, *Pleurocera*, *Sphaerium*, and fragments of *Unios*, all still living in Lake Ontario. The mammals were animals that could endure a cold climate. At present the caribou ceases about 150 miles north of Toronto, and the mammoth had a heavy coat of hair. It is probable that the climate was somewhat colder than now, though not Arctic. As in the lakes previously described, the barrier of ice forming the shore toward the northeast did not prevent the waters from being inhabited. It may be that certain crumpled Iroquois sands near Toronto have been pushed by floe ice, but there is no evidence that icebergs floated on the lake, such as might be expected under glacial conditions.

Admiralty Lake

As the ice withdrew from Covey hill north of the Adirondacks, lower outlets than that of the Mohawk valley were opened, and Lake Iroquois came to an end.[3] The successive outlets were of relatively brief duration and only feeble records have been left in the way of beaches. One of the stages has been named Lake Frontenac, since it was held up by an ice barrier resting on the Frontenac axis of Precambrian rocks, but no definite shore line has been identified with it.[4]

Formerly it was supposed that as soon as the ice withdrew from the Thousand Islands the Ontario basin was

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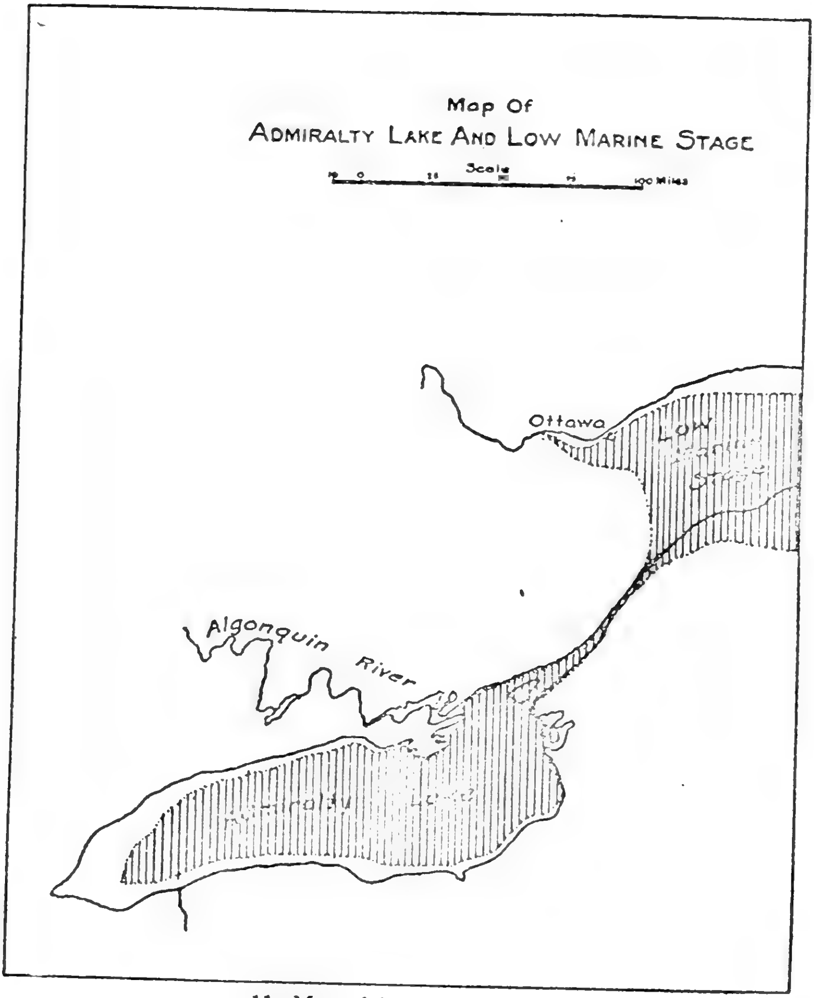
[1]Geol. Can., 1863, p. 914.
[2]Bull. Geol. Soc. Am., Vol. 15, 1904, p. 366.
[3]Fairchild, N.Y. State Mus. Bulls. 209 and 210.
[4]Taylor, U.S. Geol. Sur. Mon., LIII, p. 445.



11. Map of Admiralty Lake

flooded by the sea. The continuation of the Algonquin river channel down the Trent Valley, as mentioned on a former page, makes this view untenable. The base to which the valley was cut must have been somewhat below the level of Lake Ontario, and soundings in the Bay of Quinte suggest a possible delta near the mouth of the river, which may have been formed by Algonquin river or perhaps by the present Trent river. Some soundings lower down the Bay of Quinte reach 100 feet, perhaps in an ancient deep channel now partially filled; but there is no certainty that Algonquin river extended much below the present water level.

At that time the sea must have stood much lower than now, probably because a large amount of ice still remained unthawed upon the continents. It has been estimated by Drygalski[1] and Penck[2] that at the maximum of glaciation the amount of water withdrawn from the sea to form ice caps would lower it 150 metres. This is perhaps an over-estimate, and Daly's later determination of from 50 to 60 metres seems more probable.[3] To what extent the world's ice caps had shrunk when Lake Iroquois ceased to exist one can only guess. If we assume that only one half of the ice still remained, the ocean would still be 80 or 100 feet lower than now on Daly's assumption and 250 feet according to the German estimates.

The last beach in the Ontario region was probably formed much later, after most of the ice had melted, restoring nearly the full volume of water to the sea. At Trenton, where the Algonquin channel reaches the Bay of Quinté (level of Lake Ontario), there are several beaches, the best marked, at 78 feet above the present lake or 324 feet above the sea, probably representing the highest marine shore. If the sea was 80 or 100 feet lower when the channel was excavated, the basin must have been below the present

[1]Zeit. Geo. Erdkunde, Berlin, Vol. 22, p. 274.
[2]Morphologie der Erdoberflaeche, p. 660.
[3]Proc. Am. Acad. Sc., Vol. 51, p. 173.

lake level and therefore must have contained an independent lake.

Two other factors which probably modified the conditions of the time should be referred to. The great mass of ice still remaining to the north must have exerted some attraction on the water, but probably would not raise its level more than fifteen feet according to an estimate by Woodward,[1] so that the depression of sea level might be counteracted to this extent. On the other hand, the outlet at the Thousand Islands was probably blocked by drift materials left by the ice sheet which had just vanished, presenting a barrier between the lake and the sea. At first this probably held up the water of the Ontario basin at least 25 feet, as shown by drift deposits at Gananoque; but later so easily attacked a barrier must have been removed by the strong river flowing east. The amount of tilting of the old water levels in the eastern part of the Ontario basin is two feet per mile, as will be shown later; and Trenton is 25 miles from the parallel of Kingston, where the outlet was, along the direction of tilt. The water level at Trenton must therefore have been 50 feet below the present when the twenty or thirty feet of drift filling the channels among the islands were removed, and this must have been quickly accomplished by a river as large as the St. Lawrence.

The body of fresh water occupying the Ontario basin when the Algonquin river reached the lowest point in its valley may be called the Admiralty lake from the beautiful Admiralty group of islands, between which its waters flowed seaward. Though its outlet must have been much the same as that of the present lake, the old shore of Admiralty lake is now below water, because of the northeastward uplift of the region, and its western end must have been about twenty-five miles east of Hamilton where the present lake has a depth of 220 feet. The St. Lawrence river was probably less than fifty miles long at this time.

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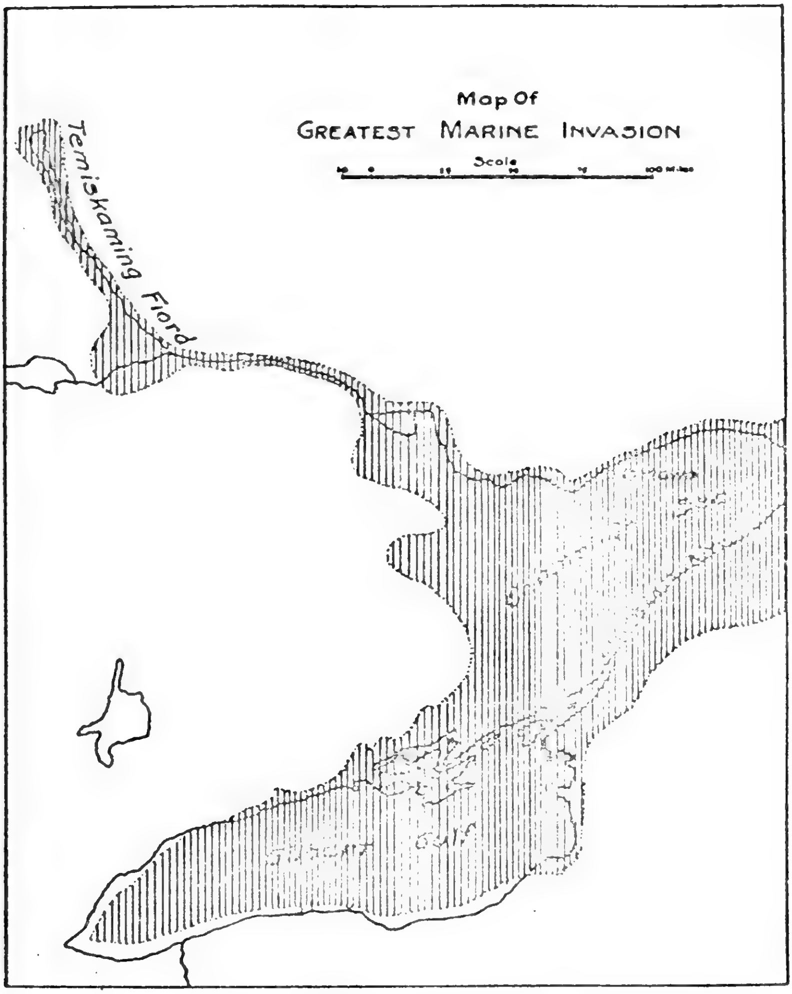
[1]U.S. Geol. Sur., Bull. 48, 1888.



12. Map of Maximum Marine Invasion

Marine Stages in Eastern Ontario

As the climate grew milder the water removed from the ocean to form glaciers was returned to it and the level rose to correspond. All the lower part of eastern Ontario was flooded by what has been called the Champlain sea, really an extension of the Gulf of St. Lawrence. This is proved by many beds of clay, sand, and gravel charged with shells of *Macoma*, *Saxicava*, *Mytilus*, and other molluscs, though no continuous beach has yet been mapped across Ontario. The upper limit of the marine invasion has been determined in some places and it is certain that it rises toward the north.[1] East of Brockville there is a beach with shells of *Macoma* rising 331 feet above present sea level, and marine shells occur also in the town itself; but west of Brockville none have been found. Fairchild has recorded higher marine terraces near Clayton in the state of New York, and has given the name Gilbert gulf to the extension of the marine water level into the Ontario basin.[2]

Though no marine beaches have been traced past Brockville, it is almost certain that shore forms in the Bay of Quinté region represent the westward extension of these levels. In the state of New York such a shore occurs from point to point as far west as Oswego, where it is lost beneath Lake Ontario. On the north side of the lake a good beach hand-levelled at Waupoos, near the east end of the county of Prince Edward, is at 340 feet. The best beach near Trenton, as already mentioned, stands at 324 feet, and other beaches occur at Brighton, Colborne, Cobourg, and Port Granby five miles east of Newcastle. At the last point there is a terrace 274 feet above the sea, or 28 above Lake Ontario. Beyond Port Granby it has not been found,

[1]Marine and Freshwater Beaches of Ont., Bull. Geol. Soc. Am., Vol. 12, 1901, pp. 129-146; also Late Pleistocene Oscillations of Sea Level, Johnston, Geol. Sur. Can., Mus. Bull. 24; and Champlain Sea in L. Ont. Basin, Mather, Jour. Geol., Vol. XXV, 1917, pp. 542-554.

[2]Bull. Geol. Soc. Am., Vol. 17, 1907, p. 112; also N.Y. State Bull., Nos. 209-10, 1919.

probably because it has been cut away by the waves of the present lake.[1]

From Waupoos to Port Granby there is an average decline of two feet per mile in the direction of tilt, and if this continued toward the southwest the old shore would sink beneath Lake Ontario a little west of Whitby. At the same rate of decline the ancient gulf would end about ten miles east of Hamilton. As no fossils of any kind have been found on the shores of Gilbert gulf, while sea shells are widely distributed and often very numerous eastward from Brockville, one may conclude that its waters were kept fresh by the inflow of Niagara river.

The changes of water level succeeding Admiralty lake have been attributed, thus far, to the continuous melting of the ice sheets restoring water to the sea. In reality, as Mather[2] and Johnston[3] have suggested, there was a complication due to the northward rise of the land brought about by relief from the load of ice. As the sea was filling up by the melting of the ice there was also a tendency for the whole region to rise higher above sea level. Probably the rise of the land lagged considerably behind the removal of the load; so that the sea had time to leave its mark in shore deposits and high level beaches before the general elevation caught up with it.

Ultimately, the Thousand Islands region rose above the level of the sea, and Gilbert gulf was replaced by Lake Ontario, the change being probably a gradual one. The northeastward rise continued till the lake stood 246 feet above the sea; but within historic times there appears to have been no further elevation.

The outlet rose faster than the southwest end of the lake, so that all the rivers toward the west have their lower ends drowned, as illustrated by the depth of Niagara river near its mouth and as may be seen in the meanders occupied

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[1]Bur. Mines, Ont., Vol. 13, 1904, p. 238, etc.
[2]Jour. Geol., Vol. XXV, pp. 542-554.
[3]G.S.C., Bull. 24.

by dead water on the last two miles of the Humber. Probably, too, the deep water behind Toronto island and Burlington beach near Hamilton is due to the continued building up of beach materials as the water was backed up toward the west. There is a great similarity between the present Burlington bar cutting off Hamilton bay and the splendid bar of Lake Iroquois rising 116 feet above the present water level and cutting off a vanished Dundas bay of the ancient lake. Both have been caused by differential elevation that continued for thousands of years.

Life and Climate of the Marine Stage

Though the fresh water deposits of Gilbert gulf afford no evidence of life, the brackish and salt water beds farther east and north are very rich both in individuals and species. The marine forms include pelecypods, gastropods, sea acorns, starfish and sponges, the caplin and two other kinds of small fish, and seals, dolphins and whales. Concretions in the marine clay at Green's creek near Ottawa have supplied a few feathers of unknown birds and some bones of a duck, as well as a chipmunk and several beetles, the latter extinct according to Dr. Scudder.

Almost all of the aquatic animals discovered in the marine beds still survive in the Gulf of St. Lawrence, and suggest a cooler climate than that of eastern Ontario at present. This may be accounted for by supposing that the entrances to the enlarged Gulf of St. Lawrence were broadened and deepened to the north and south of Newfoundland, allowing easier access for ice floes and bergs than at present. So large a body of cold water as the Champlain sea probably had a chilling effect upon the climate of its shores.

A number of plants have been obtained, including sea weeds, marsh plants and several trees, such as poplars, yellow birch and sugar maple. All of the trees still live in the Ottawa valley, where most of the fossil species have been collected. Sir William Dawson believed that the plants indicate a somewhat cooler climate than that of Ottawa at present, but milder than that of Labrador.

The *Geology of Canada*,[1] Dawson's *Canadian Ice Age*,[2] and writings of Ami[3] and Johnston,[4] may be consulted as to the inhabitants of the Champlain sea in eastern Ontario. The lists include not only species from eastern Ontario, especially the Ottawa valley, but also animals and plants from Montreal and points on the lower St. Lawrence.

Relations of Marine Levels in Eastern Canada

Dawson explained most of the glacial phenomena of Ontario and Quebec by assuming that the watershed between the St. Lawrence system and Hudson bay was lowered sufficiently to open a broad strait between the Champlain sea and an enlarged Hudson bay or sea. Through this channel he supposed that a powerful current like that off the coast of Labrador swept icebergs and floe ice from the Arctic regions, lowering the temperatures of all eastern Canada. He believed that the boulder clay of the Pleistocene was formed by floating ice and not by a Labrador ice sheet moving toward the south. This view is no longer held by any glacial geologist; yet it is of interest to enquire into the extent of the marine invasion to the north and the south of the watershed.

It is known that Hudson and James bays extended much farther south in late Pleistocene times than at present. Marine shells have been reported 450 feet above the sea and 150 miles southwest of James bay at the forks of the Albany and Kenogami rivers;[5] and also on Soweska river, a branch of the Missanabie river, 128 miles southwest of James bay.[6] None have been found, however, directly south of the bay; and it is probable that the ice withdrew from the southwest side of Hudson bay sooner than from the James bay region, allowing a narrow tongue of sea to come

[1]G.S.C., 1863, pp. 916, etc.

[2]Can. Ice Age, 1893, pp. 18, etc.

[3]Contributions to Pal. of Post-pliocene, Ottawa Naturalist, Vol. XI, pp. 22-26.

[4]G.S.C., Mem., 101, pp. 16-34.

[5]Robert Bell, G.S.C., Vol. 1871-2, p. 112.

[6]J. Mackintosh Bell, Bur. Mines, Ont., 13th Rep., Part 1, p. 164.

in between the watershed and the ice front. No gravel beaches nor shore cliffs have been described in the region and wave action was apparently only slight.

It is generally held that the sea rose to 500 feet on the southwest side of Hudson bay; while Low gives its elevation at one place on the east side as 710 feet, and mentions the interesting fact that seals live in Seal lake nearly 800 feet above the sea and nearly 100 miles inland.[1] They probably reached the lake when the sea was at its highest level. It is possible that the sea encroached even farther on the land, since the highest marine beaches usually do not enclose shells. Until careful study has been given to the Pleistocene features of the Hudson bay slope the exact southern limit of marine invasion will not be known. If we assume that it reached the 500 feet level, White's Relief Map of the Dominion shows its most southerly point to be on Abitibi river about 130 miles northwest of the head of Lake Timiskaming.

Turning now to sea levels south of the Hudson bay watershed, we find that here also there are no definite shore lines, though there is reason to believe that marine waters reached much above the highest known deposits containing sea shells. De Geer and Johnston report a beach at Kingsmere near Ottawa at 690 feet, as mentioned before, and not far off Johnston has estimated the northward rise of one of the beaches as amounting to three feet per mile. This rate of deformation is more rapid than the two feet per mile found farther southwest near Lake Ontario, but is probably correct, since all the old beaches of the region rise more rapidly toward the northeast or north.

We may apply this rate of rise to the fiord-like bay reaching to the head of Lake Timiskaming. The distance north of the parallel of Kingsmere is 133 miles, which implies a rise of 399 feet. If this is added to the height of the beach at Kingsmere, 690 feet, it gives a sea level of 1,089 feet at

[1]G.S.C., Vol. IX, 1896, p. 13 L and p. 42 L.

the most northerly point reached by an arm of the Champlain sea.

Now the watershed between Lake Timiskaming and Lake Abitibi is 935 or 940 feet above sea level, and the pass used by the T. and N. O. railway, some distance to the west, is at 1,044 feet.

From these figures it is evident that if no obstruction intervened, the broad strait suggested by Dawson must have been a reality. However, the discrepancy between the highest probable sea levels on the two sides of the watershed is so great that the northern invasion of the sea must have occurred much later than the southern one, in fact after the whole region had risen some hundreds of feet because of the relief from the load of ice. The southern side was the first to be unloaded and had already risen greatly before the northern side began to be set free.

It may be considered certain, then, that the Hudson bay watershed was never submerged and that no strait turned Quebec and Labrador into an island. The isthmus connecting northern Quebec and northern Ontario was 130 miles wide at its narrowest point.

Faunal Relations in the Lakes of Ontario

There seems to have been no break in the continuity of the fresh water fauna between Lake Iroquois and Lake Ontario, in spite of the marine stage which has just been mentioned. Lake Iroquois inherited its inhabitants, through some short lived intervening stages, from Lake Warren, which had its outlet into the Mississippi. Ultimately, then, Lake Ontario has obtained its fauna from the Mississippi waters, which escaped glaciation because of their position south of the margin of the ice sheets during their different advances. Apparently some of the Mississippi forms, perhaps for climatic reasons, failed to reach Lake Ontario, or else have found conditions unfavourable in later times, since a number of the Mississippi shellfish which lived in the Niagara

river when the Falls was at the Whirlpool are not known from Lake Ontario.

From the complicated history of the Great Lakes and their predecessors which has been outlined in this paper it will be seen that all of our Ontario Lakes, small and large, even to the north of the Hudson Bay watershed, have in one way or another had connections, and that ultimately the fluvial and lacustral faunas inhabiting them have come from the Mississippi waters, sometimes, however, in very roundabout ways. The Mississippi and its tributaries supplied a harbour of refuge when the northern part of the continent was ice-covered and lifeless, and colonized the lakes and rivers which arose after the melting of the ice sheets. If the ice had reached the Gulf of Mexico, so that no place of refuge remained for fresh water life, our lake and river fauna must have been meagre indeed. Anadromous forms coming from the sea, like the salmon which once spawned in the streams tributary to Lake Ontario, might in time have become "land locked" varieties or species, but I am not aware that this has been the case. Probably the incoming of the Mississippi fauna filled all the positions available.

The connection between the waters of the Great Lakes and Rainy Lake, Lake of the Woods and the Manitoba Lakes appears to be limited to the drainage of Lake Agassiz and of Lake Warren, etc., into the Mississippi. Here the mode of communication seems very devious, but sufficient in the lapse of hundreds or thousands of years to account for the identical or closely related species found in these distinct drainage systems.

There are a few cases of lakes on the northern watershed having two outlets, one to the Great Lakes, the other to James bay; but I am not aware of any two-outlet lakes on the height of land between the Great Lakes and Seine river to connect up the St. Lawrence drainage system with that of Nelson river, so that the connections with the Mississippi must be considered to account for the species common

to the two drainage systems, unless some mode of transport over land or through the air can be assumed.

Temperatures in Deep Lakes

A comparison of the fauna of the glacial lakes, so far as known, with that of our present lakes which have no permanent ice on their shores, shows little difference between them. Practically all of the species still live in our waters. This comes as a surprise when one recalls that the early lakes had a vast sheet of ice to the north forming their shores for many miles. Why should these subarctic waters be inhabited by the same species as live in our temperate climate lakes? The presence of caribou and fur clothed elephants and of black spruce and tamarack on the shores of Lake Iroquois suggests a colder land climate than the present at Hamilton and Toronto, as one might expect when one-third of the continent was still covered with ice; but the aquatic life shows no such difference.

To explain this requires a consideration of the peculiar physical properties of water. Unlike other liquids water does not contract uniformly ,as the temperature is lowered to the point of consolidation. After contracting steadily to 39.2 degrees (Fahr.) water begins to expand and this continues for seven degrees to the freezing point, when it changes to the solid state and suddenly expands about one eighth of its volume. Other liquids contract all the way and congeal to a solid which is heavier than the liquid. For this reason cold water floats on warmer water and ice floats on cold water. If water followed the usual law when cooled below 39°.2 (4° Cent.) it would sink to the bottom instead of remaining at the surface, and at length the whole body of water would reach the freezing point of 32° (0° Cent.), when ice would be formed, and being heavier than water, would accumulate at the bottom. During a long winter the whole lake would be transformed into a solid block of ice, in which no life could survive. Some of the surface ice would thaw in summer, but in deep lakes the lower parts would be perpetually frozen.

The anomalous physical property of water just mentioned permits the lake to cool to the point of greatest density, after which further cooling causes the water to grow lighter so that it remains at the surface and is finally changed into ice, which floats and forms a non-conducting protection to the water beneath. The importance of this for the inhabitants of lakes is manifest. With winters as long and cold as those of our region the whole volume of water in a lake must reach the temperature of greatest density, and in deep lakes the lower portions must remain at this temperature all the year round.

Temperatures at Different Depths in the Lakes

Through the kindness of Dr. W. A. Clemens the following data have been collected on this subject:[1]

Lake Ontario—W. A. Clemens, Oct. 3, 1922.

Depth	*Temperature*
Surface	67.6 Fahr.
10 fathoms	60.4 "
20 fathoms	47.0 "
30 fathoms	40.6 "
50 fathoms	39.2 "
62 fathoms (Bottom)	39.2 "

These records were obtained at a point about half way between Toronto and the mouth of the Niagara River.

Lake Erie—W. A. Clemens, off Merlin, Ont., Aug. 3, 1920 (bottom temperature), 5 and 6.6 fathoms 52°.5.

Lake St. Clair—Prof. J. E. Reighard—A Biological Examination of Lake St. Clair, Sept., 1893. 64°.4 to 69°.8 (little difference between bottom and top—not more than 1°).

Georgian Bay—A. T. Drummond, Can. Rec. Sc., Vol. IV, pp. 77-85, and Vol. V, pp. 13-19:

Aug. 20, 1886, Bottom 31 fathoms 39°.5
Bottom 47 fathoms 38°.25

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[1]As most of the data are in the form of Fahrenheit degrees, with depths in fathoms, it has been decided to recast the others to make them comparable.

Georgian Bay (*Continued*)—Bottom 42 fathoms 37°.75
July 10, 1889, Bottom 70 fathoms 38°.75
Sept. 8, 1889, Bottom 63 fathoms 39°
Surface varied from 59°.75 to 68° Fahr.

July 27, 1888,	Surface	60°.2
	10 fathoms	45°.7
	20 fathoms	41°.4
	35 fathoms	41°
	66 fathoms	39°.5

In Parry Sound Harbour, 1890:

May 2,	Surface	36°.2
	Bottom, 62 fathoms	35°.7
Aug. 23,	Surface	61°.7
	Bottom, 48 fathoms	39°.2
Oct. 15,	Surface	53°.5
	Bottom, 57 fathoms	39°

Lake Huron—Dr. Walter Koelz,[1] Department of Zoology, Univ. of Mich.:

Sept. 12, 1917,	Off Alpena,	65 fathoms	Bottom	39°.2
" 17,	Off Alpena,	15 fathoms	Bottom	57°.2
" 18,	Off Alpena,	60 fathoms	Bottom	39°.2
" 29,	Cheboygan,	35 fathoms	Bottom	39°.2
" 13, 1919,	Alpena		Surface	60°.1
" 13,	Alpena	35 fathoms	Bottom	41°.7

Lake Michigan—Prof. H. B. Ward—Biol. Exam. in Traverse Bay Region—gives 98 records of surface and bottom temperatures taken during August, 1894:

Highest Surface Temp., Aug. 15		70°
Bottom Temp., Aug. 15,	6.2 fathoms	68°
Lowest Bottom Temp., Aug. 16,	61.3 fathoms	39°.5
Lowest Bottom Temp., Aug. 18,	72.5 fathoms	39°.5
Surface Temp. on both dates		64°.9

Lake Superior—Dr. Walter Koelz:

Aug. 24, 1921, Off Ontonagon	Surface	64°.6
Aug. 24, 1921, Off Ontonagon	60 fathoms	39°.2
Aug. 25, 1921, Off Ontonagon	34 fathoms	41°

[1]Kind acknowledgment is hereby made to Dr. Koelz for permission to publish these records.

Drummond in Can. Rec. Sc., Vol. IV, pp. 78, states that Hind found the surface of Lake Superior on 30th July, at noon, as low as 39°.5 fifty miles from land.

Lake Nipigon—Dr. W. A. Clemens:

July 9, 1921		Surface 71°.6
July 9, 1921	23.2	fathoms 39°.5

(At deepest point, 67 fathoms, temp. probably would be 39°.2)

Aug. 29		Surface 62°.8
Aug. 29	45	fathoms 40°.1

(At deepest point, 67 fathoms, temp. probably would be 39°.2)

It will be seen that the data recorded are very unequally distributed, and it is probable that the bottom temperatures given by Drummond for Georgian bay and Lake Huron, reaching as low as 37°.75 and 35°.7 Fahr. are an error and should not be lower than the point of greatest density, 39°.2 (4° Cent.), or making correction for the expansion of mercury at a depth of 60 fathoms, 38°.5 Fahr.

From the tables just given, it will be seen that the temperatures of deep water in the Great Lakes are about 39°.2, as might be expected in a region having cold winters. With reference to Lake Superior it may be mentioned that the present writer found a temperature of 40° at the surface near the north shore in July, 1899, and that Professor Ramsay Wright states that the temperature has been observed to be 39° Fahr. (=4° Cent.).[1] Shallow lakes, such as Erie and St. Clair, no doubt get above this temperature in summer, but we must think of our deep water fish as living most of their lives in water constantly at 39°.2 (4° Cent.), though they may come up to shallower and warmer levels to spawn.

Toward the close of the ice age, when the glacial lakes came into existence, it is probable that their waters also were at the temperature of greatest density, and that the salmon trout and whitefish would find conditions as con-

[1]Rep. Ont. Game and Fish Commission, 1892, p. 425.

genial as in the cold depths of Lake Ontario or Lake Huron or Superior at present. The climate of these deep lakes may not have varied appreciably during the thousands of years since their basins were freed from ice; though the climate of their shores must have changed from subarctic, suitable for the reindeer and the hairy mastodon, to the present temperate conditions.

Nevertheless, there are difficulties in accounting for the deep water fauna, since all the basins were filled with ice and the Mississippi south of the glaciated region has no lakes at 39°.2 in which the deep water fish could take refuge. It may be, however, that the Mississippi of glacial times had much colder water, most of it derived directly from the melting ice front, in which they found themselves at home in spite of its shallowness. The Mississippi must have been muddy, or at least milky, during the many thousands of years when it was draining the glaciers. Whether the animals of the clear lakes could accommodate themselves to muddy river water is a point for biologists to settle. The fauna specialized for the deep, clear, cold water of the Great Lakes must have found the conditions in the Mississippi much less favourable than the shallow water species.

Time Relationships as Shown by Niagara

It is of interest from several points of view to obtain an estimate of the length of time required for the various events outlined in the history of the Great Lakes region. The chronometer usually relied on to measure the time since the Glacial period is the cutting back of the gorge of Niagara from Queenston heights to the present falls, a distance of nearly seven miles. If the length of the gorge is known, and the rate of recession can be estimated, it seems a simple matter to determine the time since Niagara began its work, *i.e.*, since the ice retreated far enough to allow the river to plunge over the escarpment. The length is known and the rate of retreat of the falls since the first accurate survey, in

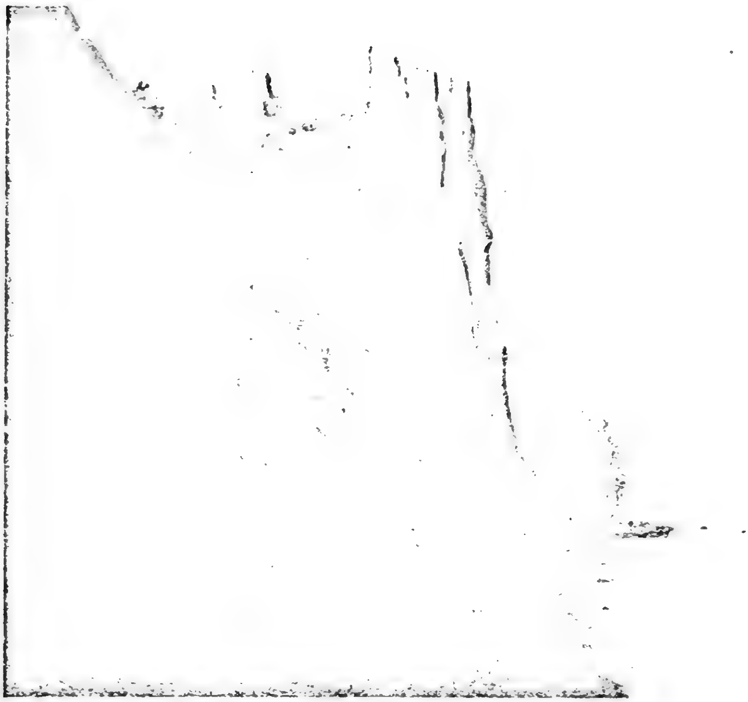
1842, has been estimated by Spencer at 4.2 feet per annum[1] and by Taylor at 4.5 feet per annum.[2] By simple division the result is 8,000 or 9,000 years as a round number; but unfortunately it cannot be assumed that the recession has been uniform, since it is known that the volume of water passing over the falls has varied greatly. At times the volume may have been greater than at present, since the natural drainage of the area was augmented by rapid melting of the ice sheet; but at other times the waters of the upper lakes were drawn off by lower outlets, through the Trent and the Mattawa channels, leaving only the drainage of the Erie basin, probably 15 per cent. of the existing flow. There were, then, two periods when the amount of water was seriously cut down so that the attacking power of the falls was greatly reduced. The times of increased and diminished flow, with other variations in conditions of less importance, are more or less completely recorded in the changing width of the ravine below the falls. The features shown in the gorge may be correlated with the known history of the lakes and their drainage channels, and thus a time table may be worked out for the cutting of its wider and narrower parts. This was attempted by Spencer, who studied the problem carefully and concluded that the total time consumed was 39,000 years.[3] Taylor has repeated the calculation with more complete knowledge of the history of the lakes and makes a less positive statement of the age of the falls which he thinks lies between 20,000 and 35,000 years.[4] He divides the work into five stages, during two of which, when Lake Algonquin drained through the Trent valley, and when the Nipissing Great Lakes had their outlet through the Mattawa valley, the recession must have been slow because of the small amount of water passing over the falls. The most certain part of the process is naturally the latest, since present conditions have been operative; and he makes the

[1]Falls of Niagara, G.S.C., p. 342.

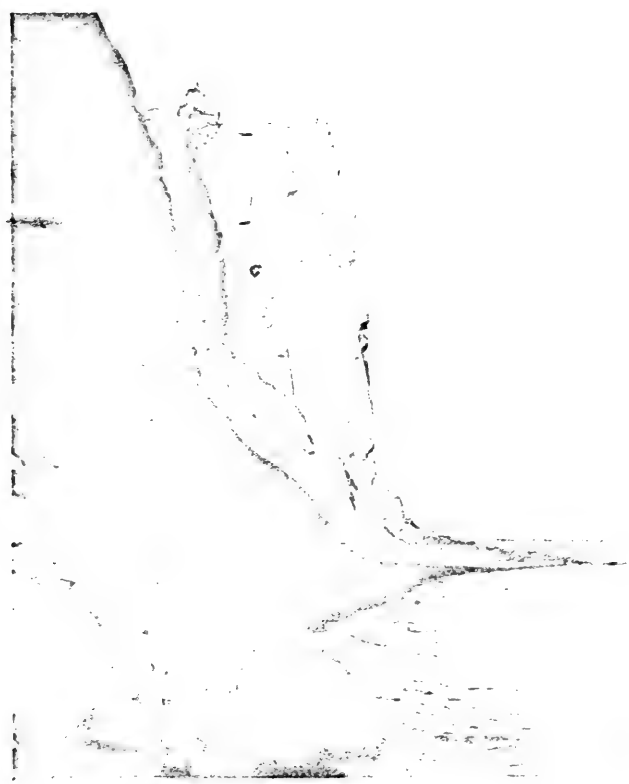
[2]Niagara Folio, U.S. Geol. Sur., No. 190, p. 23, 1913.

[3]Evolution of the Falls of Niagara.

[4]Folio 190, U.S. Geol. Sur., p. 24.



13. Dutch Church in 1900



14. Dutch Church in 1915

time required for the excavation of the Upper Great Gorge from 3,000 to 3,500 years.

In the two time-estimates just given, the amount of water in the Niagara river determines the rate at which the falls has cut its way back from Queenston Heights, and this amount is estimated in accordance with the areas draining into the river. When the waters of the upper lakes flowed over the falls the work went on as rapidly as at present; but when the supply came from the Erie basin only it was very much slower. The excavation of the narrow parts of the gorge required probably four times as long a time as the broad ones.

It will be noted that the Niagara chronology is drawn from the history of the outlet rivers of the upper lakes and provides a rough means of estimating the length of the different stages of these lakes, but has no reference to the bodies of water occupying successively the Ontario basin. After the water in this basin had fallen low enough to set at work the machinery of the falls the two systems followed separate lines of development, and it is not easy to correlate the events in the upper lake basins with those in the lower one.

Time Relations of Events in the Ontario Basin

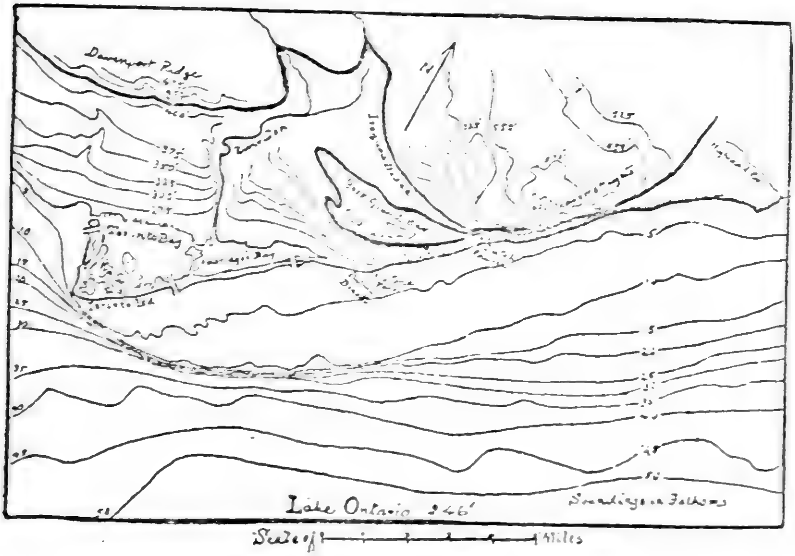
The Ontario basin began to be freed from ice during the existence of Lake Warren, but the falls did not commence its work until the outlet past Rome into the Hudson was opened and probably not until the water fell to the early level of Lake Iroquois, which at its west end may have been as low as the present Lake Ontario, giving a much greater drop than that of Niagara as we know it. It is possible, however, that there were two or three separate falls over as many hard layers in the succession of rocks during the early parts of its existence.

If one accepts the chronology of Niagara just given, the whole of the bodies of water mentioned in former pages as occupying the basin at different stages must have run

their course in from 20,000 to 35,000 or possibly 39,000 years. How is the time to be divided among them?

Two of these bodies of water, Lake Iroquois and Lake Ontario, were much alike in area and have beaches of about the same maturity. The work performed on their shores shows that both must have been long lived; while the intervening stages, including the marine episode, are represented by much less perfectly formed beaches, suggesting a shorter time for wave action. It should be added, however, that the shores of Admiralty lake, which came just before the marine invasion, are probably mostly submerged under Lake Ontario and so out of reach.

Lake Ontario is still at work and it is possible to measure the results of its wave action. For this purpose the recession of the cliffs of glacial and interglacial deposits at Scarborough Heights east of Toronto is well suited. The first accurate survey of Scarborough was made in 1862 and the distance of the cliffs from seventeen fixed points was remeasured in 1912. Some of these lines came out at ravines which were



15. Map of Shore and Island at Toronto

being rapidly cut back by streams and were left out of the computation, but the average of thirteen which seemed normal gives a recession of 81 feet in the fifty years.[1] This works out to 1.62 feet per annum. Soundings show that shallow water extends for about 13,000 feet from the shore before the more rapid slope of the lake bottom toward greater depths; and it is inferred that the cliffs once reached this point. At the present rate of destruction a recession of 13,000 feet implies about 8,000 years.

A computation of the time required to build Toronto island at the present rate of movement of sand along the shore suggests the same age, but the problem is more complicated, and the results much less certain.

Spencer strongly opposed this estimate and held that Lake Ontario has existed for only 3,500 years.[2] So far as one can judge from his rather obscure statement, his reason for taking this as the age of the lake is that 3,500 years ago the northeast angle of Lake Huron was tilted, turning more water into the St. Lawrence drainage. By this he means, no doubt, the closing of the North Bay outlet of the Nipissing Great Lakes, inaugurating the present régime for the upper lakes. Taylor estimates the time during which the upper lakes have emptied through Niagara river at 3,000 to 3,500 years, as mentioned before, confirming Spencer's view which one may agree is correct; but it is not apparent why this event in connection with the upper lakes should fix the age of Lake Ontario. There is good reason to believe that the basin has been greatly tilted since Gilbert gulf came to an end, as shown by the depth of the channel of the Niagara and by the 78 feet of water behind Burlington beach. No definite reason has been mentioned by Spencer why Lake Ontario should not have begun during the lifetime of the Nipissing Great Lakes. They were entirely post-glacial and their outlet through the Mattawa valley must have reached the Ottawa after the marine waters had greatly fallen, since

[1]Compte-Rendu, 12th Geol. Congress, Toronto, 1913, pp. 435-449.
[2]Am. Jour. Sc., Vol. LXIII, No. 257, 1917, p. 360.

the point of junction is now only 488 feet above sea level. Mattawa is fifty miles north of the parallel of Kingsmere, and with a rise of three feet per mile would be 150 feet above it when the Champlain sea reached its highest level. The Kingsmere beach is at 690 feet, so that the highest stage of the sea at Mattawa must have been 840 feet, implying a sinking of 352 feet before the Nipissing Great Lakes ceased to exist. Mattawa is 150 miles north of the parallel of the Thousand Islands, and it is probable that while the outlet of Lake Ontario rose 246 feet to its present level Mattawa rose at least 488 feet, allowing for differential elevation toward the north, which would be only 1.6 feet per mile, about one half of the rate worked out for the highest beaches.

As the Iroquois shore is about as mature as the present Ontario shore one may assume that the two lakes lasted about the same length of time. If we suppose them equal in this respect and take Spencer's estimate of 3,500 years as the age of each of them, only 7,000 years are accounted for out of the 20,000 to 39,000 years provided by the Niagara chronology. What happened during the other 13,000 or 32,000 years? Was the marine episode with its feebly developed beaches four times as long as the Iroquois or Ontario time? This seems highly improbable, and the natural conclusion is that Ontario has lasted at least 8,000 years, and that it was for a long time contemporary with the Nipissing Great Lakes.

From the previous discussion of the correlation of events in the upper lakes region with those in the Ontario basin, it appears that during at least part of the time when the Trent outlet was in operation the water in the Ontario basin was at its lowest level, that of Admiralty lake; and that Lake Ontario was in existence and the marine waters had sunk 350 feet when the upper lakes were drained by the Mattawa valley.

It does not appear, however, that the duration of Lake Iroquois or of the marine stage or of Lake Ontario can be exactly placed with reference to Lake Algonquin and the Nipissing Great Lakes. Lake Algonquin certainly lasted

long after Lake Iroquois had ceased to exist, and, on the other hand, Lake Ontario, which began during the life time of the Nipissing Great Lakes, has long survived them. Probably Lake Ojibway, north of the divide, was a contemporary of the Nipissing Great Lakes for a part of their history, but came to an end long before they were transformed, by the northward rise of their outlet, into the present upper lakes.

Correlation Table

From the foregoing account of the lakes and arms of the sea which have occupied parts of the present St. Lawrence hydrographic region, it is evident that the relationships of the successive bodies of water in the different basins are very complicated. The following table is intended to make these relationships more clear:

Years ago	In the Ontario Basin	Upper Lake Basins	Hudson Bay Slope	Eastern Ontario
35,000	Lake Warren	Lake Duluth, Lake Chicago and Lake Warren	Lake Agassiz	
30,000	Lake Lundy, Lake Dana, etc.			
25,000	Niagara Falls and Lake Iroquois begin	Lake Algonquin begins with St. Clair Outlet Trent Outlet into Lake Iroquois		
20,000				
17,000	Lake Iroquois ends			
	Lake Frontenac Admiralty Lake	Trent Outlet into Admiralty Lake		Early (Low) Marine Stage
	Gilbert Gulf	St. Clair Outlet Nipissing Great Lakes begin, Mattawa Outlet	Lake Ojibway	Maximum Marine Stage
10,000				
8,000	Lake Ontario begins	Two Outlet Stage	Marine Stage	Marine waters gradually retreat to Quebec
3,500		Upper Lakes begin		
0				

In the table just given the estimates of time are more accurate as they approach the present. That the Upper Lakes, Superior, Michigan, and Huron, began 3,500 years ago is fairly certain from the length of time required by Niagara to cut the upper great gorge. That Ontario began 8,000 years ago is made probable from the rate of wave erosion at Scarborough heights; but that Gilbert gulf, Admiralty lake and Lake Frontenac required altogether 9,000 years is merely a guess. The beginning of Niagara Falls and of Lake Iroquois is put at 25,000 years ago, while the various computations drawn from the Niagara gorge give from 20,000 to 39,000 years.

The dates of the earlier lakes are, of course, still less certain. Lake Agassiz may have begun 45,000 years ago if Spencer's estimate of 39,000 years for the work of Niagara is correct. On the other hand, Warren Upham suggests that 8,000 years are sufficient time to allow since the ice began to disappear from the Winnipeg region and that Lake Agassiz lasted only 1,000 or 1,500 years.[1]

It may be that the late glacial and post-glacial chronology of eastern America will ultimately be put on an exact basis through the actual counting of the annual layers of clay deposited during the retreat of the ice and since that time, as DeGeer and his assistants have done in Sweden. Baron DeGeer with two assistants undertook last year to measure portions of the stratified glacial clays of eastern Canada and the United States for comparison with the results obtained in Sweden, and apparently they have been successful in correlating part of the American post-glacial record with that of Europe, though the work is not much more than begun.[2]

Connections Between the Lakes

It may be useful to summarize the connecting links in space and time between the various lakes referred to above,

[1]Glacial Lake Agassiz, U.S. Mon. XXV, pp. 238-244.
[2]Petermanns Mitteilungen, 67, 1921, June-July, p. 124.

so as to show in brief form the possible migrations of the fresh water fauna.

Lake Agassiz was probably connected with Lakes Duluth, Chicago, and Warren *viâ* the Mississippi, since all of them drained into that river. It is possible, however, that Lake Agassiz came to an end before the other lakes began.

Lakes Duluth, Chicago, and Warren became connected, as the ice lobes retreated northwards, and formed Lake Algonquin, which merged into the Nipissing Great Lakes, which at length passed into Lakes Superior, Michigan, and Huron. Lake Algonquin drained into Lake Iroquois *viâ* Niagara and Algonquin rivers (Trent valley), and later into Admiralty lake during the early low stage of sea level when Algonquin river extended down to what is now the Bay of Quinté. Bays of Lake Algonquin extended across the Hudson bay watershed at three cols as the ice retreated and thus connected with Lake Ojibway and ultimately with Abitibi and other lakes of northern Ontario. It is probable that Lake Ojibway drained for a time into the Ottawa and thus into the Champlain Sea.

The Nipissing Great Lakes drained in part through the Mattawa outlet into the Ottawa valley, then occupied by the sea, and in part *viâ* Niagara into Lake Ontario.

Lake Warren merged through various stages into Lake Iroquois, which drained through the Mohawk valley into the Hudson valley, then occupied by the sea. Lake Iroquois sank into Lake Frontenac, which was lowered to the Admiralty lake, which rose to correspond to the rising sea level and merged into Gilbert gulf, the water remaining fresh although connected with the Champlain sea, an expansion of the Gulf of St. Lawrence. Gilbert gulf passed gradually into Lake Ontario, which began just above sea level as the land rose, so that the St. Lawrence river was at first very short but grew longer as the rise of the land continued until the sea level became stationary at Quebec. Anadromous fish must have slowly adjusted their instincts to the lengthening of the river.

The Upper Lakes have had connections, often very long

and roundabout, with the Gulf of Mexico *viâ* the Mississippi; with the Atlantic *viâ* Algonquin river, Lake Iroquois, the Iri-Mohawk river, and the Hudson channel; and with the Gulf of St. Lawrence *viâ* the Mattawa outlet and the Champlain sea. None of these routes presented serious impediments such as important vertical falls. A sea salmon could have made its way up any one of the three routes. At present the falls of Niagara form an impassable barrier to any ascent from Lake Ontario or the sea, but a few thousand years ago there was much less difficulty in ascending to the Upper Lakes by the Ottawa and Mattawa valleys. The sea, probably somewhat brackish, reached as far north as the Mattawa river, now 488 feet above the sea level. Above this the climb to Lake Nipissing is only 154 feet including rapids but no important falls. Any fish with good swimming powers could have made the ascent.

Pleistocene Changes in the Life of the Region

As a sequel to the physical history of the Great Lakes region one may consider briefly the relations of its flora and fauna. Unfortunately the evidence as to the former plants and animals is very fragmentary.

In the account of the different glacial and post-glacial lakes, lists have been given of the species found in their shore deposits. All appear to be still living. The most frequent fossils are naturally shellfish and except in a few cases they still survive in the modern lakes. The few exceptions are of Mississippi molluscs, which seem to have died out in these waters.

The largest flora and fauna of post-glacial age are found in the marine beds, especially in concretions from the Leda clay of Ottawa. So far as known, none of the dozen plants, which include a few trees, differ from species of the present flora. Of the marine fishes and mammals none are extinct, so far as one can judge from the fragmentary remains preserved. Shellfish are naturally the most frequent fossil forms. Dawson describes from Ottawa and Montreal

142 species, of which he believes only two or three are extinct,[1] though some others present varietal differences. On the other hand the only sponge mentioned no longer lives, and all the insects, four in number, are extinct, according to Dr. Scudder.

The marine beds were laid down probably between 17,000 and 3,500 years ago, so that specific changes in molluscs seem to require a longer time than that, while the more highly developed insects, with their rapid succession of generations, are more quickly modified.

The only other important Pleistocene flora and fauna for comparison with present day species are those of the Toronto interglacial beds;[2] from which 63 species of plants and 122 species of animals are on record.

Of the plants 35 are trees, and all but three or four still exist, the extinct ones including *Acer pleistocenicum*, *A. torontoniensis* and perhaps another maple, and *Gleditschia donensis*, as determined by Penhallow. All are closely related to modern trees, the maples being apparently ancestors of our sugar maple.

Among the 41 shellfish, all are still living in North America, but apparently eight belong to more southern waters than Lake Ontario. The 72 insects are extinct with two exceptions, according to Dr. Scudder, as one would expect from the fate of the much later insects of the marine time. The two or three fish remains are too fragmentary for us to be sure of their species; and the six mammals are known only from separate bones or horns or tusks. The elephants, of course, are extinct, and the horn determined as *cervalces* by Bensley may be looked on as extinct also. Whether the large bear, known only from one of the bones of the head, the red deer, the caribou, and the bison belong to living or extinct forms cannot yet be decided.

The Toronto interglacial formation probably dates back at least 500,000 years and the changes in the life of the

[1]Can. Ice Age, p. 279.

[2]Geol. Congr., 1913, Guidebook No. 6, pp. 15-25.

region seem surprisingly small for so great a lapse of time. Apparently molluscs have the slowest rate of change and insects the most rapid; the mammals perhaps being modified almost equally rapidly.

While no older Pleistocene deposits are known from Ontario there is reason to believe that the Aftonian beds of Iowa are more ancient, since they occur between the Nebraskan and Kansan boulder clays and occupy the first of four interglacial intervals recognized in that state. If the Toronto formation comes about half way down in the Pleistocene, as seems probable, the Aftonian must be some hundreds of thousands of years older and its flora and fauna should be correspondingly more ancient in character. Among plants, pine, tamarack, oak, elm, ash, walnut, hickory, and sumac are reported, but unfortunately the species seem undetermined, so that one cannot be sure as to whether they are of still living forms or not. It may be observed that all of the genera except the walnut and the sumac are represented in the Toronto formation.

Among animals only mammals have been found, and these have been determined mostly from isolated bones, jaws, and tusks; though the remains are more complete than those found at Toronto. Calvin describes and figures remains of two or three species of horses, a camel, two ground sloths, cervalces, two mammoths, and one mastodon.[1] All the mammals are extinct and have left no North American descendants, unless cervalces is an ancestor of the moose.

It will be recalled that cervalces and either mammoth or mastodon occur in the Toronto formation, but that the other mammals may be of still living species. The number of extinct species of mammals is greatly increased in the older interglacial formation.

[1]Aftonian Mammalian Fauna, Bull. Geol. Soc. Am., Vol. 20, pp. 341-356.

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THE LIMNOLOGY OF LAKE NIPIGON

BY

WILBERT A. CLEMENS

OF THE DEPARTMENT OF BIOLOGY

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THE LIMNOLOGY OF LAKE NIPIGON

During the months of June, July and August, 1921, an intensive limnobiological investigation of Lake Nipigon was commenced by a field party from the Ontario Fisheries Research Laboratory, of the Department of Biology, University of Toronto, under the direction of the writer. The purpose of the investigation was to carry out a thorough study of the biological and environmental factors, with special reference to the fish fauna and its economic and conservational aspects. Lake Nipigon was selected for investigation because of its isolation for a long period of time from the Great Lakes and, as far as known, from any other drainage system. As a result, natural conditions have been undisturbed either in the drainage basin or in the lake itself, except by reason of the opening of the lake to restricted commercial fishing in recent years. In 1916, the Department of Game and Fisheries of the Province of Ontario opened the lake under supervision to commercial fishing for the purpose of augmenting the food supply during the war, and have continued the policy with some modifications to the present time. Statistics are available for only four years, 1916-1919, but during that time the following amounts of fish were removed: whitefish 2,511,614 lbs., lake trout 1,059,632 lbs., pike perch 51,431 lbs., sturgeon 21,810 lbs., other species, chiefly pike, ciscoes and northern suckers, 57,694 lbs. In 1920, the following plants were made: whitefish 8,943,000 fry, lake trout 734,000 fry, and 240 parent black bass. It seemed desirable therefore to determine the conditions existing in a lake before the effects of such disturbances of natural conditions had become pronounced. An opportunity was thus afforded of studying the effects of commercial fishing in a circumscribed body of water and of developing working plans for the best utilization of the productive possibilities of such a body.

In view of the above considerations, the investigation during the first season followed three main lines:—

(1) the identification of the species of fish, their distribution, relative abundance, natural history, food and rates of growth;

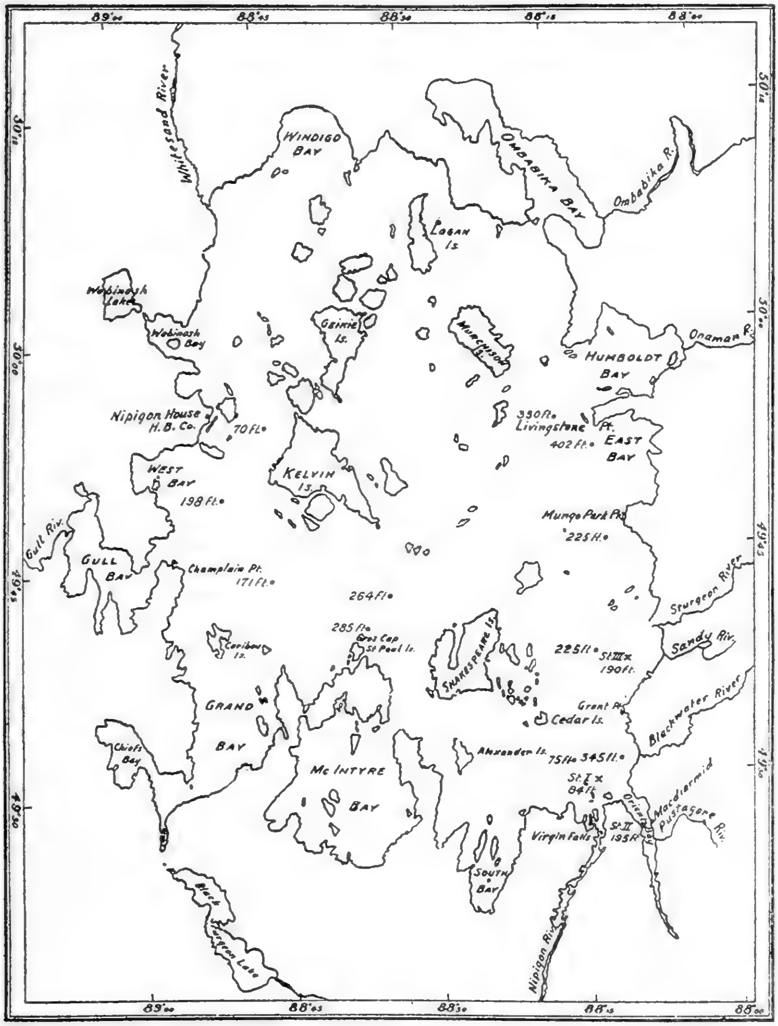
(2) qualitative and quantitative studies of the food organisms, confined largely to the plankton and the bottom fauna;

(3) a study of the physical features, particularly temperatures, dissolved oxygen and carbon dioxide, colour and transparency, and the significance of these factors in respect of the biology of the lake.

Some of the results obtained are presented in more or less preliminary form in this and the following five papers.

Lake Nipigon, the largest of the many inland bodies of water in Ontario, is situated in the northwestern portion of the province about 50 miles north of Lake Superior. It lies approximately between 87°35′ and 89°10′ west longitude and between 49°5′ and 50°30′ north latitude. The area as given by Wilson (1910) is 1769 square miles, of which about 1530 square miles is water surface, leaving an island area of about 239 square miles. The lake is roughly quadrangular in form, about 50 miles long and 30 miles wide, but very irregular in outline with numerous bays of various sizes and contours. The shore line is characterized by rocky projections and headlands alternating with indentations. The latter, when open and exposed, are rocky or sandy, but where extended and protected, tend to become muddy with an approach to marshy conditions. The length of the coast line exclusive of smaller bays and coves is over 580 miles (Bell, 1870). The islands are numerous, particularly in the northwestern portion, and range in size from small rocky projections to large wooded areas. The elevation of the water surface is 852 feet above sea level (White, 1915).

The drainage basin comprising about 6,000 sq. mi. is fairly well covered with tree growth consisting chiefly of balsam, spruce, poplar and birch, with a scattering of red pine, jack-pine, tamarack, cedar and alder, and the major portion is included in the Nipigon Forest Reserve. Numerous catchment basins, ranging in size from small ponds to large lakes, are scattered throughout the basin and drain into Lake



Map of Lake Nipigon showing depths and the location of the three stations for the taking of plankton, temperatures and water samples.

Nipigon by a large number of streams. There is, on the other hand, but one outlet, the Nipigon River, by which the drainage is carried southward into Lake Superior, through a descent of 250 feet, over a series of rapids and falls. The uppermost of the latter is the Virgin Falls (35 ft. high) practically at the origin of the river, where the estimated low water flow is 5.500 cubic feet per second (Hydro Electric Power Comm. Report, 1907).

The region surrounding the lake is typical of the Archaean area. It is rugged and hilly, with bluffs rising as high as 600 feet above the level of the lake. The present features of the district are the result of a long series of geological events whose sequence appears to be as follows. A trough existed on the Archaean surface which during a period of submergence received large deposits of sediments. (Wilson, loc. cit.) Elevation above sea level followed with extensive erosion uncovering portions of the original trough. Diabase flows later invaded the area, but in a succeeding long period of erosion much of the diabase was removed as well as a large amount of the early sedimentary deposits. During this period, and possibly to some extent earlier, disturbances occurred in the earth's crust resulting in elevations, block faulting, etc. It is probable that there were two outlets from the basin during this time, one from the southeast corner through the Pijitawabic canon (Orient Bay) and the other from the southwest corner by way of Black Sturgeon Lake. Then followed the glacial period, and when the ice finally retreated northward, the Lake Nipigon basin formed a very large bay of Lake Algonquin, the predecessor of Lake Superior (Coleman, 1922). With the development of the Great Lakes drainage system and the elevation of the region north of what is now Lake Superior, the modern Lake Nipigon was formed. A new outlet developed, the Nipigon river, the two preglacial outlets being blocked by glacial debris.

There has been as yet no hydrographic survey made of Lake Nipigon. A line of large islands lying roughly in a north to south direction divides the lake more or less into east and west portions. The eastern portion contains the deeper water which lies well over towards the eastern shore. Soundings taken in the course of dredging and limnological operations gave the following depths:—

195 feet Pijitawabic Bay, opposite Macdiarmid village.

345 feet off mouth Blackwater river.

225 feet off mouth Sandy river.

225 feet off Mungo Park Point.

402 feet was recorded by McInnes (1894) two and a half miles south of Livingstone Point. This is probably the greatest depth in the lake.

In the western portion the following records were obtained:—

198 feet west of Kelvin island.

171 feet east of Champlain Point.

264 feet northeast of Grand Cape.

285 feet was recorded by McInnes just north of St. Paul island.

It is thus evident that there is a very large body of deep water in Lake Nipigon and that the amount of shallow water is limited. The open shores are rocky or sandy and because of the size of the lake, subject to strong wave action. It is only in the deep, protected bays and shallow areas among the islands where conditions are such as to permit the growth of the larger aquatic vegetation with the accompanying abundance of animal life.

Because of the great extent of Lake Nipigon, the first season's investigations were confined largely to the southeastern portion. Three stations were established for the taking of temperature records, water samples and plankton. Station 1 was located in comparatively shallow water (depth of 28 yards) off the mouth of the Nipigon river; station 2 in the deepest water (depth of 63 yards) of Pijitawabik bay (Orient Bay) directly opposite the village of Macdiarmid; station 3 in the open water off Sandy river (depth of 63 yards). One series was obtained on August 29 off the mouth of the Blackwater river (depth of 100 yards).

The temperature records were obtained with a standardized Negretti-Zambra deep-sea reversing thermometer. Water samples were taken immediately after the temperature records with a modified Kemmerer water bottle (Birge, 1922). The water samples were put in 250cc. glass-stoppered bottles, packed in broken ice and taken to the laboratory where the analyses were carried out. The oxygen content was determined by a modification of Miller's method (Provincial Board of Health of Ontario, 1920). For the carbon dioxide determinations N/22 sodium carbonate with phenolphthalein as indicator was used (Prov. Board of Health, loc. cit.).* The temperature records and the results of the analyses are given in Tables 1, 2 and 3, and from this data Figs. 1 to 6 have been constructed.

Since no record of the temperature of the deepest water was obtained in this season it has been assumed, on the basis of the results obtained at the three stations, that the temperature was 4.0°C. Fig. 3 may be taken as a fairly accurate record of events. From June 17 to July 9 the surface waters were gradually acquiring heat and the thermocline was slowly increasing in thickness (Table 4). No record for late July was obtained for Station 3, but judging from the record for Station 2 on July 26, by the end of July the epilimnion had doubled in thickness and the thermocline therefore had shifted downward.

During the morning of July 30 a wind of considerable violence came up accompanied by some rainfall. The wind blew first from the southwest and gradually shifted to northwest reaching its maximum velocity about 2 p.m. No meteorological records are available for the Nipigon region, but judging from records obtained at various stations in Northern Ontario, it is probable that the wind attained a velocity at times of about 35 miles an hour. Captains on the fishing tugs stated that this was the worst mid-summer storm they had experienced on this lake. The temperature records on August 2 show the effects of the storm. The thermocline in the open part of the lake was obliterated. Apparently the three strata were set in motion and some of

*All the solutions were prepared by Mr. George W. Lucas of the Department of Chemistry, University of Toronto, and the Provincial Board of Health.

TABLE 1

STATION 1

Depth in yards	June 13				July 23				August 18			
	Temp. C.	Ox.	% Sat.	CO_2	Temp. C.	Ox.	% Sat.	CO_2	Temp. C.	Ox.	% Sat.	CO_2
Surface	8.3	7.8	94		19.4	5.8	87	1.4	16.2	6.2	88	1.7
1	7.1			1.7	19.4							
2	6.8				19.2							
3	6.7											
5					19.2	5.8	87	0.6	16.0			
6	6.4	7.8	89	1.6								
9	5.8											
10					18.7	6.0	89	0.9	15.9			
11	5.8	8.0	90	1.1								
13	5.7				14.2							
15					11.5	7.4	95	1.0	15.8	6.4	90	1.1
16	5.6	7.8	88	1.1								
20					6.7	7.7	89	1.1	11.3	6.7	86	2.0
21	5.5	7.9	88									
25									7.0			
26	5.4	8.0	89	0.0								
28					4.8	7.7	85	1.4	6.5	7.1	82	2.2

TABLE 2

STATION 2

Depth in yards	June 14				June 28				July 8			
	Temp. C.	Ox.	% Sat.	CO_2	Temp. C.	Ox.	% Sat.	CO_2	Temp. C.	Ox.	% Sat.	CO_2
Surface	9.4.	7.7	95	none	17.4	6.2	90	1.1	20.2	6.55	100	0.9
1					15.5							
2					12.9							
3												
4					12.4							
5	8.2	8.0	96		12.4	6.9	91	0.6	11.4	7.00	90	0.9
8									9.3	7.65	94	1.1
10	7.1	7.9	92		10.4	6.9	87	0.6	7.2			
15	6.8				9.0	7.8	95	0.8	6.4	7.70	88	1.1
20	6.5	8.1	93		7.2	7.8	91	1.1	5.8			
25	5.4	8.3	93		6.4				5.4	7.85	88	1.1
30	5.1				5.6	7.7	87	1.1				
35									4.8			
40	4.9				5.1	7.8	87	1.1				
45	4.8								4.5			
50		8.0	88		4.6	7.9	87	1.1				
55									4.3			
60										7.80	85	1.1
63					4.0	8.0	86	0.8				
65									4.2			

TABLE 2 (*continued*)

STATION 2

Depth in yards	July 26				August 1				August 17			
	Temp. C.	Ox.	% Sat.	CO_2	Temp. C.	Ox.	% Sat.	CO_2	Temp. C.	Ox.	% Sat.	CO_2
Surface	20.1	5.80	89	1.4	17.7	5.90	86	0.9	17.2	6.00	87	1.4
1												
2												
3									16.1			
4												
5	19.9	5.75	87	0.9	17.7				15.7			
8	19.1	6.00	90	1.1								
10	12.9				17.6				15.4			
15	8.0	6.05	72	1.1	17.2	5.95	86	1.1	15.0	6.15	85	1.4
20	6.8				10.3	7.00	88	1.1	11.0	6.50	83	1.7
25	6.0				8.6	7.40	90	1.7	7.4	6.85	75	1.1
30	5.6	7.75	87	1.7	7.6				6.4			
35												
40	5.0				6.3	7.50	89	1.7	5.8			
45												
50	4.8				5.6				5.6			
55	4.6	7.85	86	1.9								
60									5.4	7.15	80	1.7
63					4.8	7.60	84	2.2				
65												

TABLE 3

STATION 3

Depth in yards	June 17	June 23				July 9				August 2			
	Temp. C.	Temp. C.	Ox.	% Sat.	CO_2	Temp.C.	Ox.	% Sat.	CO_2	Temp.C.	Ox.	% Sat.	CO_2
Surface	12.5	14.9	7.7	106	1.4	22.0	6.3	99	1.2	16.2	6.3	89	1.1
5	8.5	13.4	7.8	104	1.1	16.6	6.4	91	1.1	15.9			
8						11.3							
10	7.7	8.2	7.9	94	1.7	9.3	7.3	90	1.1	15.8	6.4	90	1.1
15	7.4	7.1				6.7				15.0			
18													
20	6.0	5.8	7.9	89	1.1	6.2	7.6	87	1.7	13.0	6.6	88	1.1
25	5.2	5.2								11.8	6.9	90	1.1
30	5.0		8.0	88	1.7	4.9	7.6	84	1.4	8.8	7.0	85	1.1
40	4.8		7.9	87	1.7	4.3				6.5			
45						4.2	7.7	84	1.4				
50										5.1			
53	4.0												
60													
63										4.6	7.65	84	2.2
80													
90													
100													

STATION 3 (*continued*)

Depth in yards	August 29†			
	Temp. C.	Ox.	% Sat.	CO_2
Surface	17.1	6.05	87	1.1
5	16.8			
8				
10	15.9			
15	15.2	7.00	97	1.1
18	9.0			
20	8.0	6.25	74	1.1
25	6.7			
30	6.3			
40	5.7			
45				
50				
53				
60	5.2			
63				
80	4.9			
90	4.5	6.40	70	1.6
100	4.2	5.70	62	2.2

†Off mouth Blackwater river.

TABLE 4

STATION 2

	July 8, 1921		July 26		August 1		August 17	
	Depth m.	Temp. C.	Depth m.	Temp. C.	Depth m.	Temp. C.	Depth m.	Temp. C.
Epilimnion	0.0- 1.0	20.2-19.9	0-5	20.5-19.5	0-11	17.7-17.1	0-12	17.2-14.0
Thermocline	1.0- 7.0	19.9- 7.2	5-10	19.5- 8.5	11-14	17.1-10.6	12-17	14.0- 8.2
Hypolimnion	7.0-60.0	7.2- 4.2	10-60	8.5- 4.4	14-60	10.6- 4.8	17-60	8.2- 5.3

STATION 3

	June 17		July 9		August 2		August 29	
	Depth m.	Temp. C.	Depth m.	Temp. C.			Depth m.	Temp. C.
Epilimnion	0-3	12.5-11.0	0-2	22-21			0-14	17.1-15.0
Thermocline	3-4	11.0- 9.0	2-8	21-10			14-16	15.0- 9.5
Hypolimnion	4-123.4	9.0- 4.0	8-123.4	10-4			16-123.4	9.5- 4.0

the warm surface waters were carried almost to the bottom of the lake. At Station 2 in the sheltered bay (Fig. 2) the thermocline was not obliterated but was decreased in thickness and pushed downward several metres. We have here a good example of the effect of the wind in distributing heat in a lake. Later on in August typical stratification was again established as shown by the record for August 29.

The records in Figs. 1 and 2 coincide in general with that in Fig. 3 to depths of 30 and 60 metres respectively.

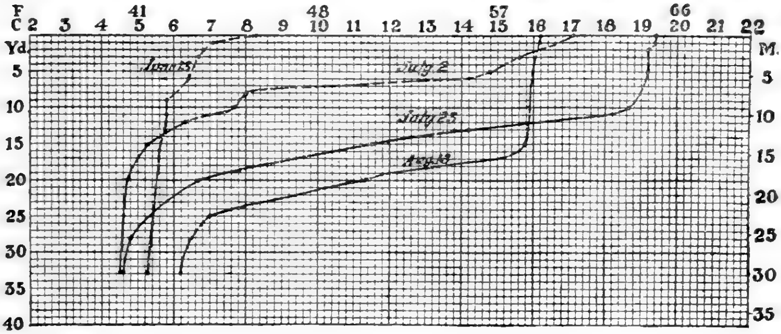


FIG. 1. Curves illustrating temperature records at Station 1, Lake Nipigon.

DISTRIBUTION OF HEAT.

In the absence of an hydrographic survey of Lake Nipigon, it is impossible at the present time to calculate the summer heat income and the work involved in the distribution of the heat on the basis of mean temperature and reduced thickness. Calculations have been made, however, for a column of water one square centimetre in area extending from surface to bottom. These figures are of some interest in indicating the distribution of heat and work for those particular points in the lake but do not furnish very accurate data which may be compared with that calculated for other lakes on the basis of mean temperature and reduced thickness (Birge, 1916).

In Tables 5, 6 and 7 are given, (1) the temperatures at five-metre intervals as taken from Figs. 1, 2 and 3, and (2) the mean temperature for each five-metre stratum. The latter figures have then been used for the calculation of the number of gram calories per square centimetre of surface received by each five-metre stratum above 4°C. using the formula $(T-4)\times500$. These results are given in Tables 8, 9 and 10 and show:

(1) that by the middle of June about a third of the total amount of heat of the season had been gained and that this heat was contained in the upper half of the lake, that is, in the upper 60 metres;

(2) that by the end of the first week in July there had been a considerable gain in heat by the upper waters, confined largely to the upper five metres.

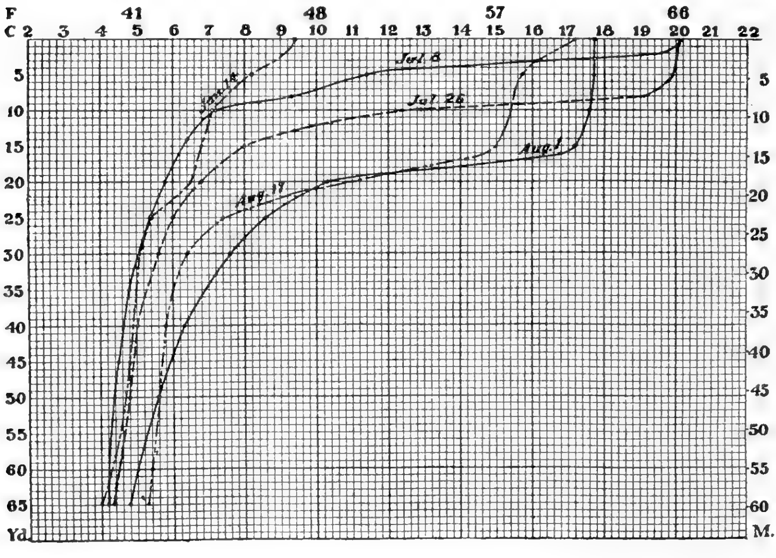


FIG. 2. Curves illustrating temperature records at Station 2, Lake Nipigon.

(3) that by the end of July there had been large gains in heat by the upper 20 metres. Unfortunately no temperature records were obtained in late July in the open waters, but it is doubtful if at the end of July any appreciable amount of heat had penetrated below 60 metres.

(4) that the effect of the storm on July 30 was to dis-

TABLE 5

TEMPERATURES—STATION 1

	June 13		July 2		July 23		August 18	
Depth m.	Temp. C.	Av. Temp. per 5-m. l.	Temp. C.	Av. Temp. per 5-m. l.	Temp. C.	Av. Temp. per 5-m. l.	Temp. C.	Av. Temp. per 5-m. l.
0	8.30		17.1		19.40		16.2	
5	6.45	7.37	14.5	15.80	19.15	19.27	15.95	16.07
10	5.80	6.12	7.4	10.95	18.35	18.75	15.9	15.92
15	5.60	5.70	5.1	6.25	10.00	14.17	15.7	15.80
20	5.50	5.55	4.65	4.87	6.1	8.05	9.5	12.60
25	5.40	5.45	4.55	4.60	4.9	5.50	6.6	8.05
30	5.30	5.35	4.50	4.52	4.6	4.75	6.2	6.40

TABLE 6

TEMPERATURES—STATION 2

	June 14		July 8		July 26		August 1		August 17	
Depth m.	Temp. C.	Av. Temp. per 5-m. l.	Temp. C.	Av. Temp. per 5-m. l.	Temp. C.	Av. Temp. per 5-m. l.	Temp. C.	Av. Temp. per 5-m. l.	Temp. C.	Av. Temp. per 5-m. l.
0	9.4		20.2		20.1		17.7		17.2	
5	8.0	8.70	11.0	15.6	19.9	20.00	17.7	17.70	15.65	16.42
10	7.05	7.52	7.0	9.0	11.4	15.65	17.55	17.62	15.35	15.50
15	6.7	6.87	6.1	6.55	7.6	9.50	16.40	16.97	14.40	14.87
20	6.15	6.42	5.6	5.85	6.45	7.02	9.55	12.97	9.2	11.80
25	5.2	5.67	5.2	5.4	5.80	6.12	8.1	8.82	6.9	8.05
30	5.05	5.12	4.9	5.05	5.40	5.60	7.2	7.6	6.15	6.52
35	4.95	5.00	4.7	4.8	5.15	5.27	6.6	6.9	5.9	6.02
40	4.85	4.90	4.5	4.6	4.95	5.05	6.0	6.3	5.7	5.80
45	4.7	4.77	4.4	4.45	4.80	4.87	5.6	5.8	5.6	5.65
50	4.55	4.62	4.3	4.35	4.65	4.72	5.3	5.45	5.5	5.55
55	4.30	4.42	4.2	4.25	4.50	4.57	5.0	5.15	5.4	5.45
60	4.0	4.15	4.2	4.20	4.30	4.40	4.75	4.87	5.3	5.35

TABLE 7

TEMPERATURES—STATION 3

	June 17		July 9		August 2		August 29	
Depth m.	Temp. C.	Av. Temp. per 5-m. l.	Temp. C.	Av. Temp. per 5-m. l.	Temp. C.	Av. Temp. per 5-m. l.	Temp. C.	Av. Temp. per 5-m. l.
0	12.5		22.0		16.2		17.1	
5	8.4	10.45	15.8	18.9	15.8	16.02	16.75	16.92
10	7.7	8.05	8.7	12.2	15.7	15.77	15.8	16.27
15	7.1	7.4	6.5	7.6	14.4	15.05	12.8	14.30
20	5.6	6.35	6.05	6.27	12.6	13.5	7.4	10.10
25	5.1	5.35	5.3	5.67	10.4	11.5	6.5	6.95
30	4.95	5.02	4.6	4.95	8.15	9.27	6.15	6.32
35	4.8	4.87	4.35	4.47	6.9	7.52	5.8	5.97
40	4.7	4.75	4.2	4.27	5.95	6.42	5.6	5.70
45	4.3	4.5	4.15	4.17	5.2	5.57	5.45	5.52
50	4.0	4.15	4.0	4.07	4.85	5.02	5.35	5.40
55	4.0	4.0	4.0	4.0	4.65	4.75	5.2	5.27
60	4.0	4.0	4.0	4.0	4.6	4.62	5.1	5.15
65	4.0	4.0	4.0	4.0	4.55	4.57	5.0	5.05
70	4.0	4.0	4.0	4.0	4.5	4.52	4.95	4.97
75	4.0	4.0	4.0	4.0	4.45	4.47	4.85	4.90
80	4.0	4.0	4.0	4.0	4.4	4.42	4.75	4.80
85	4.0	4.0	4.0	4.0	4.35	4.37	4.65	4.70
90	4.0	4.0	4.0	4.0	4.3	4.32	4.60	4.62
95	4.0	4.0	4.0	4.0	4.25	4.27	4.55	4.57
100	4.0	4.0	4.0	4.0	4.2	4.22	4.45	4.50
105	4.0	4.0	4.0	4.0	4.2	4.20	4.35	4.40
110	4.0	4.0	4.0	4.0	4.15	4.17	4.25	4.30
115	4.0	4.0	4.0	4.0	4.1	4.12	4.15	4.20
120	4.0	4.0	4.0	4.0	4.05	4.07	4.05	4.10
123.4	4.0	4.0	4.0	4.0	4.0	4.00	4.00	4.00

TABLE 8

CALORIES ABOVE 4° C.—STATION 1

Depth m.	June 13		July 2		July 23		August 18	
0-5	1685		5900		7635		6035	
5-10	1060		3475		7375		5960	
10-15	850		1125		5085		5900	
15-20	775		435		2025		4300	
20-25	725	5095	300	11235	750	22870	2025	24220
25-30	675	675	260	260	375	375	1200	1200
		5770		11495		23245		25420

TABLE 9

CALORIES ABOVE 4° C.—STATION 2

Depth m.	June 14		July 8		July 26		August 1		August 17	
0-5	2350		5800		8000		6850		6210	
5-10	1760		2500		5825		6810		5750	
10-15	1435		1275		2750		6485		5435	
15-20	1210		925		1510		4485		3900	
20-25	835	7590	700	11200	1069	19145	2410	27040	2025	23320
25-30	560		525		800		1800		1260	
30-35	500		400		635		1450		1010	
35-40	450		300		525		1150		900	
40-45	385		225		435		900		825	
45-50	310	2205	175	1625	360	2755	725	6025	775	4770
50-55	210		125		285		575		725	
55-60	75	285	100	225	200	485	435	1010	675	1400
		10080		13050		22385		34075		29490

TABLE 10

CALORIES ABOVE 4° C.—STATION 3

Depth m.	June 17		July 9		August 2		August 29	
0-5	3225		7450		6010		6460	
5-10	2025		4100		5885		6135	
10-15	1700		1800		5525		5150	
15-20	1175		1135		4750		3050	
20-25	675	8800	835	15320	3750	25920	1475	22270
25-30	510		475		2635		1160	
30-35	435		235		1760		985	
35-40	375		135		1210		850	
40-45	250		85		785		760	
45-50	75	1645	35	965	510	6900	700	4455
50-55					375		635	
55-60					310		575	
60-65					285		525	
65-70					260		485	
70-75					235	1465	450	2670
75-80					210		400	
80-85					185		350	
85-90					160		310	
90-95					135		285	
95-100					110	800	250	1595
100-105					100		200	
105-110					85		150	
110-115					60		100	
115-120					35		50	
120-123.4					0	280	0	500
		10445		16285		35365		31490

tribute heat practically to the bottom of the lake. The amount distributed to the deep water is relatively small, however, the great bulk being retained in the upper five metres.

(5) that by the middle of August the lake had begun to

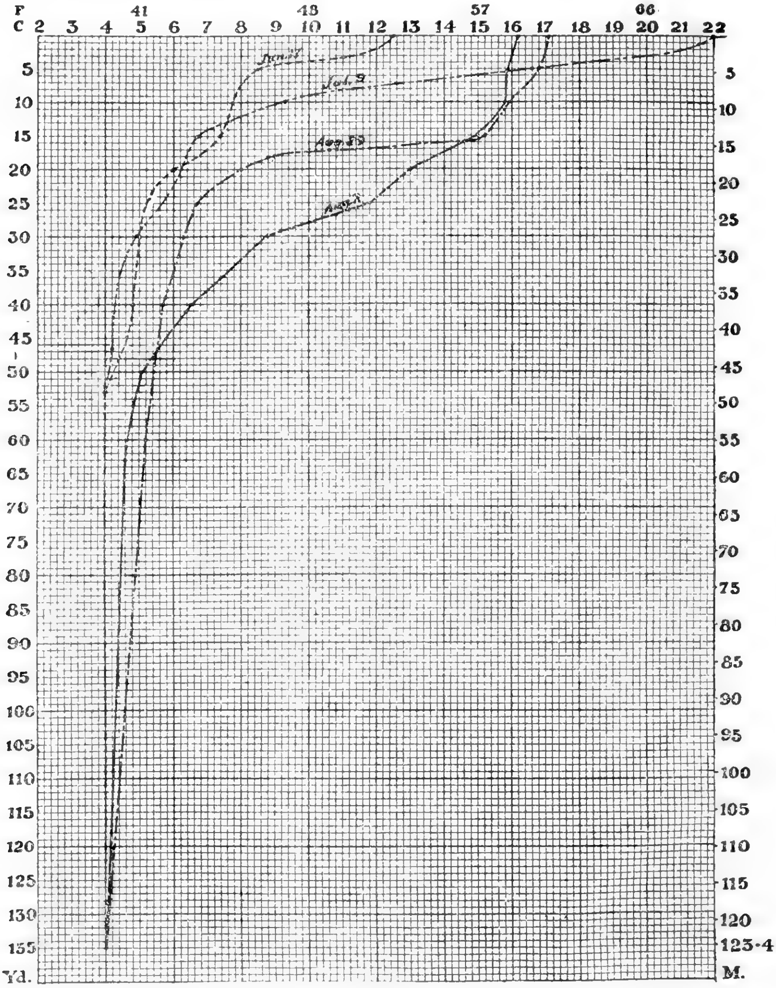


FIG. 3. Curves illustrating temperature records at Station 3, Lake Nipigon.

give up some of its heat. The loss in the upper 25 metres has probably been into the air, while the 25-50 metre area may have contributed of its heat to the underlying waters which apparently continued to gain heat for some days following the storm.

It is probable that the summer heat income for Lake Nipigon in 1921 was in the neighbourhood of 30,000 gram calories per sq. cm. of surface. The mean summer heat income for Cayuga Lake, N.Y., over a period of five years was 29,480 calories (Birge and Juday, 1921), with the maximum in one year of 30,910 calories. The two lakes have approximately the same maximum depth, Cayuga 133 metres, Nipigon 123.4 metres.

Distribution of Heat

The amount of work in gram-centimetres involved in the distribution of the heat contained in a column of water one square centimetre in area has been calculated for each metre stratum using the formula $(I-D)\times CG$, where $(I-D)$ is the loss of density due to warming, C, the depth in centimetres and G, the weight in grams. This is based on the principle stated by Birge (1916), that for the most part, the warming of the water in a lake is done by the transference of warm lighter water from the surface downward through water at its maximum density, by the agency of the wind. This involves an expenditure of work which can be calculated.

The results here given are for each five-metre stratum and the temperatures used in the calculations are the means of the five-metre strata as given in Tables 5, 6 and 7. Further accuracy in this instance did not seem warranted. The results are shown in Tables 11, 12 and 13. The significant points are:—

(1) that from the middle of June to the end of the first week in July practically all of the work was expended in the upper 10 metres and particularly in the upper five metres.

(2) that during July, the work was expended to a greater depth but especially in the 5-10 metre stratum.

TABLE 11

DIRECT WORK—STATION 1

Depth m.	June 13	July 2	July 23	August 18
0-5	13.50	150.00	243.75	156.75
5-10	14.00	144.00	608.00	406.00
10-15	14.95	26.00	490.75	650.00
15-20	18.00	5.40	112.50	490.50
20-25	19.55	3.45	20.70	143.75
25-30	21.00	2.80	7.00	63.00
	101.00 g. cm.	331.65 g. cm.	1482.70 g. cm.	1910.00 g. cm.

TABLE 12

DIRECT WORK—STATION 2

Depth m.	June 14	July 8	July 26	August 1	August 17
0-5	25.50	144.75	265.50	198.75	165.00
5-10	38.80	76.00	390.00	524.00	380.00
10-15	42.25	32.50	149.50	773.50	555.75
15-20	42.30	25.20	63.90	531.00	409.50
20-25	25.30	18.40	40.25	207.00	143.75
25-30	14.00	12.60	29.40	140.00	70.00
30-35	13.20	8.25	23.10	107.25	54.45
35-40	13.30	5.70	17.10	79.80	49.40
40-45	10.75	2.15	12.90	55.90	47.30
45-50	7.20	2.40	9.60	40.80	48.00
50-55	2.65	2.65	7.95	29.15	45.05
55-60	0	0	2.90	17.40	43.50
	235.25 g. cm.	330.60 g. cm.	1012.10 g. cm.	2704.55 g. cm.	2011.70 g. cm.

TABLE 13

DIRECT WORK—STATION 3

Depth. m.	June 17	July 9	August 2	August 29
0-5	47.25	232.50	154.50	177.75
5-10	50.00	200.00	396.00	428.00
10-15	58.50	65.00	571.00	500.50
15-20	40.50	36.00	594.00	252.00
20-25	17.25	25.30	483.00	80.20
25-30	11.20	9.80	294.00	60.20
30-35	9.95	3.30	161.70	49.50
35-40	7.60	1.90	89.30	43.70
40-45	4.30	0	43.00	38.70
45-50	0	0	19.20	38.40
50-55			10.60	34.45
55-60			8.70	31.90
60-65			9.45	28.35
65-70			6.80	27.20
70-75			7.30	25.55
75-80			3.90	19.50
80-85			4.15	16.60
85-90			4.40	13.20
90-95			4.65	13.95
95-100			0	9.80
100-105				5.15
105-110				5.40
110-115				0
115-120				0
120-123.4				0
	246.55 g. cm.	573.80 g. cm.	2865.65 g. cm.	1900.00 g. cm.

(3) that during the storm of July 30, the expenditure took place chiefly in the 10-20 metre area of the open portion of the lake, but in the 10-15 metre area of the more or less sheltered bay. In both cases considerable work was involved in distributing heat in the hypolimnion. It would appear that during the storm probably about 10,000 calories per sq. cm. of surface were distributed in the open waters of the lake requiring about 1500 g. cm. of work.

(4) that a considerable amount of work was expended in the deeper waters of the hypolimnion during August, since these waters continued to gain heat for some time following the storm.

In approximate terms then it may be said that in 1921, 2500 gram-centimetres of work per square centimetre of area were needed to distribute 30,000 gram-calories of heat per square centimetre of area in the waters of Lake Nipigon. This means, then, that our northern waters are essentially similar to those of more southerly distribution in the matter of summer heat income and its distribution. Where they differ, is in the length of the period from the time when the temperature begins to rise above 4°C. until a uniform temperature of 4°C. is again reached in the autumn. This summer period is of short duration. For example, ice may appear in Lake Nipigon in November and the lake be entirely frozen over by the end of December. The lake may not be free of ice again until the middle of May and occasionally not until early in June. In contrast to this, Cayuga Lake rarely freezes over and when it does so, the period lasts but little over a month (Birge and Juday, 1914). Strong summer winds would therefore appear to be of special importance in the northern regions. It is probable that in a season of little wind the summer heat income for Lake Nipigon would be very small. It is evident that the summer or growing period for the organisms in Lake Nipigon is comparatively short and it is hoped that data in regard to the effect of this condition in causing a slow rate of growth for fish may be presented later. However, it does not appear that the productiveness of such a lake in respect of those fish which can tolerate a short summer period, such as the common white-fish, will be any less than that of a lake with a longer summer period, if other factors such as those of food, oxygen supply, spawning conditions, etc., are equal. That the short summer period is one of the factors contributing to the absence of certain species of fish from our northern waters is probable, in that doubtless some species are unable, in the short time available, to accumulate sufficient reserve material to carry them through the long winter period and allow them to spawn successfully in the spring.

Colour and Transparency

A white wooden disk 20 cm. in diameter was used in the determination of the transparency and a U.S. Geological Survey standard colorimeter for the colour. The following records were obtained by Mr. George Geiger:

No.	Date	Time	Location	Transparency feet	Colour
1	Sept. 11	10 a.m.	off Cedar Island		7
2	" 11	10 a.m.	east of Shakespeare Island	11.7	10
3	" 13	3.30 p.m.	2 mi. south of Echo Rock		7
4	" 16	2 p.m.	Sturgeon river	12.6	37
5	" 17	11 a.m.	Gull river		61
6	" 17	12 noon	Gull Bay		31
7	" 17	12.30 p.m.	Gull Bay		31
8	" 23	11.45 a.m.	Open waters south of Cedar Is.	17.0	7

In No. 2, the water seemed to be slightly turbid with clay. In determining the colours the standard tube was used empty since no distilled water was available. Many other tests in the open parts of the lake gave colour values of about 7.

The transparency of the open waters is thus high, comparing closely with those of Cayuga Lake (Birge and Juday, loc. cit.). The colour is slight in the open waters but is very dark brown in all of the streams tested and observed and persists to some extent in the shore waters of the lake, particularly around the mouths of the streams. This dark brown colour, no doubt, has some relation to the dark colouration of many shore-water fish such as the pike perch, lake trout and some of the whitefish.

Dissolved Gases

The results of the oxygen determinations (Tables 1, 2 and 3, and Figs. 4 and 5), for this season show:

(1) that from the middle of June to the middle of August

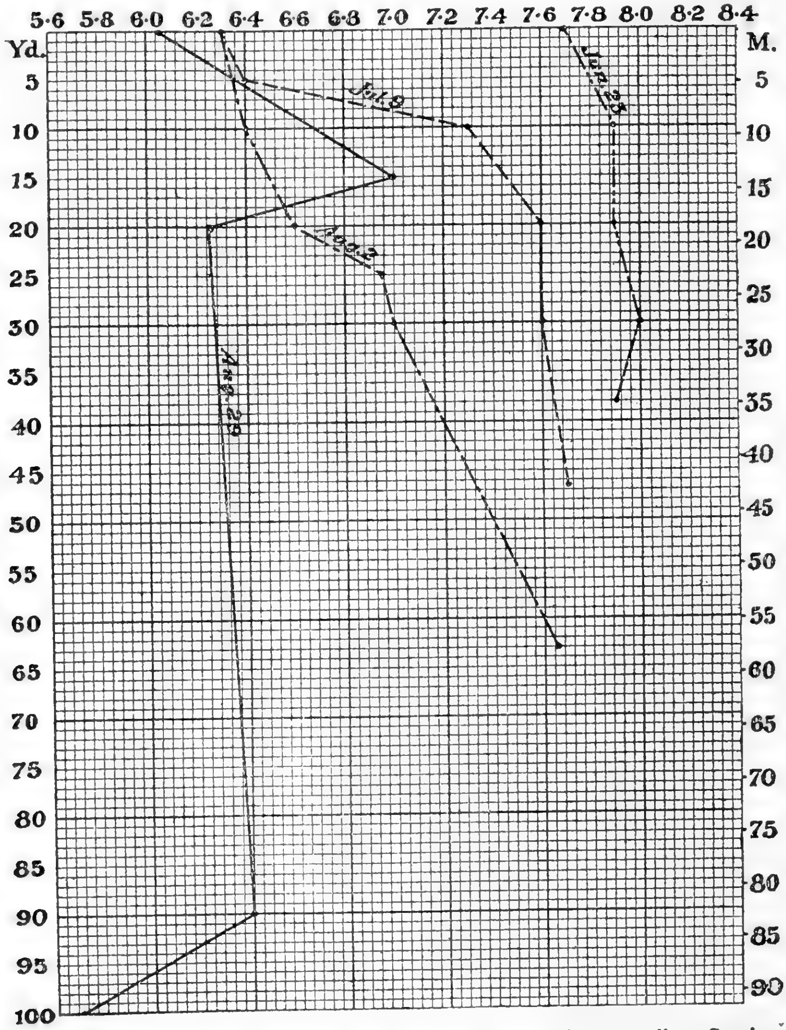


FIG. 4. Curves illustrating amounts of dissolved oxygen in cc. per litre, Station 3, Lake Nipigon.

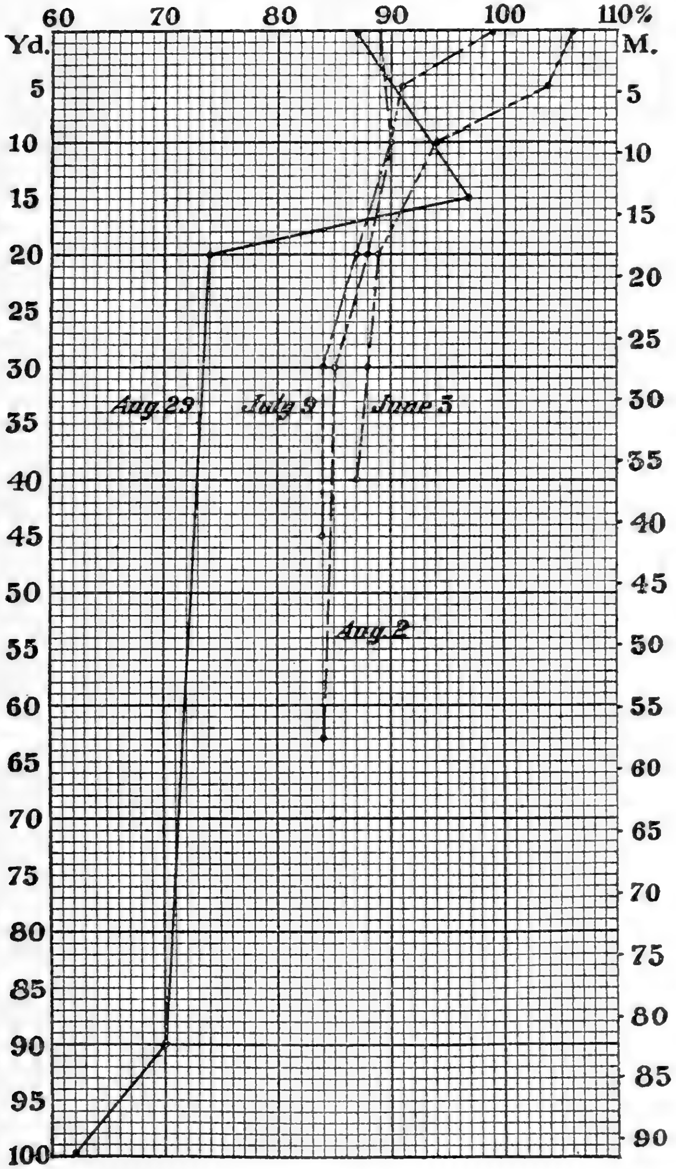


FIG. 5. Curves illustrating percentages of saturation of dissolved oxygen, Station 3, Lake Nipigon.

there was a plentiful supply of dissolved oxygen, the content seldom going below about 85% of saturation.

(2) that toward the end of August, the waters of the hypolimnion showed a marked reduction in oxygen content, the bottom waters at a depth of 100 yards having but 62% of saturation.

(3) that it is unlikely that the oxygen supply in the deep waters ever nears depletion and that in respect of dissolved oxygen, the lake is well suited to a deep-water fish fauna.

The results of the free carbon dioxide determinations (Tables 1, 2 and 3) show:—

(1) that at no time during the summer months was the amount of carbon dioxide large at any depth.

(2) that in the early part of the summer the upper waters contained the larger amounts but as the season advanced this condition was reversed, doubtless correlated with the growth of phytoplankton in the upper waters and the increase in decomposition processes in the bottom waters.

Conclusion

In conclusion it may be said (1) that Lake Nipigon possesses those features characteristic of large open bodies of water and does not appear to present any striking peculiarities in respect of physico-chemical conditions thus far investigated, except in regard to the short summer period; (2) that the peculiarities of its fauna and flora are the result of, at least the following three outstanding factors, (a) the short summer period, (b) the limited amount of shallow, protected water areas, (c) the isolation from the Great Lakes because of the falls and rapids in the single outlet.

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UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 12

A PROVISIONAL LIST OF THE FISHES OF LAKE NIPIGON

BY

JOHN R. DYMOND
OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

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1923

A PROVISIONAL LIST OF THE FISHES OF LAKE NIPIGON

The following brief account of the fishes of Lake Nipigon is based upon material obtained by the first field party of 1921. It contains a list of the species so far identified, with some reference to undetermined varieties, and is preliminary to a more comprehensive study and report, the material for which will, it is expected, be obtained during the summer of 1922.

The most striking feature of the fish fauna of Lake Nipigon, in view of its size, is the small number of species which inhabit it. As a result of the first season's work there fewer than thirty species were found in the waters of the lake itself. This is in striking contrast to what is found in other large lakes. Dymond (1922) gives ninety-one species of fish and two species of lamprey as occurring in Lake Erie, while Bensley (1915) records forty-eight species from Georgian Bay.

The small number of species occurring in Lake Nipigon is no doubt due in part to the physical conditions in the lake and in part to its geological history. Its waters have been isolated for long ages from the waters of the lower lakes, by means of falls sufficiently high to offer an insurmountable obstacle to the ascent of species from the south. Some species found in neighbouring lakes are absent from Lake Nipigon, which probably means that conditions in the lake are unsuitable for these forms.

The Sturgeon, *Acipenser rubicundus* Le Sueur, is fairly abundant. During 1919, 17,595 pounds were taken from the lake. The largest specimen recorded weighed 99 pounds.

The Long-nosed or Northern Sucker, *Catostomus catostomus* (Forster), and the Common Sucker, *Catostomus com-*

mersonii (Lacépède), are very abundant. The former, especially, is taken in considerable numbers in deep waters in gill nets set for whitefish and lake trout. The Common Sucker is found in shallower water. On account of the distance from market it is not profitable to ship these species, and those taken in the nets are consequently destroyed.

Only four species of *Cyprinidae* were found in the lake. In the order of their relative abundance they are, the Spot-tailed Minnow, *Notropis hudsonius* (De Witt Clinton), Lake Chub, *Couesius plumbeus* (Agassiz), Long-nosed Dace, *Rhinichthys cataractæ* (Cuvier and Valenciennes), and the Shiner, *Notropis atherinoides* Rafinesque. None of them appears to be at all common, and no specimens of any of them were identified in the stomachs of fishes. *Leuciscus neogæus* (Cope) is found in a number of small lakes in the neighbourhood, but has not been taken from Lake Nipigon itself. This species has not been previously recorded from Ontario.

Speckled Trout, *Salvelinus fontinalis* (Mitchill), of unusual size are taken on the line in the Nipigon river. The largest one taken in recent years weighed 14½ pounds, but specimens of five pounds in weight are quite commonly secured. They are also found in the fishermen's pound nets, but fish so taken are returned to the water.

The Lake Trout, *Cristivomer namaycush* (Walbaum), is, next to the whitefish, the most important commercial species of Lake Nipigon. It is usually taken in gill-nets in deep water, but a very dark, slim form is commonly taken in pound nets in shallow water. The significance of the latter variety is to be further investigated.

The Round Whitefish, *Coregonus quadrilateralis* Richardson, is not uncommon. It appears to remain in comparatively shallow water. On account of its slimness, it is not taken in the fishermen's nets.

The Common Whitefish, *Coregonus clupeaformis* (Mitchill), is the most important commercial species in the lake. The fishermen recognize two types, *viz.*, the deep-water and the shallow-water forms. In general, the latter is a darker, slimmer fish than the former, although both types are taken in deep water. The two extremes are connected by intergradations. The variation in colour, form, and other characters dependent on depth and other factors has not yet been fully investigated.

The Ciscoes or Lake Herrings, *Leucichthys* spp., have not yet been definitely worked out, but there appear to be at least three varieties. The commonest form is a dark fish with black fins. It averages about $1\frac{1}{2}$ pounds in weight. A larger, lighter-coloured form, locally known as "Tullibee", is occasionally taken in the gill-nets in deep water. A much smaller variety with longer head and very pale fins appears to be confined to comparatively shallow water.

The Pike, *Lucius lucius* (Linn.), is common in small bays along shore, and is occasionally taken in the fishermen's nets.

The Brook Stickleback, *Eucalia inconstans* (Kirtland), is much less common than the nine-spined Stickleback, *Pygosteus pungitius* (Linn.). The latter is perhaps the most abundant of the smaller species inhabiting the lake, some specimens being taken in nearly all seine catches. It was also commonly found in the stomachs of Pike Perch, and less commonly in Lake Trout, Ling, Pike, and Whitefish.

The Trout Perch, *Percopsis omisco maycus* (Walbaum), appears to be common. A few specimens were taken from the stomachs of predaceous species, and thousands were taken in July in a specially constructed bag net set in a stream a few hundred yards above where it enters the lake.

The Small-mouthed Black Bass, *Micropterus dolomieu* Lacépède, is believed not to occur naturally in Lake Nipigon. Small specimens of the year were taken in the seine near the foot of Orient Bay in July. They were probably the progeny of some parent fish planted the previous season.

The Yellow Pickerel or Pike Perch, *Stizostedion vitreum* (Mitchill), is an important commercial species in Lake Nipigon. It is taken in pound nets in shallow water. The maximum size attained is about nine pounds.

The Yellow Perch, *Perca flavescens* (Mitchill), was taken in considerable numbers in small bays by means of the seine.

For some reason the species does not reach a very large size, the largest specimen secured being six inches in length.

The only species of darter taken was the Tessellated Darter, *Boleosoma nigrum* (Rafinesque.) It was commonly taken in the seine in shallow water.

A number of specimens of the Miller's Thumb, *Cottus ictalops* (Rafinesque), and of *Uranidea gracilis* (Heckel), were taken about the middle of June in a specially constructed bag net set in a stream a short distance from where it enters the lake. Partly digested specimens, too fragmentary for definite determination, taken from the stomachs of ling may represent a third species of the family *Cottidae*.

The Ling, *Lota maculosa* (Le Sueur), is very common in deep water, and large numbers are taken in gill nets set for Whitefish.

Although this list is not extensive, it includes the principal commercial species characteristic of the Great Lakes. Its deficiency is mainly in *Cyprinidae* and other small forms. To what extent this deficiency limits the productivity of the lake by curtailing the food of the larger predaceous species cannot be estimated until other bodies of water, rich in the smaller species, have been investigated.

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UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 13

THE PLANKTON OF LAKE NIPIGON AND ENVIRONS

BY

N. K. BIGELOW

OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

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THE PLANKTON OF LAKE NIPIGON AND ENVIRONS

The following preliminary record of the more minute fauna and flora of Lake Nipigon and vicinity is the result of extensive collections made during the summer of 1921. The material studied was obtained from four sources:—

(1) By means of a vertical closing net, plankton samples were taken from the open waters at all depths. Three stations were established, and visited regularly. Station I was located off the mouth of the Nipigon River; Station II, in the deep water of Pijitawabik Bay (Orient Bay), directly opposite the village of Macdiarmid; Station III, in the open waters opposite the mouth of Sandy River. The usual type of closing net was used, made of bolting silk, size No. 20, and vertical tows were made through five and ten yard intervals. The quantitative results will be presented in a later paper.

(2) Surface tows were made in many places in the lake and in the lower portions of some of the larger streams.

(3) Many interesting forms were secured by sweeping with a small, conical net among aquatic vegetation in streams, bayous, ponds, pools, cold springs, etc.

(4) The stomach contents of many species of fish yielded much valuable data. Young fish, particularly the young of the common sucker (*Catostomus commersonii*) were found to be excellent collectors of small organisms. Several hundred small suckers were examined, and their digestive tracts were found each to contain from 30 to 50 or more different species of microscopic animals and plants. When from two to four centimetres in length, they were found to have subsisted almost entirely upon plankton. Slightly larger specimens taken a little later in the season were found to have fed upon the surface of the bottom ooze, where myriads of *Rotatoria*, *Cladocera*, *Diatoms*, etc., occurred.

In the lists of organisms mentioned in this paper the following designations are used: A. = abundant; V.C. = very common; C. = common; F. = fairly common; I. = infrequent; R. = rare.

An asterisk after the name of an organism denotes that the species had been taken as food by the young suckers previously mentioned.

ALGAE

CLASS MYXOPHYCEAE

The abundance of blue green *Algae* in Lake Nipigon and its vicinity was found to be insignificant in comparison with that of the diatoms; nevertheless, a considerable number of species were found to occur. The only genera found in the open-water plankton were *Microcystis*, *Anabaena*, and *Aphanizomenon*. The other genera occurred in creeks, bayous, ponds, and pools.

ORDER COCCOGONEALES

FAMILY CHROOCOCCACEAE

Chroococcus limneticus Lemmermann I.

Chroococcus turgidus Nägeli * F.

Coelosphaerium sp. I.

Merismopedia elegans Braun * F.

Microcystis aeruginosa Kützing * A. Although this species was not present in sufficient numbers to be the direct cause of lake bloom, it contributed to this formation by mingling with the more abundant *Anabaena*.

Microcystis flos-aquae Kirchner * V.C.

Aphanocapsa sp. * I.

Aphanothece sp. I.

Gloeothece sp. I.

Dactylococcopsis sp. * I.

ORDER HORMOGONEALES

FAMILY OSCILLATORIACEAE

Lyngbya birgei Smith * I.

Oscillatoria sp. F. Myxophytes of this genus were found only in small pools.

FAMILY NOSTOCACEAE

Nostoc sp. Pale green colonies of a species of this alga were found attached to weeds in a sluggish creek near Orient Bay. The colonies were spherical, but only about 8 mm. in diameter.

Anabaena circinalis Rabenhorst A.

Anabaena lemmermanni Richter * A. Long strips of lake bloom in the latter part of July and in August were found, on microscopic examination, to be masses of spores of this species, from which the surrounding filaments had disintegrated. Masses of the same kind of spores were found occasionally in the digestive tracts of young suckers.

Aphanizomenon flos-aquae Ralfs. R.

FAMILY RIVULARIACEAE

Rivularia sp. F.

CLASS BACILLARIACEAE

Of all the minute organisms found in Lake Nipigon diatoms were by far the most numerous. They occurred in prodigious numbers in the plankton, being often so very numerous that other organisms had to be specially searched for. They were also very abundant in the ooze and among aquatic vegetation. A large percentage of the food of bottom-feeding fish was found to be diatomaceous. The genera of diatoms found in open-water plankton in order of greatest abundance were *Melosira*, *Asterionella*, *Tabellaria*, *Synedra*, *Stephanodiscus*, and *Fragillaria*.

FAMILY MELOSIRACEAE

Melosira granulata Ehr. * A. During the month of June this diatom was so abundant that, if the net were towed behind a motor-boat at Station I or Station II for five minutes, it would contain at least half-a-pint of greenish-coloured plankton, which was found to be composed of about 95% of this particular organism. Quantitative methods of counting sometimes showed as many as 145,000 filaments per cubic centimetre. By the middle of July, *Asterionella* was much commoner on the surface, but *Melosira* was still quite common in the deeper water. In the latter part of August, *Melosira* had become a rather uncommon species.

FAMILY COSCINODISCACEAE

Stephanodiscus sp. * C.

FAMILY RHIZOSOLENIDACEAE

Rhizosolenia sp. F. A diatom of this genus was fairly common in the plankton of Station II during the month of June. The species was very slender, and possessed very long indistinct terminal spines. In all probability it was a much commoner organism than appearances would indicate as its extreme transparency rendered it difficult to see.

FAMILY NAVICULACEAE

Pleurosigma sp. * I.
Pinnularia sp. * V.C.
Navicula sp. * V.C.
Stauroneis sp. * F.

FAMILY CYMBELLACEAE

Amphora sp. * I.
Cymbella sp. * C.
Cocconema sp. * V.C.
Encyonema sp. * R.

FAMILY GOMPHONEMIACEAE

Gomphonema sp. * C

FAMILY ACHNANTHACEAE

Achnanthes sp. * C.

FAMILY NITZSCHIACEAE

Nitzschia sp. F.

FAMILY AMPHIPRORACEAE

Amphiprora sp. * I.

FAMILY SURIRELLACEAE

Campylodiscus sp. * I.
Cymatopleura sp. * C.
Surirella sp. * V.C.

FAMILY DIATOMACEAE

Denticula sp. R.

FAMILY MERIDIONACEAE

Meridion circulare (Gren) C. Large brown masses of this species were found in a cold spring near Fairlock.

FAMILY FRAGILLARIACEAE

Synedra sp. * V.C.
Fragillaria sp. * C.
Asterionella formosa Hass. A. Next to *Melosira* this was the most abundant organism of the open-water plankton. It appeared to be commonest after *Melosira* had declined in numbers, but this may have been due, somewhat, to the fact that the thinning out of the latter rendered it more conspicuous. Plankton composed of *Asterionella* is very white in contrast to the green *Melosira*.

FAMILY TABELLARIACEAE

Tabellaria fenestrata Kützing * A. This was the third commonest diatom. It reached its culminating numbers in late summer, when *Asterionella* had greatly decreased and *Melosira* was scarce. Plankton composed of this species was white, but not so purely white as that composed of *Asterionella*. At the end of August the base of the stems of rushes standing in shallow water near the head of Orient Bay were found to be encased in a coating of whitish, slimy material which was found to be entirely composed of this *Tabellaria*. Apparently the long zigzag filaments had become tangled together and, being washed by the waves, had collected around the stems of the rushes. Several young suckers taken near this locality at this time had been feeding almost entirely upon this material as the contents of their alimentary tracts averaged from 95% to 98% *T. fenestrata.*

Tabellaria flocculosa Kützing * V.C.

FAMILY EPITHEMIACEAE

Epithemia sp. * V.C.

Ceratoneis arcus Kützing F. One plankton tow from Sandy Bay early in June contained fair numbers of this species; otherwise it was scarce.

CLASS HETEROKONTEAE

ORDER HETEROCOCCALES

FAMILY OPHIOCYTIACEAE

Ophiocytium capitatum Wolle C. Masses of filamentous algae in a sluggish creek near the head of Orient Bay were found to contain numbers of this species.

Ophiocytium arbuscula (Braun) C. This species was found at the same time and place as the preceding.

FAMILY BOTRYOCOCCACEAE

Botryococcus braunii Kützing * A. The only other organism responsible for lake bloom besides *Anabaena lemmermanni* was this *Botryococcus.* It produced long strips of reddish colour in the latter part of July on the surface of the lake.

ORDER HETEROTRICHALES

FAMILY TRIBONEMACEAE

Tribonema minor (Wille) V.C. This alga was found only in tiny pools along the railway in June.

CLASS CHLOROPHYCEAE

ORDER VOLVOCALES

FAMILY VOLVOCACEAE

Pandorina morum Bory F.

Eudorina elegans Ehr. C.

Volvox aureus Ehr. C.

ORDER PROTOCOCCALES

FAMILY PALMELLACEAE

Sphaerocystis sp. F.

Tetraspora lacustris Lemmermann I.

Tetraspora sp. F. Long cylindrical masses of an alga of this genus occurred in pools along the railway near Macdiarmid in the month of June. These colonies were about 2 centimetres in length by 1/5 as wide.

FAMILY DICTYOSPHAERIACEAE

Dictyosphaerium sp.

FAMILY AUTOSPORACEAE

Oocystis sp. * V.C.

Tetraedron limneticum Birge R.

Ankistrodesmus falcatus Ralfs. R.

Quadrigula sp. R.

Kirchneriella lunaris Mobius * I.

Scenedesmus bijuga Lagerheim * I.

Coelastrum cambricum Archer * I.

Coelastrum proboscidium Bohlin R.

Sorastrum americanum Bohlin I.

Sorastrum spinulosum Nägeli I.

Actinastrum hantzschi Lagerheim F.

FAMILY HYDRODICTYACEAE

Pediastrum duplex Meyen * V.C.

Pediastrum boryanum Turpin * V.C.

Pediastrum tetras Ehr. I.

Pediastrum biradiatum Meyen R.

None of the *Algae* belonging to the orders *Volvoccales* or *Protococcales* were very abundant members of the flora of the Nipigon region. The only plankton in which they were found was that of bays and creeks.

ORDER ULOTRICHALES

FAMILY ULOTRICHACEAE

Ulothrix zonata Kützing C. Stones in shallow water near the margin of the lake were covered with a brown matting composed of this alga.

FAMILY CHAETOPHORACEAE

Chaetophora pisiformis Ag. C. Beautiful green masses of this species were attached to sticks and stones in a sluggish creek.

Coleochaete sp. F. The flattened colonies of this alga were found on the under surface of water-lily leaves.

ORDER SIPHONOCLADIALES

FAMILY CLADOPHORACEAE

Cladophora sp. A. The bottom of the lake for some distance from the margin was found often carpeted with a species of this plant. It is rather important as food for sturgeon, whitefish, and other bottom-feeding fish.

ORDER CONJUGALES

FAMILY ZYGNEMACEAE

Spirogyra sp. V.C. Several species of this alga occurred in ponds, creeks, and along the margin of the lake.

Zygnaema stellinum Ag. C. This species was common in sluggish creeks near Orient Bay.

Mougeotia viridis (Kützing) * A. This was the commonest species of the *Conjugales*, and was found in ponds, streams, and creeks, as well as at the margin of the lake.

FAMILY DESMIDIACEAE

Desmids occurred in considerable numbers in plankton swept from among weeds in sluggish creeks and bayous of the lake. They were especially numerous near the head of Orient Bay where the water is rather shallow. Weedy bayous occur along the bank and several sluggish creeks flow into the lake at this point, forming ideal conditions for their growth. Although many species of desmids were found they were never abundant enough to be an important constituent of the plankton. The following list contains only the recognized forms, besides which a great number of others occurred:

Penium sp. * I.

Closterium lunula Ehr. * I.

Closterium lineatum Ehr. C.
Closterium rostratum Ehr. V.C.
Docidium baculum (Breb.) * C.
Staurastrum coronulatum Wolle * I.
Staurastrum orbiculare Ralfs I.
Micrasterias rotata Ralfs * V.C.
Micrasterias furcata Ralfs F.
Micrasterias truncata Ralfs F.
Micrasterias americana Kutz F.
Cosmarium octhodes Nord. * V.C.
Sphaerozosma pulcrum Bailey I.
Hyalotheca sp. * F.
Desmidium swartzii Ag. * V.C.
Aptogonum baileyi Ralfs * R.
Gymnozyga sp. R.

PROTOZOA

CLASS RHIZOPODA

As might be expected these organisms were found mainly in the ooze and in the digestive tracts of bottom-haunting fish which had fed upon this material. With one or two exceptions none were found in open-water plankton except an occasional adventitive individual

ORDER GYMNAMOEBIDA

FAMILY AMOEBIDAE

Amoeba proteus Leidy F.

ORDER TESTACEA

FAMILY ARCELLIDAE

Arcella vulgaris Ehr. * F.
Arcella dentata Ehr. * R.
Centropyxis aculeata Stein * V.C.
Lecquereusia modesta Rhumbler * C.
Difflugia corona Wallich * V.C.
Difflugia lobostoma Leidy * V.C. Although *Difflugia* is usually considered to be a bottom-haunting organism, one small round form, answering in every way the description of

D. lobostoma, appeared in such numbers in the open-water plankton as to preclude the possibility of its being adventitious there. It was found most commonly on the surface, but occurred at all depths.

Difflugia pyriformis Perty * V.C.
Difflugia acuminata Ehr. * V.C.
Nebela sp. * R.

Order Testacea

Family Euglyphidae

Campascus ? * F. The test of an undetermined Sarcodinid protozoan was occasionally taken as food by small suckers. This rhizopod resembles *Campascus*, but the processes of the shell are closer together and more terminal than in *Campascus cornutus*.

Cyphoderia ampulla Ehr. * V.C.
Cyphoderia ampulla var. *papillata* Wailes * I.
Assulina seminulum Ehr. * F.
Euglypha alveolata Dujardin * C.

In all probability several species of *Euglypha* occurred.

The list of rhizopods would probably be greatly extended if sphagnum bogs and other likely spots had been specially searched for them.

Class Actinopoda

Order Aphrothroracida

Actinophrys sol Ehr. F.

Order Chalathoraca

Pompholyxophrys punicea Archer I.

Class Zoomastigophora

Order Euglenida

Family Euglenidae

Trachelomonas hispida Stein I.
Phacus longicaudus Ehr. I.

CLASS PHYTOMASTIGOPHORA

ORDER CHRYSOFLAGELLIDA

Mallomonas sp. F. These organisms were commonest in a plankton tow, not on the surface, but at a depth of about 8 metres, near North Bay on July 19.

Spongomonas sp. F. Long, slender, yellowish-brown colonies, often twisted and irregular, were found among weeds in a sluggish creek near Orient Bay during the latter part of August.

Rhipidodendron splendidum Stein F. Small masses of the tubules of this flagellate were found at the same time and place as the colonies of the preceding species.

Synura uvella Ehr. F. Colonies of these protozoa were fairly common in ponds and pools.

Dinobryon sertularia Ehr. A. This species was sometimes abundant during the month of June in plankton from bays and creeks.

Dinobryon bavaricum Imhof. F. Very typical example of this species occurred during the latter part of June in plankton from Station II. It was always found with the preceding species, but never was so abundant.

Peridinium sp. F.

Ceratium hirundinella Müller A. This species was occasionally abundant during the month of July in plankton from bays and creeks.

CLASS CILIATA

The ciliates included in the following list were mostly found in ponds and pools. *Codonella* is a typical open-water planktont and was found at all depths. *Vorticellae* were attached to colonies of *Anabaena* in the lake.

ORDER HOLOTRICHA

Coleps hirtus Ehr. C.
Didinium nasutum Müller F.
Nassula ornata Ehr. R.
Trachelius ovum Ehr. F.

Urocentrum turbo Müller C.
Ophryoglena atra Ehr. I.
Colpidium sp. F.
Cyclidium sp. F.
Paramoecium caudatum Ehr. C.

ORDER HETEROTRICHA

Stentor coeruleus Ehr. C.
Halteria grandinella Müller C.
Codonella sp. V.C.

ORDER HYPOTRICHA

Oxytricha sp. C.

ORDER PEROTRICHA

Vorticella sp. V.C. A number of species occurred.

Ophrydium eichhornii Ehr. I. Two beautiful green colonies of this ciliate were found attached to vegetation in a creek.

Pyxicola sp. I.

CLASS SUCTORIA

Podophrya sp. F. A pear-shaped species of this genus, with a long stalk, was often found attached to the legs and antennae of *Limnocalanus macrurus* and *Mysis relicta.* The crustaceans were often taken from a depth of 60 metres or more.

ROTATORIA

Although a great many species of the wheel animalcules were found, no one species was conspicuously abundant. Forming, as they do, a large percentage of the first food of young fishes, their economic importance is considerable.

ORDER PLOIMA

FAMILY NOTOMATIDAE

Eosphora sp. F. In pools along the railroad track.
Notomata aurita Müller I. In weedy creeks.
Diaschiza I. Several sp. In weedy creeks.
Cephalodella forficula Ehr. I. In weedy creeks.
Monommata orbis Ehr. I. In weedy creeks.

FAMILY BRACHIONIDAE

Brachionus capsiflorus Pallas R. Only one specimen of this species and genus was found during the season. It was a typical example of the form previously known as *Brachionus bakeri* with long, gracefully curved cephalic and posterior spines. It was found in a small pond close to Macdiarmid village.

FAMILY BRACHIONIDAE

Platyias quadricornis Ehr. C. This rotifer was found throughout the summer among weeds and algae in small pools and sluggish creeks, but never in the lake. *Keratella cochlearis* Gosse * V.C. This proved to be the most widely distributed species in the region under discussion, and was found in all bodies of water examined except in temporary pools. In the lake it occurred at all depths from the surface down to a hundred metres throughout the season.

Keratella quadrata Müller F. This was an open-water form and was found from the surface down to a depth of 100 metres. It was by no means as common as the preceding species, three individuals being the greatest number noted in any one plankton haul. The rotifer was taken from the latter part of July until the end of August. The individuals had very large posterior spines, broad at their bases, and widely divergent.

Keratella serrulata Ehr. * I. This species was found only in creeks and bays. The specimens showed the typical, prominent hexagons on the lorica and roughened projections on the egg carried, as well as on the lorica.

Anuraeopsis fissa Gosse F. During the month of June this species occurred in a small pond close to Macdiarmid village.

Notholca longispina Kellicott * V.C. Next to *Keratella cochlearis*, this was the commonest rotifer. It occurred throughout the summer at all depths from the surface down to 100 metres. It was also found in creeks and some of the larger ponds.

Notholca striata Müller * C. Although found occasionally in open-water plankton this species was commonest in bays and creeks. Nearly all small suckers taken during July and August near Orient Bay had eaten it. Besides typical *Notholca striata*, the forms of this species which were previously designated as *Notholca thalassia* and *Notholca acuminata* were frequently found.

Notholca foliacea Ehr. * I. This species was taken a few times in plankton from Station II. A few were eaten by suckers in July and August.

FAMILY MYTILINIDAE

Mytilina mucronata Müller * C. This species was found in weedy creeks throughout the season.

FAMILY EUCHLANIDAE

Euchlanis deflexa Gosse * F.
Euchlanis dilatata Ehr. I.
Diplois propatula Gosse F.
Lecane ohioensis (Herrick) * C.
Lecane sulcata Gosse * C.
Lecane luna (Müller) * V.C.
Lecane leontina (Turner) I.
Monostyla bulla Gosse * C.
Monostyla lunaris Ehr. * F.
Monostyla quadridentata Ehr. R.

Members of this family and the next are found in bays and creeks among weeds and are frequently fed upon by young fish.

FAMILY LEPADELLIDAE

Lepadella ovalis Müller * F.
Lepadella acuminata Ehr. * F.
Lepadella ehrenbergii (Perte) R. A single individual was taken from the digestive tract of a young sucker.
Colurella adriatica Ehr. * F.
Colurella uncinatus (Müller) * I.
Squatinella longispinatum Tatem I. This species was found in plankton swept from among weeds in the Pustagone

River on August 23. A peculiar *Squatinella* was also found in this material which resembled a typical *S. longispinatum* except that it had a second long dorsal spine on the lorica some distance back of the first. This may be only a variation, as several quite normal individuals of this species occurred in the same material.

FAMILY TRICHOTRIIDAE

Trichotria pocillum Müller * F.

Macrochaetus collinsii (Gosse) I. Eight or nine individuals of this strange rotifer were taken from creeks and one from some plankton in the bay near Orient Bay village. The only other examples of this rotifer ever seen by the writer were from an entirely different environment, namely, in a small muddy pond in a cow-pasture near Cedar Rapids, Iowa.

Scaridium longicaudum (Müller) F. This rotifer was found among weeds in creeks.

Scaridium eudactylotum Gosse R. This rare rotifer was found but once in plankton from among weeds near the mouth of the Pustagone River.

Diurella tenuior (Gosse) * C.

Diurella stylata Eyferth * I.

Trichocerca cristata Harring F.

Trichocerca cylindrica (Imhof) I.

Trichocerca lata Jennings * C.

Trichocerca longiseta Schrank F.

Trichocerca multicrinis (Kellicott) I.

Several rotifers of this family not satisfactorily determined are not listed.

FAMILY CHROMOGASTRIDAE

Chromogaster ovalis (Bergendae) C. In middle and late summer this rotifer was rather common in open-water plankton, but was never found at any great depth.

FAMILY GASTROPODIDAE

Gastropus stylifer Imhof * V.C. This was a very common surface form in all parts of the lake throughout the season. It was also found in creeks and large ponds.

Ascomorpha eucadis Perty R. One rotifer of this species was taken from weeds growing on the bottom of a pond.

FAMILY SYNCHAETIDAE

Synchaeta stylata Wierzejski V.C. Throughout the season this species was very common in the lake. It was occasionally taken at considerable depths, but was much commoner near the surface. When this species was numerous its spiny resting eggs were sometimes common in the plankton.

FAMILY POLYARTHRIDAE

Polyarthra trigla Ehr. * V.C. In creeks, ponds, and bayous as well as in the open waters of the lake, this species was common tbroughout the season. It was commonest in the latter part of summer. It is mainly a surface form and was rarely taken in deep water.

FAMILY PLOESOMIDAE

Ploesoma lenticulare (Herrick) * V.C. This also was a surface form occurring tbroughout the summer in all parts of the lake.

Ploesoma hudsoni Imhof I. This species was found in similar conditions to the preceding, but was only seen about a dozen times.

FAMILY ASPLANCHNIDAE

Asplanchna sp. I. A large rotifer of this genus was occasionally found in open-water plankton. The specimens were in too poor a condition when examined to permit of specific determination.

FAMILY TESTUDINELLIDAE

Testudinella patina Hermann C. This beautiful discoid rotifer was common throughout the summer in weedy ponds and creeks. It was frequently attacked by some parasitic organism which filled its lorica with short cylindrical spores. Often the rotifer would be still alive when its shell had become so filled with these spores as to hide its internal organs completely from view.

Order Flosculariaceae

Family Floscularidae

Floscularia ringens (Linn.) I. On August 3 this species was found attached to weeds in South Bay.

Limnias melicerta Weisse I. The beautiful annulated tubes of this rotifer were swept from among weeds in a small creek near Orient Bay the latter part of August.

Family Conochilidae

Conochilus unicornis Rousselet I. Occasionally clusters of this rotifer were taken in open-water plankton.

Lacinularia sp. I. Masses of an undetermined species of this genus were attached to weeds in South and Orient Bays.

Order Collothecacea

Family Collothecidae

Collotheca algicola (Hudson) I. This rotifer was found in colonies of *Rivularia* attached to weeds in a creek near Orient Bay.

Collotheca ambigua (Hudson) F. This rotifer was found attached to weeds in sluggish streams.

Collotheca cornuta (Dobie) I. This species occurred under conditions similar to the above mentioned form.

Collotheca mutabilis (Hudson) F. This is a typical open-water planktont, free floating and never attached to weeds. It occurred in many parts of the lake, but always close to the surface.

Order Bdelloida

Family Adinetidae

Adineta sp. F. A species of this genus occurred in creeks and ponds and a similar, if not identical, one was taken from water contained in the leaves of pitcher plants.

FAMILY PHILONINIDAE

Rotaria rotatoria (Pallas) C.
Rotaria citrina Ehr. F.
Rotaria neptunia Ehr. R.
Philodina roseola Ehr. I.
Dissotrocha aculeata Ehr. I.

ARTHROPODA

CLASS CRUSTACEA

ORDER COPEPODA

FAMILY CENTROPAGIDAE

Epischura lacustris Forbes C. This large copepod was found near the surface in the open water of the lake and in creeks and bays. Although not frequently found in the plankton, its abundance is attested by the numbers found to have been eaten by small fishes. The stomach of a young small-mouth black bass (*Micropterus dolomieu*) contained 82 of these copepods, while 67 were found in another individual. These two fishes were 2.6 centimetres in length and were taken on July 19 at Orient Bay.

Diaptomus sicilis Forbes V.C. This was probably the commonest species of *Diaptomus* in Lake Nipigon. It was found in all parts of the lake, often at considerable depths but not in the deepest water.

Diaptomus minutus Lilljeborg C. This *Diaptomus* was not quite so common as the preceding form. It was not found until the middle of July, whereas *D. sicilis* occurred from the first of June. *D. minutus* was first found in creeks and shallow water, but as the season advanced it was taken in the surface waters of the more open parts of the lake. Quite often while making a series of vertical plankton hauls through various intervals from the bottom to the surface, *D. minutus* was found to occur in the first few metres below the surface after which *D. sicilis* would extend for a few metres more to be succeeded by *Limnocalanus*. Rather infrequently, late in the summer, both species of *Diaptomus* occurred together.

Limnocalanus macrurus Sars V.C. This copepod was found in numbers in the deeper, cooler waters of the lake. It was common from 40 to 50 metres below the surface. Sometimes over 200 individuals would be taken in a 5-metre haul at these depths. Probably this gives a very erroneous idea of its actual numbers as it is a large active creature which would swim away from the net and not be caught in the same way as the smaller constituents of the plankton, such as diatoms and rotifers. Its numbers must be enormous indeed, judging from the stomach contents of whitefish and ciscoes. Four ciscoes were found to have their alimentary tracts packed with fragments of countless thousands of this crustacean.

FAMILY CYCLOPIDAE

Cyclops * V.C Specific identifications in this genus were not attempted, although several species doubtless occur. Although often eaten by many kinds of fishes, it never was found in great numbers in any of the stomachs examined. A peculiar dark-coloured, opaque cyclops was taken on August 30 from a small pond near Fairlock.

FAMILY HARPACTICIDAE

Canthocamptus stapylinus (Jurine) * C.
Canthocamptus hiemalis (Pearse) * I.
Canthocamptus minutus (Claus.) * F.

FAMILY ERGASILIDAE

Ergasilus sp. I. A species of this copepod was found in the stomach of a ling which had been feeding upon the nine-spined stickleback (*Pygosteus pungitius*). Doubtless the parasite came from the latter fish.

ORDER OSTRACODA

Ostracods were of very great importance indeed as food for bottom feeding fish, as nearly all examined had eaten at least some of these crustaceans. A very few of the numerous species were identified.

Cypria sp. C. A species of this genus was taken from the stomach of a trout perch (*Percopsis omisco maycus*) from the Pustagone River.

Candona sp. V.C. This genus is fed upon by whitefish whenever it can be found. One whitefish's stomach was packed with fragments of the shells and appendages of thousands of these ostracods.

Spirocypris tuberculata Sharpe F. This species was found in weedy ponds.

Limnocythere reticulata Sharpe F. Although this is supposed to be a pond form, an ostracod answering the description of this species was found in a young sucker taken the latter part of summer near Macdiarmid.

Illyodromus pectinatus Sharpe R. One individual was found in the stomach of a common sucker, 26 cm. in length, on July 12.

Order Cladocera

At least 42 species and several varieties of these crustaceans were found in Lake Nipigon and its vicinity. They were found to be of great economic importance, as the food of fishes was sometimes very largely composed of them. Some outstanding points of interest concerning this group in the area under consideration are the absence of *Holopedium* and the frequency of species such as *Rhynchotalona falcata*, *Alonella nana*, *Pleuroxus hastatus*, and other *Cladocera* not supposed to be particularly common.

Family Sididae

Sida crystallina (Müller) * V.C. This entomostracan was not found in the more open parts of the lake, but was common in bays and creeks. Its frequency is shown by the fact that 40 out of 57 small suckers had eaten it, and in many instances over half of their food consisted of this crustacean. It was also eaten by the young of the small-mouth black bass (*Micropterus dolomieu*) and other fishes.

Latona setifera (Müller) I. One specimen of this cladoceran was found in ooze near Orient Bay, and three or four others in the stomachs of suckers, larger, with one exception, than those previously mentioned.

Diaphanosoma brachyurum (Liéven) * C. The fact that this species was not often found in fish stomachs is probably due to the fact that it is very perishable and its post-abdomen small and easily overlooked.

Diaphanosoma leuchtenbergianum Fischer * C.

FAMILY DAPHNIDAE

Daphnia pulex (de Geer) * V.C. The contrast in numbers between *Daphnia pulex* in Lake Nipigon and in Lake Erie was very noticeable. In the latter lake the ciscoes taken during the summer were found to have fed throughout the season upon countless thousands of this species. In Lake Nipigon only 13 out of 57 small suckers had eaten it during the latter part of July at Orient Bay. In fact, this cladoceran occurred more commonly in ponds and pools than in the lake. It was found to be very common, for example, in barrels of water on the railway bridge near Macdiarmid.

Daphnia pulex var. *minnehaha* Herrick F. This variety was found only in one small pond near Macdiarmid.

Daphnia retrocurva Forbes * F.

Daphnia longispina var. *hyalina* Leydig form *galeata* * C.

Simocephalus vetulus (Müller) I.

Scapholeberis mucronata (Müller) * C.

Ceriodaphnia reticulata (Jurine) C.

Ceriodaphnia lacustris Birge * I.

Ceriodaphnia quadrangula (Müller) F.

FAMILY BOSMINIDAE

Bosmina longirostris (Müller) * V.C.

Bosmina longispina Leydig I.

FAMILY MACROTHRICIDAE

Ophryoxus gracilis Sars * I.

Drepanothrix dentata (Eurén) * V.C.

Acantholeberis curvirostris (Müller) * V.C.

Illyocryptus spinifer Herrick * F.

FAMILY CHYDORIDAE

Eurycercus lamellatus (Müller) * F. This species was commonest among weeds in the Pustagone River. Only occasional specimens were taken elsewhere.

Camptocercus rectirostris Schoedler F. This cladoceran, like the species previously mentioned, was local in distribution. A great many specimens were found in a sucker taken at Sandy Bay.

Kurzia latissima (Kurz) * I.

Acroperus harpae Baird * V.C.

Alona guttata Sars * F.

Alona guttata var. *tuberculata* Kurz * I.

Alona affinis (Leydig) * C.

Alona quadrangularis (Müller) * C.

Alona costata Sars * C.

Graptoleberis testudinaria (Fischer) * F. This cladoceran was commonest among weeds in the Pustagone River. Only 2 specimens were taken from the young suckers.

Rhynchotalona falcata (Sars) * V.C. That this is no uncommon species is shown by the fact that 33 out of 56 small suckers had eaten it. The only part of Lake Nipigon in which it was taken was the head of Orient Bay.

Pleuroxus procurvatus Birge * C. This cladoceran was found in the greatest numbers in plankton taken from a small pond near Fairlock on August 31. Elsewhere its occurrence was only occasional.

Pleuroxus denticulatus Birge * V.C.

Pleuroxus hastatus Sars * V.C. This was the species of *Pleuroxus* found most commonly in the stomachs of small suckers.

Chydorus globosus Baird I.

Chydorus sphaericus (Müller) * V.C.

Chydorus faviformis Birge * R. Only 2 individuals of this *Chydorus* were found. One was from a small lake close to the fire ranger tower near Fairlock. The other had been eaten by a young sucker.

Alonella rostrata (Koch) R. One individual was found in a sucker from Sandy Bay.

Alonella nana (Baird) * V.C. This species was of common occurrence both in plankton from among weeds and in suckers from Orient Bay in July and August.

Alonella exigua (Lilljeborg) * C. Numbers of this *Alonella* were found among weeds in a sluggish creek but only one was eaten by the suckers examined.

Monospilus dispar Sars * F. The finding of ten specimens in one sucker would indicate that this species was not particularly rare.

FAMILY POLYPHEMIDAE

Polyphemus pediculus (Linn.) * V.C. This cladoceran was found in small pools and ponds as well as in creeks and bays. Its importance economically is shown by the fact that it had been fed upon by 48 out of 57 small suckers, taken at Orient Bay on July 19. In several instances it was the only species found, and formed the entire contents of the fishes' alimentary tracts.

FAMILY LEPTODORIDAE

Leptodora kindtii (Focke) * V.C. Locally abundant as shown by the examination of cisco stomachs.

In order to give some idea of the abundance of different species of *Cladocera* near the head of Orient Bay the following list of those species taken from three different lots of young suckers may prove useful. Lot A was taken on July 19, and the fishes averaged 2.3 centimetres in length. Lot B was taken on July 27, and the fishes averaged 3.2 centimetres in length. Lot C was taken on August 13, and the fishes averaged 3.8 centimetres in length. The number after the name of each cladoceran listed indicates how many of the fishes out of each lot had eaten that particular species.

Cladocera species	Lot A No. of fish 57	Lot B No. of fish 31	Lot C No. of fish 25
Sida crystallina	40	3	1
Diaphanosoma sp.	6	0	0
Daphnia pulex	13	0	0
Daphnia retrocurva	3	1	0
Daphnia longispina	8	0	1
Scapholeberis mucronata	20	0	0
Ceriodaphnia lacustris	3	0	0
Bosmina longirostris	20	0	20
Ophryoxus gracilis	0	2	0
Drepanothrix dentata	1	26	0
Acantholeberis curvirostris	1	20	0
Illyocryptus spinifer	0	1	11
Eurycercus lamellatus	2	4	1
Kurzia latissima	0	1	1
Acroperus harpae	27	8	0
Alona guttata	1	1	4
Alona guttata tuberculata	0	0	1
Alona costata	9	9	6
Alona quadrangularis	1	11	9
Alona affinis	6	9	13
Graptoleberis testudinaria	0	2	0
Rhynchotalona falcata	1	18	15
Pleuroxus procurvatus	4	0	0
Pleuroxus hastatus	2	23	12
Pleuroxus denticulatus	2	11	18
Chydorus faviformis	0	1	0
Chydorus sphaericus	9	21	18
Alonella nana	0	17	22
Alonella exigua	0	0	1
Monospilus dispar	0	2	10
Polyphemus pediculus	48	2	1
Leptodora kindtii	1	2	1

The greater number of open-water *Cladocera*, such as *Sida* and *Polyphemus*, in the first lot of fishes is due to the fact that, as the sucker gets larger, its mouth becomes more ventrally located and it feeds more upon the ooze and bottom forms of life. The greater numbers of some *Cladocera* in August may be due to an increase of these species in late summer. The average number of species of *Cladocera* taken from each sucker was 5, but several had eaten 12 and even 13 different species. The greatest number of different species taken from one fish was 14. This was a sucker from Lot B, and the list is as follows:—

Sida crystallina
Drepanothrix dentata
Acantholeberis curvirostris
Ophryoxus gracilis
Bosmina longirostris
Acroperus harpae
Alona quadrangularis
Alona costata
Alona affinis
Pleuroxus hastatus
Pleuroxus denticulatus
Alonella nana
Rhynchotalona falcata
Chydorus sphaericus

The presence of species such as *Sida* and *Bosmina* in bottom feeding fish is probably due to the fish eating dead or disabled individuals which have sunk from the plankton above.

CLASS ARACHNIDA

ORDER HYDRACARINA

Water mites are of considerable importance from the standpoint of fish food, as nearly all of the bottom-feeding fish contained these creatures, although never in numbers comparable with *Cladocera*. The larvae, or six-legged nymphs, were more frequently found than the adults. Those of the genus *Hygrobates* were probably most common, while the genera *Hydrachna* and *Arrhenurus* were found a few times. *Tardigrada* had been eaten by several of the young suckers.

CONCLUSION

This survey of the microscopic fauna and flora of Lake Nipigon formed a part of the larger study of the available fish food supply in this lake. The general conclusion to be drawn from this qualitative investigation is that Lake Nipigon is a body of water relatively poor in plankton, with the exception of the diatomaceous flora. The number of species occurring in the lake itself was not large, and with a few exceptions the number of individuals of a species was not large. This was particularly true of the open-water plankton. Such important forms as the species of *Daphnia* were uncommon, and apparently *Holopedium* was absent. *Leptodora kindtii* was the only cladoceran which was common in the open water. The *Copepoda* were much better represented in point of numbers, especially in the cases of *Diaptomus* and *Limnocalanus*. In the shallow protected bays, where occurred considerable growths of the higher aquatic vegetation, there was a much better representation of species and larger numbers of individuals. This was especially true of the *Rotatoria* and the *Cladocera*. From the standpoint of food-supply for the young of many species of fish, this is important.

The diatoms were vastly more numerous than all the other organisms combined. They are not directly of much value as fish food, and if of importance as food for the animal planktonts should have supported a much larger population than was found to occur. They may, however, be of considerable importance as food for the macroscopic bottom population, especially *Pontoporeia hoyi*, the larvae of the *Chironomidae* and the *Mollusca*, which are of extreme importance as fish food. The interrelations in the food complex are so involved that it is difficult at the present time to judge accurately the significance of certain organisms or groups of organisms, and it is apparent that studies of the food habits of the lower animals which serve as food for fish must be made before satisfactory conclusions may be arrived at in regard to the evaluation of the various constituents of the plankton.

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THE DISTRIBUTION AND ECONOMIC IMPORTANCE OF MOLLUSCA IN LAKE NIPIGON

BY

F. B. ADAMSTONE
OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

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THE DISTRIBUTION AND ECONOMIC IMPORTANCE OF MOLLUSCA IN LAKE NIPIGON

The limnobiological investigations carried out in Lake Nipigon during the summer of 1921 involved, amongst other work, a study of the bottom fauna. This was undertaken in order to obtain some knowledge of the species of animals inhabiting the lake bottom and to learn something of their abundance, distribution, and value as fish food. As this phase of the work came largely under the direction of the writer, the methods employed and the results obtained, in so far as they have to do with one group of animals, namely the *Mollusca*, will be given in this paper. For their interest and assistance in the carrying out of this investigation sincere thanks are given to the Honorary Advisory Council for Scientific and Industrial Research.

Methods of Investigation

The method employed in studying the animal life of the bottom was to dredge up samples of the material from the lake floor. For this purpose a small Ekman dredge* which covered an area of 81 square inches, was used. It was lowered open, by means of a small steel cable wound on a windlass, and, when released by a messenger dropped from the boat, its jaws closed upon a sample of the bottom. The material obtained in this manner was hauled up and placed in numbered trays, and data concerning depth, distance from shore, and character of bottom were tabulated in regard to each. Depth was measured directly by a counting machine, over which the cable passed, and distance from shore was estimated as accurately as possible either by judging short distances or by timing the boat. On other

*Dr. C. Juday kindly supplied this dredge.

occasions a drag dredge was used instead of the Ekman dredge. This piece of apparatus consisted of an iron frame to which a sack was attached, and as it was hauled over the bottom it scraped up any loose material with which it came into contact. It was impossible, however, to determine accurately the area of bottom covered by this dredge and it brought up so much material from one spot that the results obtained did not compensate for the time and labour involved in cleaning it. As a result, this dredge was finally abandoned in favour of the Ekman type. At times even the latter could not be used, as, for example, where the bottom was composed of rocks. The dredgings were supplemented by hand collecting along the margin of the lake.

In taking dredgings, a situation was usually chosen where the environmental features made it seem advisable to study the animal population. Then, by beginning in-shore as closely as possible, a series of from 4 to 10 hauls was made, gradually working out into deeper water, along a straight line. The distance between dredgings was governed largely by depth and character of bottom.

The material obtained was taken back to the laboratory and washed through screens of different grades of fineness, so that the loss of smaller organisms was eliminated as much as possible. The cleaned material was carefully sorted while the animals were still alive, and the specimens were preserved in seventy per cent. alcohol in vials.

For the study of the value of bottom organisms as fish food the stomach contents were taken from a large number of fish. This material was sorted over in the laboratory, and the various species of animals in it were identified and their relative importance estimated.

SPECIES OF MOLLUSCA OBTAINED

In the material collected during the summer 44 species of *Mollusca* were identified. Amongst these there are representatives of 8 families and 12 genera. A list of the species obtained is given on the following pages.

GASTROPODA

1. *Lymnaea apicina* Lea.
2. " *emarginata* Say.
3. " *galbana* Say.
4. " *stagnalis appressa* Say.
5. " *vahlii* Moll.

6. *Planorbis antrosus* Con.
   " " approaching *corrugatus* Curr.
   " " *striatus* Baker.
7. " *crista* L.
8. " *exacuous* Say.
9. " *hirsutus* Gld.
10. " *parvus* Say.
11. " *trivolvis* Say.

12. *Segmentina crassilabris* Walker.

13. *Physa ancillaria* Say.
14. " *gyrina* Say.
15. " sp.
16. " sp.

17. *Ferrissia parallela* Hald.

18. *Amnicola limosa* Say.
   " *limosa porata* Say.
19. " sp. possibly *A. pallida* Hald.

20. *Valvata sincera* Say.
21. " *tricarinata* Say.
   " " *perconfusa* Walker.

PELECYPODA

22. *Anodonta kennicotti* Lea.
23. " *marginata* Say.

24. *Lampsilis* (*Ligumia*) *superiorensis* Marsh.

25. *Pisidium compressum* Prime. (form of subsp. *pellucidum*).
26. " *fallax* Sterki.

27. *Pisidium idahoense* Roper.
28. " *indianense* Sterki.
29. " *medianum minutum* Sterki.
30. " *monas* Sterki.
31. " *pauperculum* Sterki (near subsp. *nylanderi* Sterki).
32. " *punctatum* Sterki (form *simplex*).
33. " *rotundatum* Prime.
34. " *scutellatum* Sterki.
    " " *cristatum* Sterki.
35. " *splendidulum* Sterki.
36. " *variabile* Prime.
37. " *vexum* Sterki.
38. " *walkeri* Sterki.
39. " sp. (known but not yet published).

40. *Sphaerium crassum* Sterki.
41. " *tenue* Prime.
42. " sp (probably *vermontanum* Prime).
43. *Musculium rosaceum* Prime.
44. " *securis* Prime.

There may be several additional species of *Pisidia*, according to Dr. V. Sterki.

The writer is greatly indebted to Dr. Bryant Walker and Dr. V. Sterki for assistance in the identification of specimens.

TABULATED RESULTS OF DREDGING OPERATIONS

In the following series of tables the results of the dredging operations are given. These show where operations were carried on and give data concerning the molluscan population and environment at each station. Dead specimens are not included in the numbers, but where empty shells were obtained the names have been inserted in the list.

The names of species of *Sphaeriidae* obtained in each locality are noted below each table.

ORIENT BAY AT MACDIARMID — Series II

Dredging	1	2	3	4	5	6	7	8	9
Depth (in feet)	7	45	120	162	93	72	60	12	11
Character of Bottom	Coarse Grit	Grit on Clay	Clay	Mud	Mud	Sand	Rock	Sand	Sand
Distance from Shore (yds.)	10	30	75	175	600	1200	1400	1800	1900
Planorbis antrosus	..	..	..	..	..	..	..	..	3
Planorbis parvus	6	..	..	..	..	..	..	..	..
Amnicola limosa	3	..	..	..	..	..	..	..	1
Amnicola sp.	1	..	..	..	..	..	..	..	..
Valvata sincera	..	..	..	..	..	..	..	2	5
Valvata tricarinata (var.)	..	..	..	..	..	..	..	..	1
Valvata tricarinata	..	..	..	..	..	..	..	3	3
Sphaeriidae	6	..	..	..	..	..	..	6	8

Pisidium compressum
" *pauperculum*
" *scutellatum*
" *variabile*
" sp.

SAND POINT BAY	Series III				SANDY RIVER TO N. SHAKESPEARE	Series IV				
Dredging	1	2	3	4	1	2	3	4	5	6
Depth (in feet)	6	12	21	45	12	21	27	30	48	159
Character of Bottom	Gravel	Gravel	Sand	Mud	Clay	Sand	Sand	Sand	Sand	Mud
Distance from Shore (yds.)	30	60	120	440	150	250	850	1200	2800	4550
Lymnaea galbana	..	..	1	..	..	..	..	..	..	..
Planorbis antrosus	..	2	..	..	..	..	..	..	..	..
Planorbis parvus	1	1	1	..	..	..	..	..	..	..
Amnicola limosa	..	..	..	..	..	1	..	..	..	..
Amnicola sp.	3	..	2	..	..	..	..	..	..	..
Valvata sincera	..	..	..	..	..	..	..	..	2	..
Valvata tricarinata (var.)	..	..	..	..	..	..	..	..	..	..
Valvata tricarinata	1	1	..	..	..	..	..	..	..	..
Physa sp.	..	..	..	..	..	1	..	..	..	..
Planorbis hirsutus	..	..	..	..	..	..	..	..	..	..
Sphaeriidae	1	1	..	..	..	2	..	16	8	..

Pisidium compressum
" *scutellatum*
Sphaerium tenue

SHAKESPEARE ISLAND TO SANDY RIVER — Series V

Dredging	1	2	3	4	5	6	7	8	9	10
Depth (in feet)	150	150	156	163	80	96	78	45	84	192
Character of Bottom	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Gravel	Clay	Mud
Distance from Shore	50 yd.	100 yd	200 yd	400 yd	800 yd	1 mile	2 miles	3 miles	$3\frac{1}{4}$ miles	6 miles
Lymnaea vahlii	..	..	..	..	..	..	..	..	D	..
" *stagnalis*	..	..	..	..	..	..	..	..	D	..
" sp.	..	..	..	..	..	..	..	D	..	..
Segmentina crassilabris	..	..	..	..	..	..	..	D	..	..
Planorbis hirsutus	..	..	..	..	..	..	..	..	D	..
" *parvus*	..	..	..	..	..	..	..	I	..	..
Valvata sincera	..	..	..	..	..	..	D	D	D	..
" *tricarinata*	..	..	..	..	..	..	..	..	D	..
Sphaeriidae	D	D	D	D	D	D	D	7	D	1. D

Pisidium sp.

SAND POINT BAY (OFF McCOLEMAN'S DOCK) Series VI

Dredging	1	2	3	4	5	6	7	8	9
Depth (in feet)	6	9	12	14	15	15	15	15	16
Character of Bottom	Sand	Sand	Sand	Sand & Gravel	Sand & Gravel	Sand & Gravel	Sand & Gravel	Sand & Gravel	Sand & Gravel
Distance from Shore (yd.)	75 ft.	100	150	175	200	225	250	275	300
Lymnaea galbana	..	..	1	..	..	..	..	..	..
" *emarginata*	..	..	..	..	..	..	..	..	..
Planorbis antrosus	..	..	1	1	..	1	..	1	3
Amnicola limosa	..	..	1	..	..	..	..	..	2
" sp.	..	..	..	..	..	..	..	..	3
Valvata sincera	..	..	..	..	1	..	..	1	1
" *tricarinata*	..	..	..	..	1	..	..	1	2
Lymnaea vahlii	..	..	..	..	1	..	..	..	..
Planorbis parvus	..	..	..	..	..	..	..	..	3
Sphaeriidae	..	..	..	..	..	..	..	3	1

Pisidium scutellatum
" sp. juv.
Sphaerium vermontanum

SAND POINT BAY (OFF McCOLEMAN'S DOCK) Series VII

Dredging	10	11	12	13	14	15	16	17
Depth (in feet)	15	21	27	39	53	60	69	75
Character of Bottom	Gravel	Gravel	Mud	Clay	Clay	Mud	Mud	Clay
Distance from Shore (yds.)	330	375	450	600	750	900	1200	1500
Lymnaea galbana	:	:	:	:	:	:	:	:
" *emarginata*	1	:	:	:	:	:	:	:
Planorbis antrosus	3	:	:	:	:	:	:	:
Amnicola limosa	:	:	:	:	:	:	:	:
" sp.	:	:	:	:	:	:	:	:
Valvata sincera	:	:	2	:	:	:	:	:
" *tricarinata*	2	1	:	:	:	:	:	:
Sphaeriidae	:	:	1	:	:	:	:	:

BAY EAST OF COOKE POINT — Series VIII

Dredging	1	2	3	4	5	6	7	8	9	10
Depth (in feet)	15	15	18	21	21	18	23	30	33	48
Character of Bottom	Sand	Sand	Sand	Sand	Gravel	Rock	Sand & Rock	Sand & Rock	Sand & Gravel	Mud
Distance from Shore (yds.)	100	150	200	250	325	400	500	880	1100	1800
Planorbis parvus	..	..	..	..	1	..	..	3	..	..
Amnicola limosa	..	..	..	1	..	5	..	..	..	..
Valvata sincera	..	1	..	..	..	..	..	..	..	..
" *tricarinata*	..	..	..	1	..	..	..	..	..	..
Sphaeriidae	2	2	1	1	..	..	..	..	..	..

Pisidium compressum
Sphaerium vermontanum

BLACKWATER BAY — Series IX

Dredging	1	2	3	4	5	6	7	8
Depth (in feet)	8	9	18	21	21	27	30	33
Character of Bottom	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Distance from Shore (yds.)	270	300	370	450	525	600	700	880
Lymnaea sp.	..	..	..	..	..	..	..	..
Planorbis parvus	..	..	..	..	..	..	..	..
Amnicola limosa	..	..	..	..	..	1	1	..
Valvata tricarinata (var.)	..	..	..	1	..	..	..	..
" *tricarinata*	..	..	..	..	..	2	..	..
" *sincera*	..	..	..	..	..	2	6	2

Sphaeriidae
Pisidum sp. juv.

BLACKWATER BAY — Series X

Dredging	1	2	3	4	5	6	7	8
Depth (in feet)	12	21	24	27	29	36	39	39
Character of Bottom	Sand	Gravel	Sand	Sand	Sand	Sand	Sand	Sand
Distance from Shore (yds.)	50	100	150	200	300	700	900	900
Lymnaea vahlii	. .	. .	. .	. .	. .	. .	. .	1
Planorbis antrosus	. .	1	. .	. .	. .	. .	. .	. .
" *parvus*	. .	. .	. .	. .	. .	2	. .	. .
Amnicola limosa	. .	1	. .	. .	. .	. .	. .	. .
Valvata tricarinata (var.)	. .	. .	. .	. .	. .	. .	. .	1
" *sincera*	. .	. .	. .	. .	. .	1	. .	6
" *tricarinata*	. .	. .	. .	. .	. .	3	. .	. .
Sphaeriidae	. .	2	. .	1	. .	2	. .	1

Pisidium monas
" *medianum minutum*
" *scutellatum*
" sp. juv.

SOUTH SHAKESPEARE ISLANDS — Series XI

Dredging	1	2	3	4	5	6	7	8
Depth (in feet)	3	6	27	48	48	54	51	30
Character of Bottom	Rock	Sand	Clay	Ooze	Ooze	Ooze	Ooze	Ooze
Distance from Shore (yd.)	5	15	80	200	400	600	800	900
Lymnaea vahlii	..	..	..	..	..	..	..	..
Planorbis antrosus	..	1	..	..	..	..	..	..
" *parvus*	..	2	..	..	..	..	..	1
Physa sp.	..	..	..	..	..	..	..	..
Amnicola limosa	1	29	..	..	..	..	..	..
Valvata sincera	..	1	..	..	..	..	..	..
" *tricarinata*	..	..	..	..	..	..	..	..
Sphaeriidae	3	20	..	..	..	..	..	..

Pisidium compressum
" *fallax*
" *pauperculum*
" *scutellatum*
Sphaerium vermontanum (?)

EAST SHAKESPEARE ISLANDS — Series XII

Dredging	1	2	3	4	5	6	7
Depth (in feet)	6	15	21	21	21	18	15
Character of Bottom	Sand among Rocks	Sand	Mud	Algae	Algae	Sand	Sand
Distance from shore (yds.)	15	50	100	200	400	800	1000
Lymnaea emarginata	..	..	..	..	..	..	..
" *galbana*	..	1	..	..	..	..	1
" *vahlii*	..	..	1	..	..	..	..
Planorbis antrosus	..	1	..	..	..	..	1
" *hirsutus*	..	..	..	..	..	..	..
" *parvus*	..	..	1	..	..	..	2
Amnicola limosa	..	5	..	..	..	..	..
" sp.	..	..	..	..	1	1	3
Valvata sincera	..	..	1	5	2	2	3
" *tricarinata*	..	1	1	..	..	..	..
Physa	..	..	1	..	9	1	..
Sphaeriidae	4	7	1	3	..	21	5

Pisidium compressum
" *medianum minutum*
" *scutellatum*
" *splendidulum*
" *variabile*
" sp.

NORTH SHAKESPEARE—HAT MOUNTAIN — Series XIII

Dredging	1	2	3	4	5	6	7	8
Depth (in feet)	3	15	18	24	33	57	63	69
Character of Bottom	Sand	Ooze	Mud	Ooze	Gravel & Sand	Mud	Mud	Mud
Distance from shore (yds)	15	80	130	430	530	730	900	1100
Lymnaea galbana	..	..	..	..	..	..	..	..
" *emarginata*	..	..	..	..	..	..	..	..
" *vahlii*	..	..	..	..	..	..	..	..
Planorbis antrosus	..	..	..	1	..	..	..	..
" *parvus*	..	3	3	3	..	..	..	..
Physa	..	..	..	..	..	..	..	..
Amnicola limosa	..	..	..	..	..	..	..	..
" sp.	..	3	..	5	..	..	..	..
Valvata sincera	..	5	7	5	..	..	..	..
" *tricarinata*	..	1	..	1	..	..	..	..
Sphaeriidae	..	6	5	14	1	1	..	..

Pisidium compressum
" *medianum minutum*
" *pauperculum*
" *scutellatum*
" *splendidulum*
" *variabile*

McL. BAY | Series XIV

Dredging	1	2	3	4	5	6	7	8
Depth (in feet)	3	3	6	6	9	15	30	36
Character of Bottom	Wood, Debris, & Mud	Mud	Mud	Mud	Mud	Mud	Sand	Clay
Distance from Shore (yds).	15	40	75	150	200	250	350	450
Lymnaea galbana	..	..	..	..	..	..	..	..
" *vahlii*	..	..	..	1	..	..	..	..
" sp.	..	..	..	..	..	..	..	..
Planorbis parvus	1	..	2	1	2	..	..	..
" *antrosus*	1	1	2	1	3	..	..	..
Segmentina crassilabris	..	..	..	..	..	..	..	..
Amnicola limosa	..	1	1	..	13	..	..	..
" sp.	..	3	14	7	39	..	..	..
Valvata sincera	..	..	6	2	6	..	..	..
" *tricarinata*	1	..	..	1	4	..	..	..
Sphaeriidae	1	2	8	2	18	2	..	..

Pisidium compressum
" *pauperculum*
" *scutellatum*
" *variabile*
" *walkeri*

FOOT OF ORIENT BAY

Series XV

Dredging	1	2	3	4	5	6	7	8	9	10
Depth (in feet)	12	3	2	5	3	5	9	69	51	27
Character of Bottom	Gravel	Sand	Sand	Sand	Sand	Sand	Sand	Mud	Mud	Mud
Distance from Shore (yds.)	..	100	200	300	400	550	700	800	900	1000
Lymnaea galbana	..	..	..	1	1	..	..	..	..	..
Planorbis antrosus	..	..	..	..	2	1	..	..	..	..
Segmentina crassilabris	..	..	..	..	..	..	2	..	..	..
Planorbis hirsutus	..	..	..	3	1	5	..	..	..	..
" *parvus*	..	..	..	2	1	1	..	..	..	..
Amnicola limosa	..	..	..	3	2	1	..	..	..	..
" sp.	1	..	..	1	2	..	16	..	..	..
Valvata sincera	..	..	..	..	..	..	2	..	..	..
" *tricarinata*	..	..	..	..	..	1	2	..	..	..
Sphaeriidae	2	..	..	3	..	..	5	5	..	13

Pisidium scutellatum
" sp. juv.
Musculium roseceum
" *securis*

BLACKWATER BAY — Series XVI

Dredging	1	2	3	4	5	6	7	8	9
Depth (in feet)	12	21	21	21	39	90	117	147	178
Character of Bottom	Sand	Mud & Gravel	Mud & Gravel	Mud & Gravel	Mud	Clay	Mud	Mud	Mud
Distance from Shore (yds.)	50	150	250	350	450	550	650	750	1000
Planorbis parvus	..	..	..	..	1	..	..	..	..
Amnicola limosa	..	..	..	..	1	..	..	..	..
" sp.	..	..	..	2	..	..	..	..	..
Valvata sincera	..	..	..	..	4	..	..	..	..
" *tricarinata* (var.)	..	..	..	1	..	..	..	..	..
" *tricarinata*	..	..	..	..	1	..	..	..	..
Sphaeriidae	..	1	..	1	..	2	..	..	..

Pisidium sp. juv.
Sphaerium sp.

SECOND CHANNEL W. OF NIPIGON RIVER — Series XVII

Dredging	1	2	3	4	5	6	7	8	9
Depth (in feet)	18	18	12	12	12	3	27	28	..
Character of Bottom	Mud	Mud	Mud	Mud	Mud	Sand	Gravel	Mud & Sand	..
Distance from Shore (yds.)	25	75	150	250	350	550	750	1150	..
Lymnaea vahlii	..	..	..	..	..	..	..	..	..
Planorbis antrosus	..	..	..	..	3	..	2	..	..
" *parvus*	..	..	1	2	..	2	1	..	..
Physa	..	..	..	..	..	..	..	..	..
Amnicola limosa	3	4	2	7	2	..	5	..	..
" sp.	..	3	3	1	4	3	13	..	..
Valvata sincera	1	4	5	..	..	2	2	..	..
" *tricarinata* (var.)	..	..	1	..	4	..	4	..	..
" *tricarinata*	1	..	..	2	..	..	..	..	..
Sphaeriidae	..	1	7	14	2	..	6	1	..

Pisidium compressum
" *pauperculum*
" *scutellatum*
" *variabile*
" sp. (known, not published)
" sp. juv.
Musculium sp.

SOUTH BAY (WEST SHORE) — Series XVIII | SOUTH BAY (WEST SHORE) — Series XIX

	Series XVIII				Series XIX			
Dredging	1	2	3	4	1	2	3	4
Depth (in feet)	1½	3	6	6	2	4	5	5
Character of Bottom	Sand	Sand	Mud & Gravel	Mud & Gravel	Mud & Sand	Mud	Mud	Mud
Distance from Shore (yds.)	25	50	75	200	15	25	40	65
Lymnaea galbana	..	..	1	..	7	..	..	..
Planorbis antrosus	..	..	1	..	..	..	..	..
" *parvus*	..	..	1	..	1	..	..	..
Amnicola limosa	..	..	..	..	..	2	3	..
" sp.	..	..	11	3	..	1	5	..
Valvata sincera	..	..	4	..	..	..	..	..
" *tricarinata*	..	..	1	..	..	..	1	..
Physa gyrina	..	..	..	..	..	..	..	..
Lymnaea emarginata	..	..	..	..	..	..	..	..
Sphaeriidae	..	..	5	7	37	12	15	6

Pisidium compressum
" *pauperculum*
" *scutellatum*
" *variabile*

Pisidium compressum
" *medianum minutum*
" *pauperculum*
" *scutellatum*
" *variabile*
" sp.
" sp.
Sphaerium tenue

SECOND BAY WEST OF NIPIGON RIVER — Series XX

Dredging	1	2	3	4	5	6	7	8	9
Depth (in feet)	5	18	18	33	33	33	12	6	5
Character of Bottom	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud
Distance from Shore (yds.)	15	50	150	250	300	350	400	450	550
Lymnaea galbana	..	..	..	..	..	..	..	..	..
" *vahlii*	..	..	..	..	..	..	1	..	..
" sp.	..	..	..	..	..	..	..	..	..
Planorbis antrosus	..	..	..	..	..	..	..	..	..
" *hirsutus*	..	..	..	..	..	..	..	..	..
" *parvus*	2	..	..	..	..	..	..	1	..
Amnicola limosa	1	..	1	..	..	..	3	2	..
" sp.	2	1	..	..	..	..	4	8	..
Valvata sincera	1	..	..	..	..	..	2	..	..
" *tricarinata*	..	1	..	..	..	..	..	..	..
Sphaeriidae	17	..	1	..	..	..	1	3	..

Pisidium scutellatum
" *vexum*
" *variabile*
" sp. juv.

BEAR CREEK — Series XXI

Dredging	1	2	3	4	5	6
Depth (in feet)	18	9	9	9	9	9
Character of Bottom	Mud	Mud & Debris	Sand & Debris	Sand	Sand	Sand
Distance from Shore (yds.)	20	300	600	900	1300	1700
Segmentina crassilabris	..	..	..	..	..	..
Plano bis exacuous	..	..	..	..	..	..
" *parvus*	..	..	..	..	..	..
Amnicola limosa	..	..	..	..	..	..
" sp.	..	..	..	..	..	..
Valvata sincera	..	..	..	..	..	..
" *tricarinata*	..	..	..	..	..	..
Sphaeriidae	1	2	..	..	..	1

Pisidium variabile
Musculium juv. (apparently *rosaceum*)
Sphaerium sp. juv.

NORTH SHAKESPEARE BAY — Series XXII

Dredging	1	2	3	4	5	6	7	8	9
Depth (in feet)	4	18	18	36	24	15	9	6	2½
Character of Bottom	Mud	Mud	Mud & Gravel	Mud	Mud	Mud	Mud	Sand	Sand
Distance from Shore (yds.)	10	60	110	210	610	710	760	810	840
Lymnaea galbana	..	..	..	..	..	..	..	..	..
" *vahlii*	1	..	..	..	..	..	..	..	..
Planorbis antrosus	2	..	..	..	..	..	..	..	..
" *hirsutus*	4	..	..	..	..	..	..	..	..
" *parvus*	..	..	..	..	..	1	..	..	..
Amnicola limosa	8	..	..	..	..	1	2	20	..
" sp.	14	..	1	..	..	..	1	11	..
Valvata sincera	3	3	..	..	..	..	..	..	..
" *tricarinata*	1	..	1	..	..	..	2	1	..
Sphaeriidae	14	2	..	6	..	1	3	4	..

Pisidium pauperculum
" *punctatum* (f. *simplex*)
" *scutellatum cristatum*
" *variabile*
" sp. juv.
Sphaerium crassum
" sp. juv.

NORTH SHAKESPEARE ISLANDS — Series XXIII

Dredging	1	2	3	4	55	6	7	8
Depth (in feet)	5	17	21	21	15	9	42	42
Character of Bottom	Gravel among Rocks	Sand	Sand	Sand	Sand	Sand	Mud	Mud
Distance from Shore (yds.)	10	40	40	60	100	130	230	380
Lymnaea galbana	1	1	..	..	..	..	..	..
" *vahlii*	..	..	..	..	..	..	..	..
Planorbis antrosus	..	..	..	..	..	3	..	..
" *parvus*	..	..	..	..	..	7	..	..
Segmentina crassilabris	..	..	..	..	..	..	..	..
Physa	..	..	..	..	..	1	..	..
Amnicola limosa	..	..	..	..	..	11	..	..
" sp.	..	1	..	..	..	12	..	..
Valvata sincera	1	..	1	..	..	6	..	..
" *tricarinata*	..	1	..	..	..	5	..	..
Sphaeriidae	..	12	..	..	..	15	..	3

Pisidium compressum
" *pauperculum*
" *rotundatum*
" *scutellatum*
" *variabile*
" sp.
Sphaerium tenue
" *vermontanum* (?)

ORIENT BAY (AT MACDIARMID) — Series XXIV

Dredging	1	2	3	4	5	6	7	8	9
Depth (in feet)	6	39	90	150	87	69	63	11	9
Character of Bottom	Sand	Mud	Mud	Mud	Mud	Mud	Clay	Sand & Clay	Mud
Distance from Shore (yds.)	10	30	60	160	800	1000	1100	1500	1700
Lymnaea galbana	..	..	..	..	..	..	..	..	..
" *vahlii*	..	..	..	..	..	..	..	..	1
Planorbis antrosus	..	..	..	..	..	..	..	..	1
" *parvus*	1	..	..	..	..	..	..	..	..
Segmentina crassilabris	..	..	..	..	..	..	..	..	..
Amnicola limosa	2	..	..	..	..	..	..	..	1
" sp.	1	..	..	..	..	..	1	4	2
Valvata sincera	1	1	..	..	..	..	..	4	..
" *tricarinata*	..	..	..	..	..	..	..	1	..
Sphaeriidae	4	1	..	..	..	2	4	7	2

Pisidium compressum
" *monas*
" sp. juv.
Sphaerium sp. juv.

NAONAN IDS.

	Series I	NIPIGON HOUSE Series VII		MACDIARMID HARBOUR Series XXV		
Dredging	1	1	2	1	2	3
Depth (in feet)	150 (?)	144	36 (?)	9	8	5
Character of Bottom	Mud & Shells	Clay	Mud	Mud	Mud	Mud
Distance from Shore (yds.)	800	800	125	100	75	25
Lymnaea galbana	..	..	..	1	..	..
" *emarginata*	..	..	..	1	..	1
Planorbis antrosus	..	..	..	11	..	..
" *parvus*	..	..	..	2	..	..
Amnicola limosa	..	..	1	2	..	..
" sp.	..	..	..	2	..	..
Valvata sincera	..	..	2	3	..	..
" *tricarinata*	..	..	..	..	..	..
Physa gyrina	..	..	..	..	3	1
Sphaeriidae	..	..	..	15	..	..

Pisidium compressum
" *pauperculum*
" *punctatum* (f. *simplex*)
" *variabile*
" sp.?

ORIENT BAY and NORTHWARD—EAST SHORE | Series XXVI

Dredging	1	2	3	4	5	6	7	8	9
Depth (in feet)	9	18	8	12	18	24	27	48	129
Character of Bottom	Sand	Sand	Sand	Sand	Gravel	Sand	Sand	Sand	Mud
Distance from Shore (yds.)	30	60	85	130	230	280	330	380	430
Lymnaea vahlii	..	..	..	..	..	..	..	..	..
Planorbis antrosus	..	..	..	..	..	..	..	..	..
" *exacuous*	..	..	..	..	..	..	..	..	..
" *parvus*	..	..	..	..	..	..	..	1	..
Physa gyrina	..	..	..	..	..	..	..	..	..
Amnicola limosa	2	4	..	..	..	..	..	..	..
" sp.	2	..	..	..	..	..	..	..	..
Valvata sincera	1	..	..	..	..	..	1	..	..
" *tricarinata* (var.)	1	1	..	..	..	..	..	..	..
Sphaeriidae	2	1	1	..	..	..	..	3	..

Pisidium compressum
" *pauperculum*
" sp. juv.
Sphaerium sp. juv.

VIRGIN ISLANDS

Series XXVII

Dredging	1	2	3	4	5	6	7	8	9
Depth (in feet)	6	12	15	150	15	12	9	5	3
Character of Bottom	Sand	Sand	Sand	Sand	Sand	Mud & Sand	Mud & Sand	Mud & Sand	Mud
Distance from Shore (yds.)	10	50	100	150	200	300	400	500	600
Lymnaea emarginata	1	..	..	..	..	..	..	..	..
" *galbana*	..	..	..	1	..	..	..	1	..
" *vahlii*	..	..	..	..	..	..	..	1	..
Planorbis antrosus	18	..	..	..	..	..	..	1	6
" *hirsutus*	..	..	..	..	..	..	..	..	..
" *parvus*	..	1	..	..	3	..	..	3	7
Amnicola limosa	16	2	..	1	..	..	2	9	48
" sp.	11	..	..	..	3	1	5	7	62
Valvata sincera	..	1	..	..	3	3	1	..	..
" *tricarinata*	9	1	..	..	1	1	1	..	17
Sphaeriidae	41	9	..	1	..	7	1	9	3

Pisidium compressum
" *indianense*
" *pauperculum*
" *scutellatum*
" *variabile*
" sp.?
" sp ?

McINTYRE BAY (SOUTH END) Series XXVIII

Dredging	1	2	3	4	5	6		8	9
Depth (in feet)	1	3	9	12	15	18	21	24	24
Character of Bottom	Sand	Mud on Sand	Mud & Gravel	Mud & Sand	Mud & Sand	Mud	Mud	Mud	Mud
Distance from Shore (yds.)	23	75	125	175	225	325	425	525	625
Lymnaea galbana	..	..	..	..	..	1	1	..	..
Planorbis antrosus	..	..	..	1	1	1	..	..	..
" *hirsutus*	..	..	2	3	1	..	..	..	..
" *parvus*	..	..	..	1	2	..	1	1	..
Amnicola limosa	..	..	2	..	..	..	..	1	..
" sp.	..	..	4	2	1	1	..	..	1
Valvata sincera	..	..	1	1	..	..	2	..	4
" *tricarinata* (var.)	..	..	..	..	1	1	..	..	..
" *tricarinata*	..	..	1	..	..	..	..	..	1
Sphaeriidae	4	1	7	4	..	2	2	1	2

Pisidium compressum
" *medianum minutum*
" *monas*
" *pauperculum*
" sp.?
" sp.?
Sphaerium vermontanum

McINTYRE BAY (EAST SIDE AMONG ISLANDS) — Series XXIX

Dredging	1	2	3	4	5	6	7	8
Depth (in feet)	3	6	12	18	18	21	21	15
Character of Bottom	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud
Distance from Shore (yds.)	10	60	110	160	210	260	310	360
Planorbis antrosus	..	..	..	..	..	..	..	..
" *parvus*	..	..	..	..	..	..	..	..
Amnicola limosa	..	..	..	..	..	..	..	5
" sp.	4	4	..	1	..	1	..	..
Valvata sincera	..	1	..	..	..	..	..	..
" *tricarinata* (var.)	..	..	2	..	..	..	..	1
" *tricarinata*	..	..	..	..	2	2	..	..
Sphaeriidae	12	3	1	2	4	7	5	3

Pisidium compressum
" *medianium minutum*
" *pauperculum*
" *punctatum*
" *scutellatum cristatum*
" *variabile*
" sp.?
Sphaerium vermontanum

McINTYRE BAY (NORTH END) Series XXX

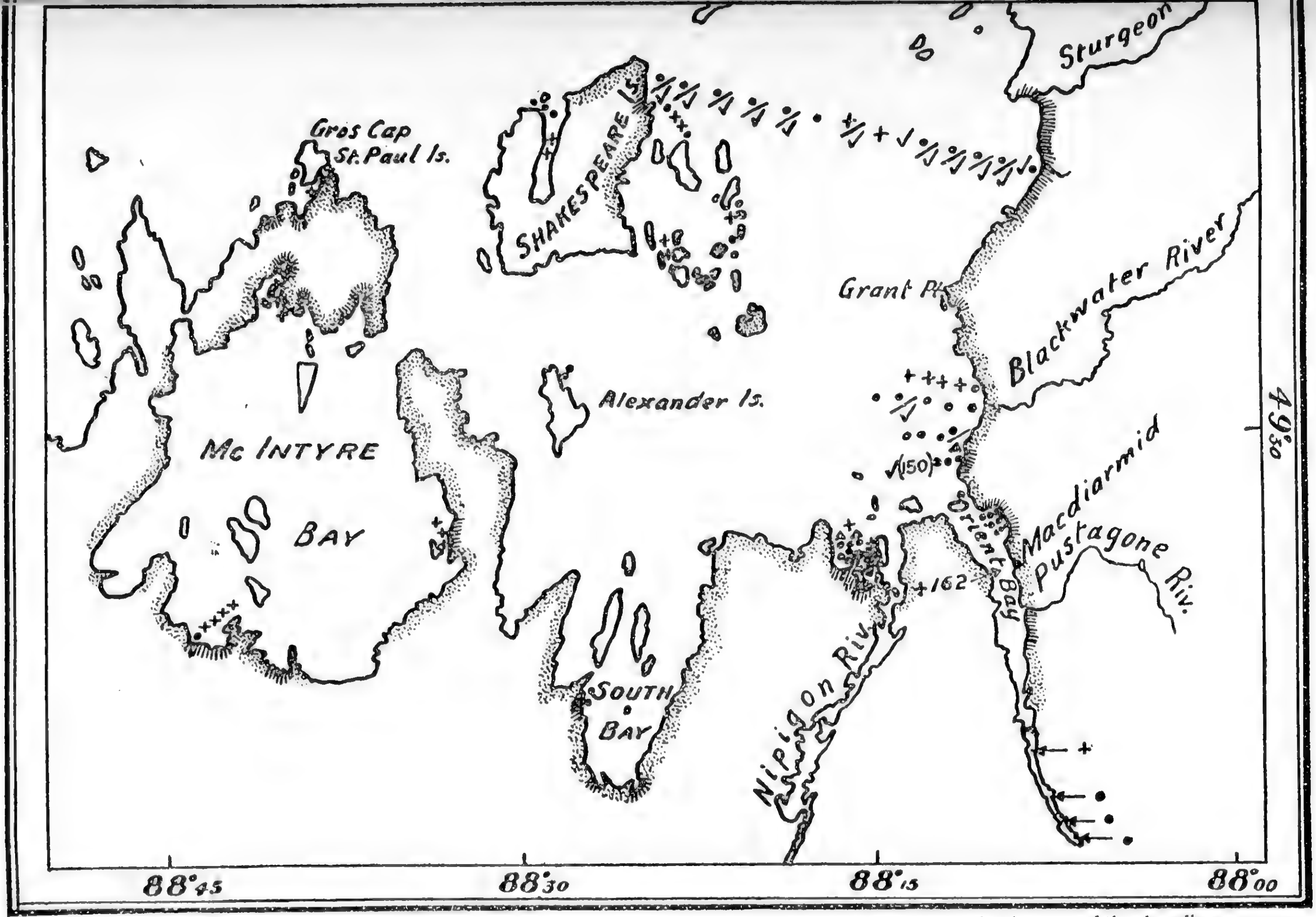
Dredging	1	2	3	4	5	6
Depth (in feet)	6	9	9	21	45	48
Character of Bottom	Mud	Mud	Mud	Mud	Mud	Mud
Distance from Shore (yds.)	30	80	130	180	230	280
Planorbis trivolvis	..	..	..	..	..	..
" *hirsutus*	..	..	2	..	..	..
" *parvus*	..	..	1	1	2	..
Amnicola limosa	24	2	1	..	..	..
" sp.	20	14	4	..	..	..
Valvata sincera	..	..	..	..	..	..
" *tricarinata* (var.)	..	1	1	1	..	..
Sphaeriidae	3	..	..	..	..	..

Pisidium variabile
" sp.?

GROS CAP	Series XXXI					ALEXANDER ID. Series XXXII			
Dredging	1	2	3	4	5	1	2	3	4
Depth (in feet)	3	9	15	24	30	1	4	6	9
Character of Bottom	Mud	Mud	Mud	Mud	Mud	Mud	Sand	Sand	Sand
Distance from Shore (yds.)	10	35	60	110	210	10	25	50	100
Lymnaea vahlii	..	..	..	..	..	..	..	1	1
" *galbana*	..	..	..	..	..	..	5	14	..
Segmentina crassilabris	..	..	..	..	..	..	..	..	..
Planorbis antrosus	..	..	..	..	..	..	..	2	..
" *hirsutus*	..	..	1	..	..	..	..	..	..
" *parvus*	4	3	..	..	..	1	2	12	1
Amnicola limosa	3	19	..	..	..	..	..	6	2
" sp.	15	8	..	3	..	..	..	..	..
Valvata sincera	1	..	1	1	..	1	1	..	1
" *tricarinata* (var.)	..	5	..	..	..	..	2	1	..
" *tricarinata*	..	..	2	..	..	..	..	..	..
Sphaeriidae	15	3	1	1	..	1	40	16	15

Pisidium medianium minutum
" *pauperculum*
" *splendidulum*
" *variabile*
Sphaerium vermontanum

Pisidium compressum
" *idahoense*
" *medianum minutum*
" *pauperculum*
" *scutellatum*
" *variabile*
" sp.?
" sp.?



Map of the southeastern portion of Lake Nipigon showing the localities where dredgings were taken and the character of the shore line. *Shore:* dots indicate rock; lines indicate sand. *Bottom:* + = mud; • = sand; ν = clay; △ = rock; •/ν = sand on clay.

In the foregoing series of tables the results of all dredging operations are given. These were supplemented by a large number of shore collections. In all, some 235 samples were obtained with the dredge. Each sample represented an area of 81 square inches, and in the results that area is taken as a unit. The largest number of dredgings were made in water down to 21 feet in depth, a total of 144 having been secured in this range. The greatest depth from which specimens were brought up was 192 ft. In the detailed consideration of the *Mollusca*, no account is taken of dead specimens, but a very large number of them were obtained.

DISTRIBUTION OF SPECIES

Study of the data obtained makes it evident that, as regards distribution, the species of *Mollusca* form two distinct groups:

1. Species inhabiting very shallow water close to shore.
2. Species inhabiting deeper water at some distance from shore.

The first group includes the various species of *Lymnaea*, *Physa*, and all but two of the species of *Planorbis*. Specimens of these were generally obtained in shore collections, and were nearly always found in rocky situations or in restricted areas having some peculiar environmental features. In most cases the species involved did not have a very general distribution, but, taken as a whole, the group cannot be neglected. The following table gives the species of this division, as well as their habitats.

The peculiar localization of some species is well illustrated by the two species *Planorbis trivolvis* and *Planorbis crista*. Each was found in only one situation where conditions were favourable. The former was obtained in a quiet, well-sheltered harbour at the north end of Alexander Island where the water was very calm. Here the species was very abundant because the environment was quite suitable to its fragile shell. The other species, *Planorbis crista*, was found in a small bay at the south end of the lake. Large numbers of the minute spiny shells occurred on stones in very shallow water close to shore. Of the other members of the group, some were found in protected shallow bays, but the majority of them inhabited rocky, exposed shores, often where they were scarcely covered with water.

Species	Character of Bottom	Remarks
Lymnaea apicina	Rock	Exposed shores, water 1-3 ft. deep.
" *emarginata*	"	" "
" *galbana*		
" *stagnalis* (var.)	Rock, Sand, Mud	Common in water, 1-12 ft. deep.
" *vahlii*		
Planorbis crista	Rock	Limited to one locality—very shallow water.
" *exacuous*	"	Common in shallow water only.
" *hirsutus*	"	Frequent in shallow water.
" *trivolvis*	Mud	Limited to one locality—water 4 ft. deep.
Physa ancillaria	Rock	Exposed shores.
" *gyrina*	"	" "
" sp. (1)	"	Taken only in Pustagone River.
" sp. (2)	"	" " " " "
Segmentina crassilabris	Mud	Rare.
Ferrissia parallela	Rock	In streams.

The species included in the second group, which is composed of forms inhabiting deeper water, are much more abundant and widely distributed. Consequently, they will be considered in more detail.

Genus Amnicola

The two species of *Amnicola* were obtained in the dredging operations in considerable numbers. From the data secured in this manner the following table has been prepared to show the distribution according to depth and character of bottom. The averages given were obtained by dividing the number of specimens from any particular depth by the total number of dredgings for that depth and for the kind of bottom considered. Intervals of three feet were taken because the counting machine, which registered depth, gave the distance in yards, and, as fractions had to be estimated, personal error resulted in most of them coming near an even number of yards.

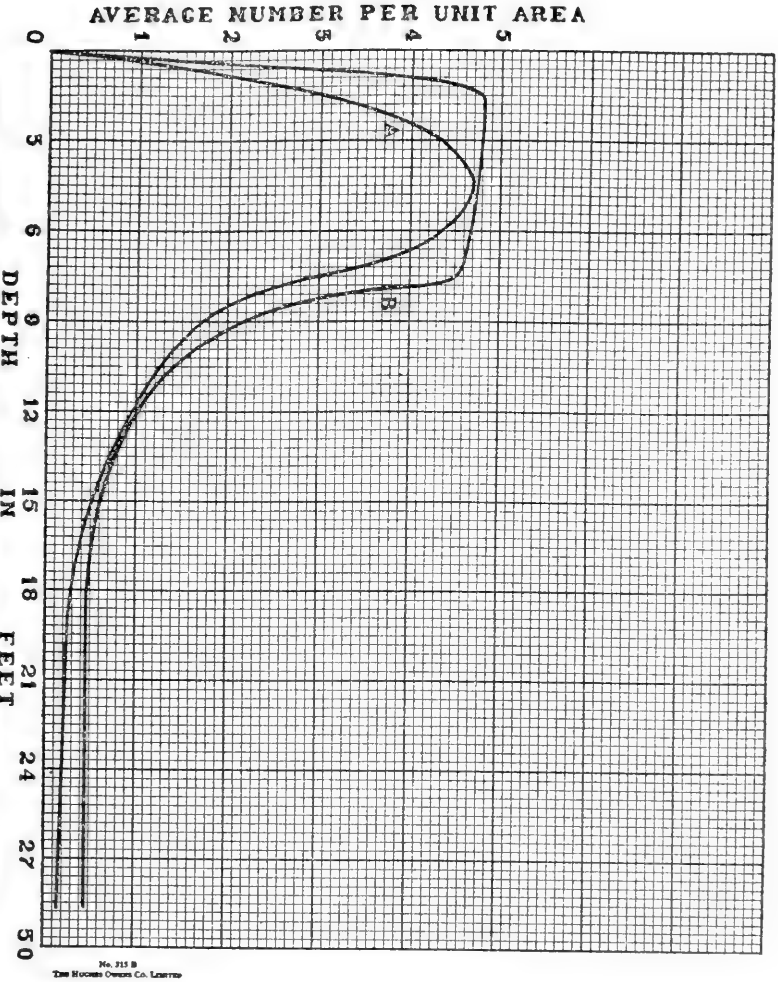
Depth.	*Amnicola limosa*						*Amnicola* sp.					
	Mud		Sand				Mud		Sand			
	No.	Av.	No.	Av.	Total	Av.	No.	Av.	No.	Av.	Total	Av.
0-3	52	6.50	3	.33	55	3.05	84	10.5	5	.55	89	4.94
3-6	50	3.33	77	6.42	127	4.70	96	6.4	27	2.25	123	4.55
9	44	4.9	17	1.42	64	3.05	69	7.7	31	2.6	100	4.76
12	14	1.55	4	.40	18	.90	15	1.7	1	1.0	16	.80
15	6	1.0	6	.43	12	.60	4	.66	6	.43	18	.90
18	8	.72	11	1.57	18	1.0	7	.64	5	.70	12	.66
21	0	0	3	.30	3	.15	4	.50	2	.20	6	.30
24	1	.2	0	0	1	.12	6	1.2	0	0	6	.75
27	0	0	6	1.2	6	.75	0	0	10	2.00	10	1.2
30	0	0	1	.2	1	.12	2	.66	0	0	2	.25

From the results given in the preceding table, curves have been drawn (Graph 1), which illustrate the distribution of these species according to depth. A study of these curves shows that, whereas the optimum depth for *Amnicola limosa* (and its variety) is between 0-9 ft., the other species reaches a maximum between 3-6 ft. Both species, however, are about equally abundant at their optimum depth.

The table brings out another peculiar feature, in that both species are most abundant at a depth between 0-3 ft. on mud bottoms, and at a depth between 3-6 ft. on sand bottoms.

Genus Valvata

Two species of *Valvata*, namely, *Valvata sincera* and *Valvata tricarinata*, were fairly common. In working out the distribution according to depth, the last species and its variety are considered together because of their similarity



GRAPH I. Curves illustrating distribution according to depth. A. *Amnicola limosa*; B. *Amnicola* sp.

and because the total number of specimens was not very great.

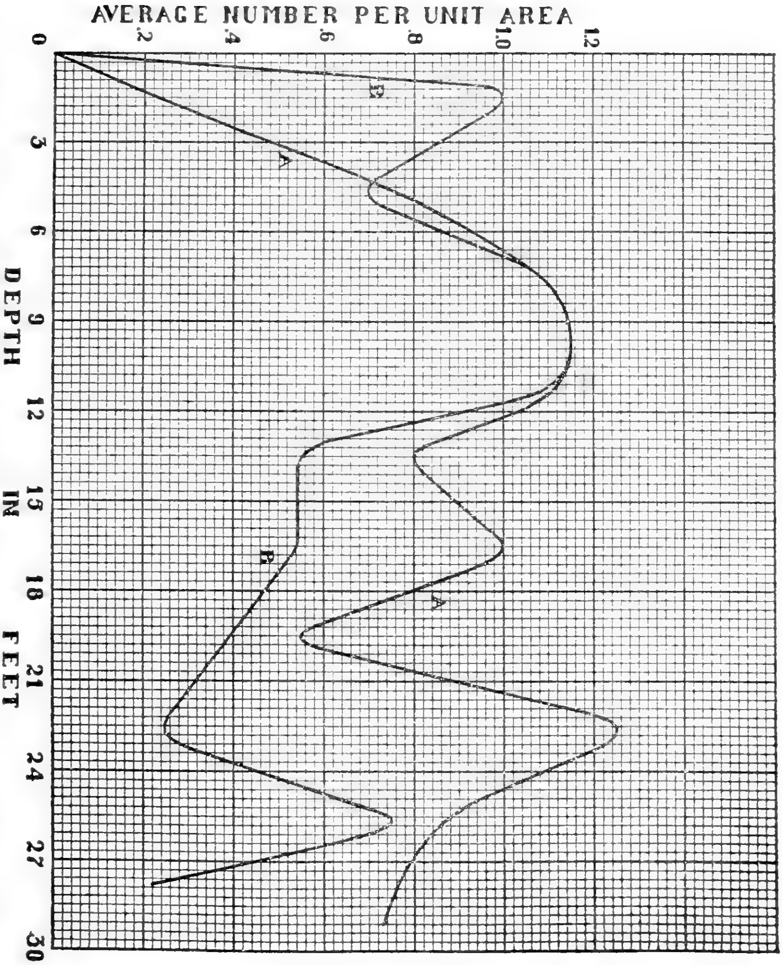
Depth	*Valvata sincera*						*Valvata tricarinata*					
	Mud		Sand				Mud		Sand			
	No.	Av.	No.	Av.	Total	Av.	No.	Av.	No.	Av.	No.	Av.
0-3	2	.25	2	.22	4	.22	18	2.25	0	0	18	1.00
3-6	17	1.13	4	.33	21	.74	4	.27	15	1.25	19	1.70
9	13	1.44	10	.83	23	1.09	15	1.66	8	.66	23	1.09
12	11	1.22	12	1.20	23	1.15	10	1.11	13	1.30	23	.15
15	6	1.00	10	.71	16	.80	5	.83	6	.43	11	.55
18	15	1.36	3	.43	18	1.0	6	.55	4	.57	10	.55
21	10	1.25	1	.10	11	.55	5	.62	3	.30	8	.40
24	10	2.0	0	0	10	1.25	2	.40	0	0	2	.25
27	2	1.0	5	1.0	7	.87	4	2.0	2	.40	6	.75
30	0	.0	6	1.20	6	.75	0	0	0	0	0	0
33	0	0	2	.66	2	.33	0	0	0	0	0	0
36	2	1.0	1	1.0	3	.75	0	0	3	3.0	3	.75
39	5	1.66	6	3.0	11	1.83	1	.33	1	.5	2	.33

The curves (Graph 2), obtained from the data given in the above table, are both very irregular. This indicates, in all probability, that the two species are distributed fairly uniformly over a large range of depths. There is, however, a difference between the two in that *Valvata tricarinata* becomes quite abundant between depths of 0-3 ft. but *Valvata sincera* does not reach a maximum until a depth between 6-9 ft. is reached.

If the averages are taken into consideration, both species are apparently more abundant on mud than on sand bottoms.

Genus Planorbis

Two species of the genus *Planorbis*, namely, *Planorbis antrosus* and *Planorbis parvus*, extend out into fairly deep waters. A table showing the relation of the abundance of these two species to depth is given below.



GRAPH II. Curves illustrating distribution according to depth. A. *Valvata sincera*; B. *Valvata tricarinata*.

Depth	*Planorbis antrosus*				*Planorbis parvus*			
	Mud	Sand			Mud	Sand		
	No.	No.	Total	Av.	No.	No.	Total	Av.
0-3	8	2	10	.55	14	3	17	.88
3-6	7	22	29	1.07	10	21	31	1.15
9	15	3	18	.86	8	14	22	1.05
12	4	6	10	.50	4	2	6	.30
15	1	8	9	.45	6	5	11	.55
18	1	3	4	.22	3	1	3	.33
21	0	1	1	.05	33	2	5	.25
24	1	0	1	.12	4	0	4	.50
27	0	2	2	.24	0	1	1	.12
30	..	..	..	..	1	3	4	.50

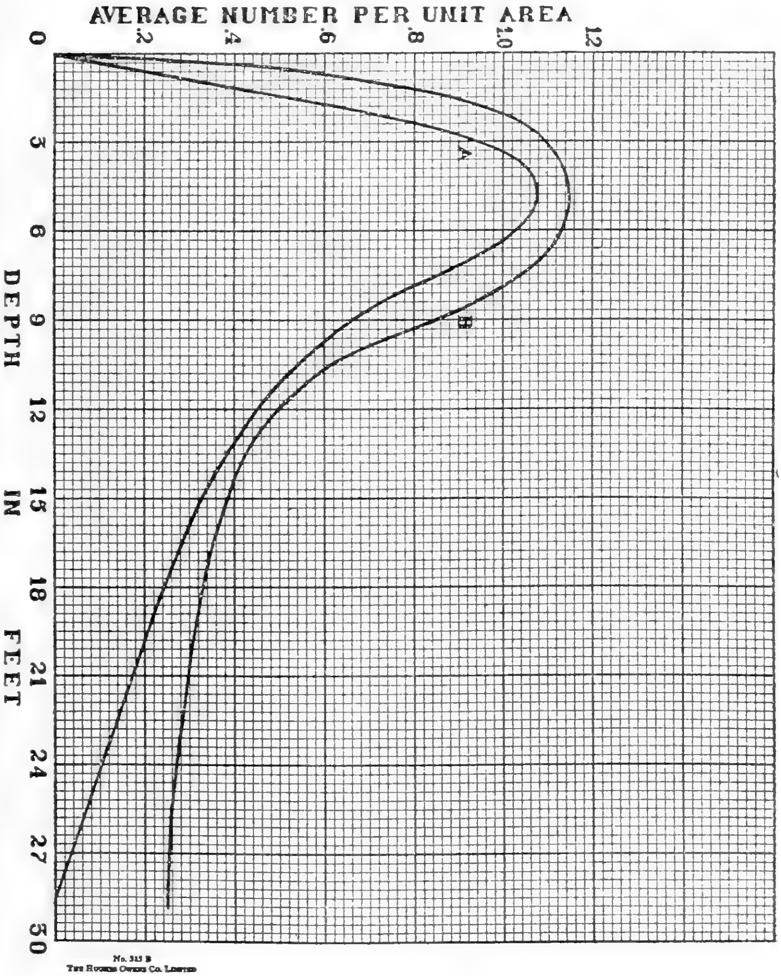
Curves drawn (Graph 3), by using the data given in the table, show that both *Planorbis antrosus* and *Planorbis parvus* reach a maximum in a depth between 3-6 ft. *P. antrosus* and its varieties do not extend beyond a depth of 27 ft. but the other species goes on out into much deeper water, some having been taken from a depth of 45 ft.

Family Sphaeriidae

The species belonging to this family have all been grouped together in drawing up tables showing their relation to depth. This was done because there were only a few specimens of some species, and also because, in general, the species seem to live under similar environmental conditions. The summarized results are given in the following table.

A graph has also been drawn (Graph 4), by using the averages given in this table, to show the distribution of the *Sphaeriidae* with depth. From this it is apparent that the optimum depth is between 3-6 ft., although they extend, in fair numbers, into depths of over 30 ft. Some specimens were also obtained at a depth of 192 ft.

A consideration of all the curves shows that the optimum depth for most species of *Mollusca* inhabiting deep water is from 3-6 ft., but, in the range of depths between 0-12 ft.,



GRAPH III. Curves illustrating distribution according to depth. A. *Planorbis antrosus*; B. *Planorbis parvus*.

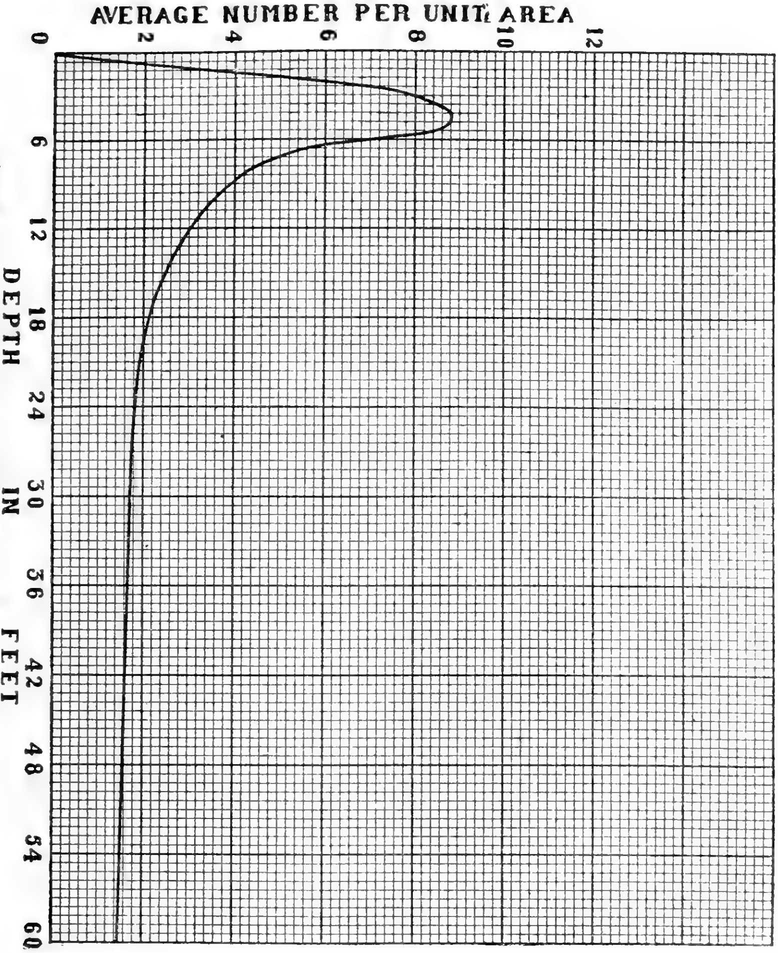
	Sphaeriidae					*Sphaeriidae*			
	Mud	Sand				Mud	Sand		
Depth	No.	No.	Total	Av.	Depth	No.	No.	Total	Av.
0-3	72	7	79	4.39	36	6	2	8	2.0
3-6	104	133	237	8.85	39	1	1	2	.33
9	61	45	96	4.57	42	3	0	3	1.50
12	36	30	66	3.30	45	0	7	7	1.75
15	13	20	33	1.65	48	0	11	11	1.83
18	18	37	55	3.05	57	..	..	1	..
21	20	5	25	1.25	63	..	..	4	..
24	18	0	18	2.25	69	..	..	7	..
27	14	7	21	2.62	90	..	..	2	..
30	1	16	17	2.12	117	..	..	2	..
33	0	2	2	.33	192	..	..	1	..

there is nearly always a fairly large number of them. Moreover, of the various species obtained in dredgings, *Amnicola limosa* and *Amnicola sp.* are by far the most numerous.

The remainder of the *Mollusca*, *i.e.*, the larger *Pelecypoda*, were quite scarce throughout the whole of the southern end of the lake. They were obtained in only a few restricted areas in fairly shallow water, and in situations where there was ample protection from wave action. Such conditions were found at the ends of long narrow bays or in the channels between islands, and only in such locations were large bivalves obtained, as the following table shows.

Species	Where found
Anodonta kennicotti	Shakespeare Islands, Channel West of Nipigon River. Orient Bay, Virgin Islands.
Anodonta marginata	Shakespeare Islands, Channel West of Nipigon River. Virgin Islands.
Lampsilis (Ligumia) superiorensis	Pustagone River.

Because of the great scarcity of these animals in the south end of the lake it was not thought advisable to make any estimate of their numerical abundance. The work done by



GRAPH IV. Curve illustrating distribution according to depth. *Sphaeriidae.*

Muttkowski (1918) shows a similar rarity of the larger *Pelecypoda* in Lake Mendota, although there was an abundance of the small *Sphaeriidae*. This is almost identical with conditions in Lake Nipigon.

The reason for the infrequent occurrence of these forms in Lake Nipigon is doubtless due to the fact that areas, furnishing a suitable habitat, where there is quiet water and an abundance of food material as well as the proper kind of bottom, are very restricted.

ENVIRONMENTAL FACTORS LIMITING DISTRIBUTION

A consideration of the habitats of the various species of *Mollusca* shows that the ecological features, which might have a bearing on the distribution of these animals, are: abundance of food, temperature, chemical content of the water, depth, character of bottom, and protection from wave action. Temperature would not appear to be a limiting factor in the distribution of the species occurring in Lake Nipigon, since all the species are subjected to a temperature at least as low as 4° C. during a large portion of the year, and up to the present no species has been found to occur only in the cold waters of the lake. Temperature, however, may be an indirect factor in view of the fact that, in depths of less than 30 feet, all species have their maximum numbers, and this is the zone of highest temperatures.

The amount of oxygen in the water was seemingly of no significance, for there was no deficiency in the amount of dissolved oxygen at any depth during this season. The amount of carbon dioxide dissolved in the water was very small during this season, and would not therefore be a factor either.

Depth of water is, of course, a feature which indirectly, at least, has to do with the distribution of *Mollusca*. This has been amply demonstrated (1) in the division of *Mollusca* into the two groups of shore and deep water forms, a grouping having its basis largely, no doubt, on the differences in the respiratory system, and (2) in the variation of the optimum depth for the various species.

The character of the bottom also influences the abundance of *Mollusca*. This is evident in the fact that the shore forms are nearly always found among rocks, while those inhabiting deeper water prefer mud or sand. Furthermore, as the consideration of the *Amnicolas* showed, the optimum depth may vary with the bottom according to the species.

Protection from wave action and abundance of food would seem to be the most important factors which influence the distribution of *Mollusca*. The shore forms have a good supply of food in the filamentous algae on the rocks, and when violent storms come up they are able to retreat into crevices amongst the boulders. Their shells are, moreover, solid enough to withstand moderate wave action, and as a result they are found in large numbers on more exposed parts of the shore. The species inhabiting deeper water appear to choose, uniformly, sheltered locations in which an ample supply of food material is available on the bottom. This is shown by the fact that dredgings taken in exposed places or where the bottom was composed of clean sand were nearly always poor in animal life, not only in regard to *Mollusca* but in regard to other forms as well.

VALUE OF MOLLUSCA AS FISH FOOD

The number of species of fish found in Lake Nipigon during the past season was not large. In all only about 25 or possibly 26 species were obtained, and nearly half of these were small forms such as sticklebacks, darters, minnows, etc. As a result the number of species which might feed on *Mollusca* was correspondingly limited and, in fact, only five were found to contain them. From the work done with a view to finding out the extent to which *Mollusca* are taken as food by fish, the following summary of the results obtained is given.

Sturgeon (Acipenser rubicundus Le Sueur)

The sturgeon is the largest food fish caught in Lake Nipigon. It is confined largely to shallow water near shore.

Unfortunately, the fish obtained were caught in the pound nets, and, as a result, the digestive tracts were often empty. Enough specimens were obtained, however, to show conclusively that the sturgeon subsists to a very large extent upon *Mollusca*. Nearly all the smaller *Gastropoda* and *Pelecypoda* fall prey to it. A total of 16 species of *Mollusca*, as listed below, were taken from sturgeon stomachs.

Lymnaea galbana	*Planorbis antrosus*
" *emarginata*	" *exacuous*
" *stagnalis appressa*	" *hirsutus*
" *vahlii*	*Physa ancillaria*
	" *gyrina*
Valvata sincera	*Sphaeriidae 3 sp.*
" *tricarinata*	
Amnicola limosa	
" *sp.*	

The extent of the list given above proves that *Mollusca* are very important as food for the sturgeon, and indeed may constitute almost 100% of the material present. But often other animals which live on the bottom are eaten, and hence the proportion of *Mollusca* varies greatly.

Common Whitefish (Coregonus clupeaformis Mitchill)

The common whitefish is the most abundant and important food fish taken in Lake Nipigon. It lives mostly in deep water, but occasionally it comes into shallower areas. At such times it feeds extensively on *Mollusca*, but only upon the smaller species, as can be seen from the list following. Out of a total of 155 whitefish examined, the stomachs of all but one contained *Mollusca* and in amounts estimated to range all the way to 100%. The importance of *Mollusca* can be better appreciated if exceptional cases are considered. Two specimens are very impressive examples. In one of these over 4000 *Mollusca* were counted, and in the other over 1800, besides fragments of hundreds more. The species of *Mollusca* found in whitefish stomachs are as follows:

Lymnaea vahlii	*Valvata sincera*
" *apicina*	" *tricarinata*
" *galbana*	*Amnicola limosa*
Planorbis antrosus	" " *porata*
" *parvus*	" *sp.*
Physa gyrina	*Sphaeriidae 4 sp.*
" *sp.*	

Round Whitefish (*Coregonus quadrilateralis Richardson*)

This species was fairly abundant in the lake, although it was not of commercial importance, since it was not large enough to be caught in the 4½ inch gill-net. A total of 41 stomachs were examined, and in 37 of these it was estimated that less than 1% of the food material consisted of *Mollusca*. In the remaining four, the amount was considerably greater, being estimated at 5%, 10%, 20%, and 75% of the total. From this it appears that while *Mollusca* are eaten by the round whitefish to some extent, they are not, as a general rule, a very important constituent.

The following species were identified:

Lymnaea vahlii	*Valvata sincera*
" *galbana*	" *tricarinata*
Physa gyrina	*Sphaeriidae* 1 *sp.*
Amnicola sp.	

Common Sucker (*Catostomus commersoni* (*Lacépède*))

While having no commercial value, the sucker is very abundant in Lake Nipigon. It apparently consumes a large number of *Mollusca*, for 24 out of 25 stomachs which were examined contained them. In 19 of these the amount was estimated to range from 1% to 25%: in the remainder, less than 1%. The species represented are:

Physa gyrina	*Valvata sincera*
Planorbis hirsutus	" *tricarinata*
" *parvus*	*Sphaeriidae* 1 *sp.*

Northern Sucker (Catostomus catostomus (Forster))

Twenty-two stomachs of this species were examined and from these it is apparent that the northern sucker takes *Mollusca* in quantity only on rare occasions. Of the material examined 10 stomachs contained no *Mollusca*, 11 less than 1%, and one 20%. The species identified are as follows:

Lymnaea sp.? fragmentary	*Valvata sincera*
Planorbis antrosus	*Sphaeriidae 2 sp.*
" *parvus*	

Ciscoes

Among the ciscoes of Lake Nipigon there are probably three species, two of which reach such a size as to make them commercially important. They are caught in considerable numbers and are a valuable food fish. They generally inhabit very deep water, and are plankton feeders. In the stomachs examined, 3 out of 47 contained *Mollusca*, and these were small *Sphaeriidae*. Their presence was probably due to the fact that the ciscoes feed at times on the bottom and hence take in *Sphaeriidae* with other small organisms.

The other large fish in the lake are mostly piscivorous and do not, except accidentally or on very rare occasions, take *Mollusca* as food. Included in this group are the pike perch, pike, ling, lake trout, and brook trout. The smaller species, such as the darters and sticklebacks, live on small organisms such as insects and larvae of various kinds, and do not make much use of *Mollusca*.

COMPARISON OF LAKE NIPIGON WITH OTHER LAKES

Work similar to that done in Lake Nipigon has not, as yet, been carried out very extensively in North America, except in Lake Mendota in Wisconsin and Lake Oneida in New York. It is desirable, therefore, that some comparison should be made between these lakes and Laké Nipigon.

As regards physical features Lake Nipigon appears to have very little in common with the other two, which are both small shallow lakes, whereas Lake Nipigon is both very large and very deep. The greatest depth from which dredgings were taken in Lake Nipigon was 192 ft., but depths of over 300 ft. were sounded, and McInnes (1894) records a depth of 402 ft. In Lakes Mendota and Oneida work does not appear to have been carried on much below 30 ft. Moreover, Lake Nipigon is largely open water, and the only situations which correspond, in general, with conditions in the other two lakes are the small sheltered bays. Even in these, Lake Nipigon has not the large masses of higher vegetation and abundance of algae which is apparently a characteristic feature of the other lakes. The contrast between the Canadian and United States lakes is that between a young primitive lake, and old highly evolved lakes, as defined by Pearsall (1921).

Corresponding with the difference in physical features, there is also a difference in the distribution of animals, and particularly *Mollusca*, in the lakes considered. The number of species of *Mollusca* found in Lake Oneida was 91 (Baker, 1918), whereas in Nipigon the total was 44. Figures from Lake Mendota are apparently not available. In regard to distribution of species, it appears that in Lake Nipigon most forms are found in greatest abundance in shallower water than in the other lakes. This may be due to the fact that Lake Nipigon is subject to storms of considerable violence, with the result that the *Mollusca* seek the shallower water of protected bays. The storms, moreover, result in a washing of the exposed shores and a gradual transfer of food material and débris to quiet bays. Furthermore, the total average number of *Mollusca* per unit area in Lake Nipigon is intermediate between that of the other two—the results from dredging operations showing an average of 165 *Mollusca* per square metre in the Canadian lake.

While the results of stomach analysis show that *Mollusca* are a very valuable component of fish food, it is also evident that the number of species which feed on them is less in Lake Nipigon than in Lake Oneida, where some 18 out of 41 species consume them (Baker, 1916). This is, of course, due to the limited number of species in Lake Nipigon.

CONCLUSION

The results considered as a whole bring out several important facts: 1. As regards animal life, and particularly *Mollusca*, the most productive parts of the lake are small sheltered bays and the channels between islands. This is true especially where the bottom is covered with sand or mud, on which there is much organic débris to furnish food material. A depth of less than 30 ft. is the optimum, in general, for bottom organisms. Clean sand or clay bottoms, exposed points, and very deep water are relatively unproductive.

2. The fact that there is an average of 165 *Mollusca* per sq. metre of bottom shows that there must be an enormous number available in the lake. Nearly all species represented are valuable as food for whitefish and sturgeon, and these are the two most valuable fish in the lake.

3. The large molluscan resources suggest that sturgeon could be supported in much larger numbers than occur at the present time. As a result, some attempt should be made to propagate this fish artificially, as is done in the case of the whitefish.

While the work done makes no pretence of being exhaustive, nevertheless, the results afford some idea of the productivity of the lake in regard to *Mollusca*. The dredging operations give an accurate and efficient quantitative method of studying the animal population of the lake bottom. The importance of this work can be realized when it is considered that the bottom organisms furnish a large part of the fish food of the lake. Hence, in the intensive cultivation of any body of water, including re-stocking and the introduction of new species of fish, a knowledge of the food resources is absolutely essential. In this report an attempt has been made to furnish this information with respect to the *Mollusca* of Lake Nipigon.

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THE BOTTOM ORGANISMS OF LAKE NIPIGON

BY

F. B. ADAMSTONE and W. J. K. HARKNESS
OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

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THE BOTTOM ORGANISMS OF LAKE NIPIGON

As one phase of the investigation of the available food supply for the fish population of Lake Nipigon, an extensive series of dredging operations was carried out in order to obtain quantitative data in regard to those organisms which live on the bottom of the lake and form the food of those species of fish which feed at the bottom, such as the sturgeon, the whitefishes and the suckers. Special attention was paid to the Mollusca which were found to be one of the most important constituents of the bottom fauna and this part of the work is dealt with by Mr. Adamstone in a separate paper which includes a general account of the apparatus and methods employed in the dredging operations.

The present paper presents the results obtained *in toto* and such particular data for the various groups, other than the *Mollusca*, as it has been possible to bring to completion at the present time.

The following groups of animals were secured in the bottom samples: *Nematoda*, *Acanthocephala*, *Oligochaeta*, *Hirudinea*, *Crustacea*, *Insecta*, *Arachnida* and *Mollusca*. The details concerning the number of specimens of each group obtained in each dredging, as well as information regarding depth and character of bottom, are given in the appended series of tables.

I. Nematoda

The free-living round worms were not very abundant, for a total of only 77 specimens was obtained in all the dredgings. These were about equally distributed on mud and sand bottoms, but were somewhat more numerous in shallower water. The specimens were submitted to Dr.

N. S. Cobb of the U.S. Department of Agriculture, who kindly undertook to identify them. He has reported the following species:

1. *Dorylaimus crassus* de Man.
2. " *speciosus* (n. sp. Cobb mss.)
3. " *canadensis* (n. sp. Cobb mss.)
4. *Mermithidae* several sp.

Two of the species listed, viz., *Dorylaimus speciosus* and *Dorylaimus canadensis*, are new species. There are also several species of *Mermithidae* which have not yet been determined.

II. ACANTHOCEPHALA

This class is represented by five specimens which were dredged up from a depth of 36 ft., off a clay bottom (Series XIV, D. 8). Their occurrence in this particular place is thought to have been accidental, most probably, since all members of the group are parasitic.

III. OLIGOCHAETA

Oligochaetes were obtained very frequently and in the most diverse situations. Identification of the species has not yet been completed so that it is impossible at present to give any details in this regard. An attempt has been made, however, to work out the distribution of the class as a whole and in the following table the average number of specimens per

Depth	No. on Mud	No. on Sand	Total	Av.
0- 3	59	26	85	3.7
3- 6	69	61	130	4.8
9	101	54	155	7.4
12	19	69	88	4.4
15	19	32	51	2.5
18	25	28	53	2.9
21	21	16	37	1.8
24	12	7	19	2.3
27	6+(1 clay)	3	10	1.2
30	9	6	15	1.9

unit area (81 sq. inches) is given for intervals of 3 feet in depth down to 30 feet. Beyond this, specimens were not numerous although some were obtained from various depths down to 178 feet.

From the table it can be seen that the number of individuals was almost the same on mud and sand bottoms. Distribution according to depth is illustrated by the curve, Fig. 1, from which it is evident that the optimum depth for these animals is between 6-9 ft. The fall in the curve shows that they are most abundant in shallow water especially between depths of 3 and 12 feet.

IV. HIRUDINEA

Leeches were uncommon in the material secured in dredging. This, however, was to be expected, since they usually seek more protected situations among stones, and in such places the dredge could not be used. Some shore collections were made but these were not very extensive. Specimens were submitted to Prof. J. P. Moore of the University of Pennsylvania, who very kindly identified them. The species reported are:

1. *Actinobdella triannulata* (n. sp. Moore mss.)
2. *Dina parva* Moore.
3. *Erpobdella punctata* (Leidy)
4. *Glossiphonia complanata* (Linn)
5. *Haemopsis marmoratis* (Say)
6. *Helobdella stagnalis* (Linn)
7. *Nephelopsis obscura* (Verrill)
8. *Piscicola milneri* (Verrill)

Of the eight species listed the first, namely, *Actinobdella triannulata*, is noted tentatively as a new species.

V. CRUSTACEA

Representatives of three sub-classes of *Crustacea* occurred amongst the bottom organisms, including the following:

1. *Branchiopoda*—Order *Cladocera*
2. *Ostracoda*
3. *Malacostraca*—Order *Amphipoda*

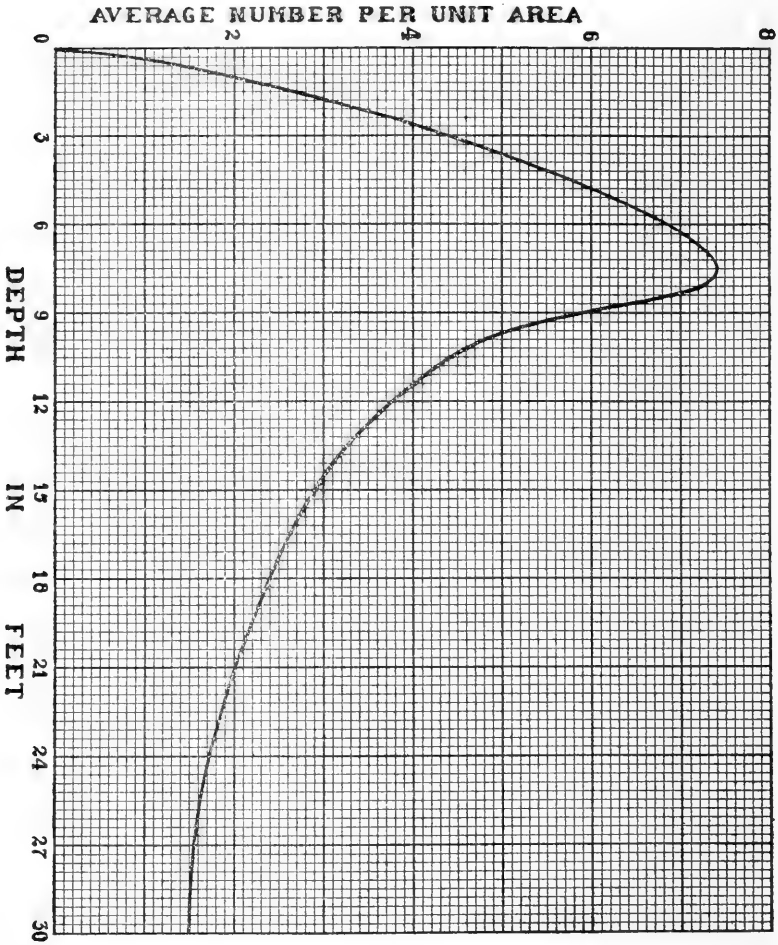

FIG. 1. Curve illustrating distribution according to depth. Oligochaeta.

Cladocera: Very few specimens of *Cladocera* were obtained. This was due, most probably, to the fact that they were usually lost, on account of their small size, in the process of washing and cleaning the material. This was unfortunate especially since some of these forms are important constituents in the food of bottom feeding fish.

Four species were identified, namely:

1. *Alona affinis* (Leydig)
2. *Chydorus sphaericus* var *coelatus* Schoedler
3. *Sida crystallina* (Müller)
4. *Eurycercus lamellatus* (Müller)

2. *Ostracoda:* The *Ostracoda,* like the *Cladocera,* were very frequently lost in washing the samples. However, in some 23 dredgings a number of specimens were found. The different species amongst them have not yet been determined. Examination of fish stomachs showed that in some localities *Ostracoda* must be extremely abundant and may form a very high percentage of the stomach contents.

3. *Amphipoda:* *Amphipoda* were quite common throughout the southern end of the lake. Three species were obtained:

1. *Pontoporeia hoyi* Smith
2. *Hyalella knickerbockeri* (Bate)
3. *Gammarus limnaeus* Smith

Pontoporeia hoyi Smith

Of the three species, *Pontoporeia hoyi* was by far the most numerous. It was taken in almost all situations and at all depths down to 192 feet. Data pertaining to the distribution of this species are given in the following table and from it the curve, Fig. 2A, has been drawn.

The curve in Fig. 2A shows that this species is not very plentiful in shallow water but it becomes more abundant as the depth increases. This, of course, does not go on indefinitely but after a depth of about 75 ft. is reached, the distribution becomes more uniform and the maximum is apparently reached between 120-150 ft.

Depth	Total	Av.
0-30	512	3.05
30-60	428	12.23
60-90	305	21.78
90-120	87	21.75
120-150	231	33.0
150-180	85	17.0
180-192	45	.....

Hyalella knickerbockeri (Bate)

In contrast with the preceding species this amphipod was comparatively scarce. Usually it is found, with *Pontoporeia hoyi*, in about equal numbers, but the dredgings in Lake Nipigon yielded a much smaller number of specimens. It was obtained mostly in shallow water but a few specimens were brought up from deeper places. Data with regard to the abundance of this species at various depths are given in the following table.

Depth	Total	Av.
0-3	5	.31
3-6	39	1.5
9	13	.62
12	23	1.15
15	29	1.45
18	30	1.66
21	79	3.95
24	1	.12
27	5	.62
48	3	
90	2	
159	2	

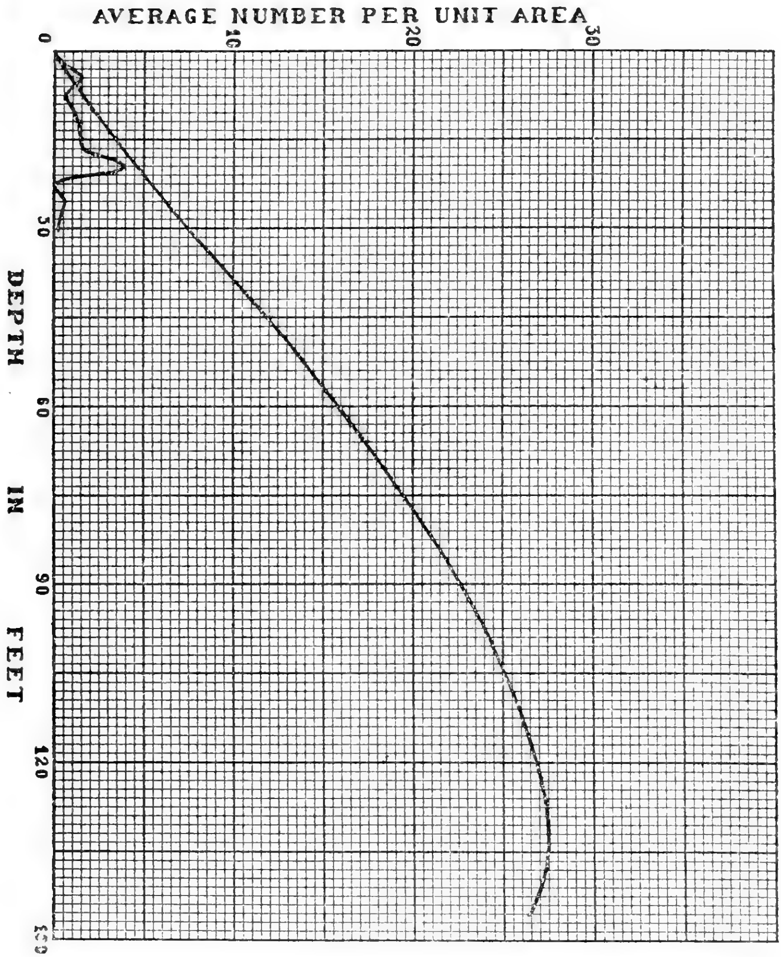

FIG. 2. Curves illustrating distribution according to depth.
Amphipoda. A. Pontoporeia hoyi (Upper).
B. Hyalella knickerbockeri (Lower).

The curve, Fig. 2B, drawn from the results given above, shows that there is a decided difference in the distribution of this species as compared with the other, not only in regard to relative abundance, but also in the fact that it is practically confined to shallow water near shore.

Gammarus limnaeus Smith

This species was quite rare and was obtained on only a few occasions and then only in the protected channels between islands. A total of 7 specimens was secured and these came from some of the outer Shakespeare islands in water from 3 to 21 feet deep. The species is apparently of very little importance numerically.

VI. INSECTA

The larval and nymphal stages of several insects occurred in the material from dredgings, and representatives of the following Orders were found amongst them: *Ephemerida, Odonata, Neuroptera, Trichoptera, Coleoptera, Diptera* (chiefly *Chironomidae*).

Ephemerida

May fly nymphs were found most frequently in bottom samples taken from small sheltered bays. The specimens obtained were identified by Dr. W. A. Clemens who reports the species enumerated below:

1. *Hexagenia bilineata* Say
2. *Ephemera simulans* Walker
3. *Caenis diminuta* Walker
4. *Ephemerella* sp.
5. *Baetis* sp.

The first three species were fairly common but the remaining two were dredged up on only a few rare occasions. A summary of the numbers obtained at different depths is given in the following table from which the graphs, Fig. 3, have been drawn.

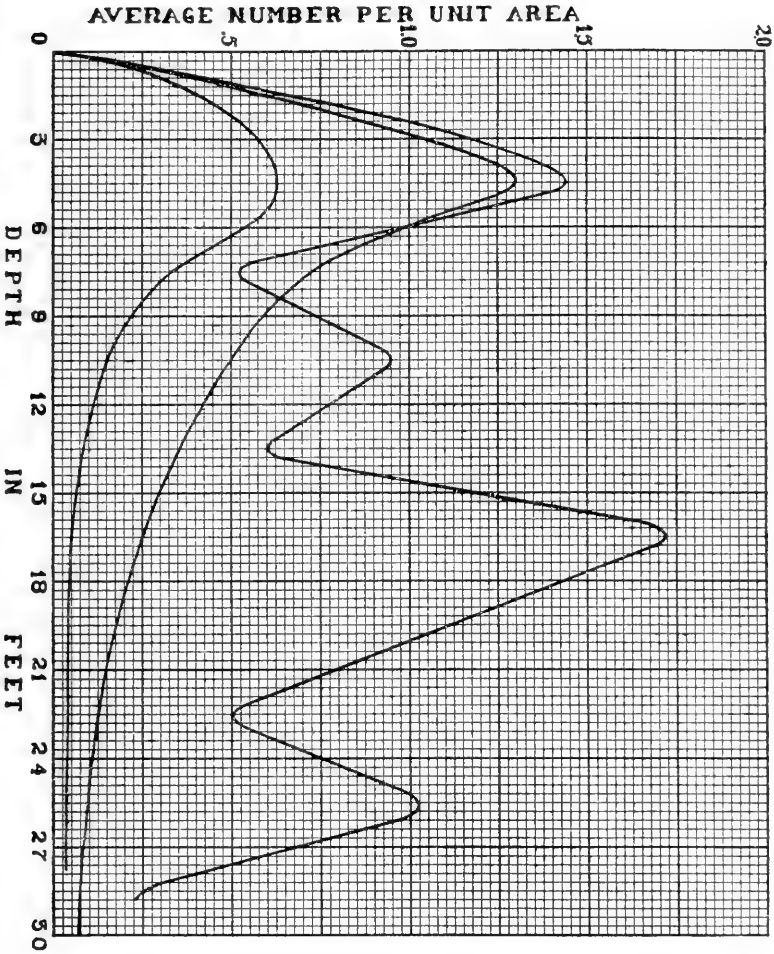

FIG. 3. Curves illustrating distribution according to depth. Ephemerida. A. Hexagenia bilineata (Upper). B. Ephemera simulans (Middle). C. Caenis diminuta (Lower).

Depth (ft.)	No. of Dredgings	*Hexagenia bilineata*			*Ephemera simulans*			*Caenis diminuta*			*Ephemerella* sp.	*Baetis* sp.
		Sand	Mud	Average	Sand	Mud	Average	Sand	Mud	Average		
0-3	18	7	4	.65	6	4	.60	1	6	.41	..	..
3-6	27	4	35	1.44	32	3	1.55	12	5	.37	4	1
6-9	21	1	10	.52	8	4	.62	2	5	.33	..	..
9-12	20	1	18	.95	2	5	.35	..	3	.10	..	..
12-15	20	1	11	.60	7	1	.40	2	..	.10	..	..
15-18	18	5	26	1.72	6	2	.44	..	..	0	..	..
18-21	20	1	19	1.11	2	..	.11	..	1	.06	..	..
21-24	8	0	4	.5	0	1	.12	..	..	..	..	..
24-27	8	2	2	1.12	1	..	.12	1	..	.12	..	..
27-30	8	..	2	.25	..	..	..	..	..	..	..	..
30-33	6	..	..	..	1	..	.16	..	..	..	..	..
33-36	..	..	..	..	..	..	..	..	..	..	..	..
36-39	..	..	..	..	..	..	..	..	..	..	..	..
48	..	..	..	..	..	..	..	..	2	..	..	..

From the table it is evident that the species *Hexagenia bilineata* prefers a muddy bottom, whereas the species *Ephemera simulans* is most abundant in sandy situations. The latter as well as *Caenis diminuta* are most numerous in shallow water, as can be seen from the curves, Fig. 3, and their optimum range is between depths of 0-9 feet. The other species, *Hexagenia bilineata*, is apparently fairly uniformly distributed over all depths between 5-25 ft., this being probably the significance of the very irregular curve representing the species.

Trichoptera

A total of 116 caddis fly larvae were obtained in the dredgings, amongst these were representatives of nine families:

Rhyacophilidae
Hydropsychidae
Psychomyidae
Polycentropidae
Sariscostomatidae
Mollanidae
Leptoceridae
Phryganidae
Limnophilidae

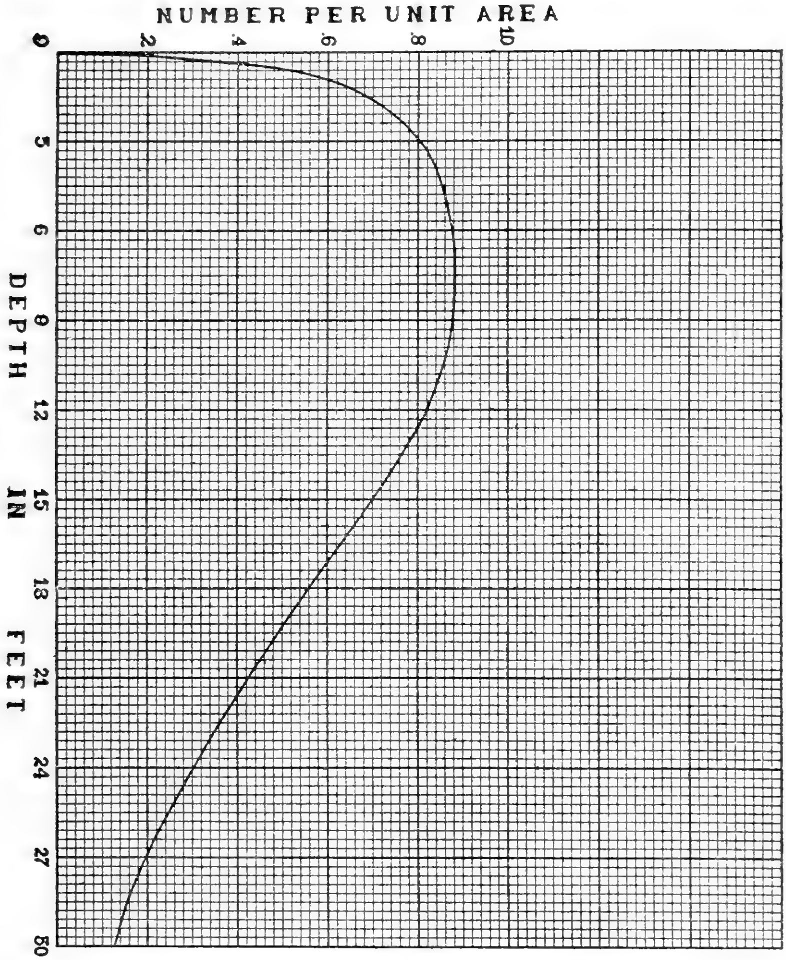

FIG. 4. Curve illustrating distribution according to depth. Trichoptera.

The specific determinations have not yet been completed and hence no data will be given at present concerning them. The average numbers taken at various depths are given in the table below and from it the graph, Fig. 4, illustrating the distribution of the order with depth has been drawn.

Depth	No.	Av.	Depth	No.	Av.
0-3	12	.66	24	1	.12
3-6	22	.81	27	4	.50
9	18	.86	30	3	.37
12	18	.90	39	1	..
15	15	.75	45	2	..
18	14	.78	48	1	..
21	5	.25	..	..	..

From the curve it is evident that caddis larvae are most numerous in shallow water between 0-18 feet deep. They were found mostly in small protected bays or in the channels between islands.

Diptera—Chironomidae

Of all the bottom organisms, the larvae of the *Chironomidae* proved to be the most abundant. Owing to the large amount of material obtained it has been impossible to bring to completion at the present time the details in respect of specific distribution, relative abundance and importance. The results here presented deal for the most part with the group as a whole. Table I gives the data concerning the numbers obtained at the various depths and on the various kinds of bottom. Graph 5 shows the quantitative distribution on the basis of the average number of larvae per 15-foot intervals.

The results show that in a total of 228 dredgings extending to a depth of 180 feet, 3723 larvae were obtained, this being an average of 16 per dredging, that is, per 81 square inches. In some cases as high as 159 larvae were obtained from the above unit area.

About two-thirds of the dredgings, that is 168, were taken in water less than 30 feet in depth and in this range the largest number of *Chironomidae* were found to occur, namely 3225, which is an average of 19 per 81 square inches. Between the depths of 30 and 60 feet the number of larvae tended to decrease but there was a marked increase again between 60 and 75 feet. In water beyond 75 feet in depth the number of larvae was relatively small, but even at a depth of 178 feet eight were obtained in a single dredging.

Table II is given to illustrate the distribution of species as obtained in four series of dredgings. No specific names are used because some of the identifications are tentative and because it is thought that several species are new to science. Life history studies will be necessary in many cases before identifications can be completed. It is probable that certain species are characteristic of certain limited ranges of depth, while others are widely distributed. Species 1, for example, evidently occurs only in shallow water and is abundant there; species 22, on the other hand, is doubtless a deep water form, while species 6 was found at depths from 12 to 150 feet.

TABLE I

Depth	No. of dredgings	Total No. of larvae	Average per dredging	Average per dredging per 15 ft.		
				Mud	Sand	Clay
0-15	106	2153	20.3	26.1	16.3	0.0
15-30	62	1072	17.3	26.5	9.6	15.0
30-45	22	236	10.8	12.1	11.0	1.5
45-60	13	78	6.0	8.0	3.0	0.0
60-75	8	115	14.7	20.1	1.0	5.0
75-90	6	13	2.2	1.5	..	2.5
90-105	2	5	2.5	5.0	...	0.0
105-120	2	6	3.0	6.0	..	0.0
120-135	1		5.0	5.0	..	0.0
135-150	6	38	4.6	4.6	..	4.6
150-165	4	6	1.5	1.0	..	2.0
165-180	1	8	8.0	8.0	..	0.0

CHIRONOMIDAE: TABLE II

	Depth	Sp. 1	Sp. 2	Sp. 3	Sp. 4	Sp. 5	Sp. 6	Sp. 7	Sp. 8	Sp. 9	Sp. 10	Sp. 11	Sp. 12	Sp. 13	Sp. 14	Sp. 15	Sp. 16	Sp. 17	Sp. 18	Sp. 19	Sp. 20	Sp. 21	Sp. 22	Sp. 23	Sp. 24	Sp. 25	Sp. 26
Series II																											
1	7 ft.	..	4	..	..	1	..	1	..	..	..	1	..	..	..	..	..	..	2	..	..	..	..	1	..	..	1
2	45	..	..	1	..	..	..	1	..	..	..	1	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..
3	120	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4	162	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5	93	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6	72	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7	60	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8	12	11	..	..	..	1	..	2	..	..	..	2	..	..	1	..	..	..	..	3	..	..	..	..	..	1	..
9	11	2	3	..	..	4	..	5	..	1	..	3	..	..	6	..	..	..	11	2	1	..	..	..	..	..	..
Series III																											
1	6	18	..	3	1	1	..	1	..	1	..	3	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..
2	12	6	..	1	..	2	1	1	1	1	..	1	..	2	1	1	1	..	..	..	..	..	..	..	..	..	..
3	21	3	..	..	..	..	..	1	..	..	1	1	2	..	..	..	1	..	..	..	3	..	..	..	..	..	..
4	45	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Series IV																											
1	12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2	21	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
3	27	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4	30	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5	48	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6	159	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..

CHIRONOMIDAE: TABLE II—*Cont.*

	Depth	Sp. 1	Sp. 2	Sp. 3	Sp. 4	Sp. 5	Sp. 6	Sp. 7	Sp. 8	Sp. 9	Sp. 10	Sp. 11	Sp. 12	Sp. 13	Sp. 14	Sp. 15	Sp. 16	Sp. 17	Sp. 18	Sp. 19	Sp. 20	Sp. 21	Sp. 22	Sp. 23	Sp. 24	Sp. 25	Sp. 26
Series V																											
1	150	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	..	..	..
2	150	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
3	156	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..
4	163	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..
5	80	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6	96	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7	78	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8	45	..	..	..	..	..	5	..	..	..	..	1	..	..	..	..	..	2	..	..	..	..	8	1	1	..	..
9	84	..	..	..	..	..	..	..	..	..	..	4	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..
10	192	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

FIG. 5. Curve illustrating distribution according to depth.
Chironomidae. A. On mud bottom.
B. On sand bottom.
C. On clay bottom.
D. On all bottoms.

The curves would seem to graphically illustrate this point also, in that, on the various kinds of bottom there are depths at which larvae were especially abundant, doubtless representing associations of species.

The number of larvae on the bottom of the lake of course is not constant over any extended period of time during the open season. Throughout the summer and autumn large numbers of larvae are maturing, pupating and adults emerging. Eggs are being deposited and larvae hatching. No doubt considerable numbers of small, newly hatched individuals were lost in the processes of sifting materials and the actual numbers on the bottom were slightly larger than the results obtained would indicate. It is evident, however, in spite of the fluctuations in numbers, that the supply of larvae available as food for fish is always large. This would be expected of course in view of the large numbers of species with their extended periods of emergence, and is confirmed by the dredging results. Adults were observed in large numbers during the three months spent on the lake.

As a preliminary experiment for obtaining some information regarding the extent of this life history cycle, a tent trap covering 540 sq. inches of water surface was constructed and set out at various times. The results obtained were as follows:

STATION 1. Depth of water 5 ft., 10 yds. from shore.
- July 15, 96 hrs., windy and rain, 17 adults and 9 pupae.
- Aug. 1, 9 hrs., day, windy, clear, 1 adult.
- Aug. 2, 13 hrs., night, calm, clear, 8 adults.
- Aug. 16, One dredging, bottom sandy, 19 larvae = 127 per 540 square inches.

STATION 2. Depth of water 8 ft., 50 yards from shore.
- Aug. 4, 12 hrs., night, clear and warm, 1 adult.
- Aug. 5, 12 hrs., day, wind and rain, 0 adults.
- Aug. 16, One dredging, bottom—debris, sand, stones; 39 larvae = 260 per 540 square inches.

STATION 3. Depth of water 10 ft., 80 yards from shore.
Aug. 9, 12 hrs., night, windy and rainy, 50 adults.
Aug. 16, 12 hrs., day, calm, clear and cool, 90 adults.
Aug. 19, 9 hrs., day, windy and cloudy, 5 adults.
Aug. 16, One dredging, bottom—debris, sand and stones; 54 larvae = 360 per 540 square inches.

The results obtained at Station 3 are perhaps the most satisfactory and give some idea of the extensive emergings which may take place.

In Lake Nipigon the *Chironomidae* are very important economically in that the larvae form one of the most important sources of fish food. The following fish have been found to feed more or less extensively on the larvae and to some extent on the pupae and adults: sturgeon, northern sucker, common sucker, two minnows (*Notropis hudsonius* and *Couesius plumbeus*), common whitefish, round whitefish, ciscoes, trout perch, young small mouth black bass, young yellow perch and ling. One whitefish, 28 cm. in length, taken June 30, contained 354 larvae, constituting approximately 70% of the stomach contents. A sturgeon, taken June 24, had eaten at least 331 larvae. Percentages in bottom-feeding fish ranged as high as 96%. The *Chironomidae* thus play a very significant rôle in the economy of the lake.

Besides the orders of Insecta which have been considered in more detail, specimens of a few others were obtained. These include:

Neuroptera—Sialidae
Coleoptera—{*Dytiscidae*, *Chrysomelidae*}
Odonata

The occurrence of these organisms seems to have been more or less incidental in dredging operations although they were certainly abundant and widely distributed. However, the number secured in bottom samples in this season was so small that no statement can be made in regard to them.

VII. Arachnida

In a number of situations specimens of water mites (*Hydracarina*) were dredged up. The total, however, was small and since identifications have not yet been completed details will be given in a future report.

VIII. Mollusca

Details concerning the species, abundance and distribution of this group are given in another paper.

Conclusions

I. Study of the bottom fauna of Lake Nipigon has revealed an abundant and varied population of many different kinds of organisms, and it has been found, with few exceptions, that the shallow waters of small protected bays or the channels between islands were most productive of these animals. The open lake was relatively unproductive. These facts are apparently quite in accord with observations made in other bodies of water which have been studied in a similar manner.

II. Although the data at hand, as a result of the first season's study, are perhaps not quite extensive enough to allow of making general statements in regard to the abundance of some of the animals found on the lake bottom, it is desirable, nevertheless, that some estimate of the number of organisms available on a unit area of the bottom should be made. In the following table the average number of animals of each of the various groups is given for a unit area.

	Av. per sq. yd.	Av. per sq. metre
Mollusca	138	165
Oligochaeta	51	63
Amphipoda	131	160
Ephemerida	20	25
Trichoptera	8	10
Chironomidae	253	303
Animals of all kinds	630	753

III. The results given in the table indicate a rich source of food supply for fish and the fact that it is drawn upon very extensively by several species has been amply demonstrated by the examination of stomach contents.* The common whitefish (*Coregonus clupeaformis*), which is the most abundant and most important commercial fish in the lake, feeds almost exclusively upon bottom organisms. The sturgeon (*Acipenser rubicundus*), also important commercially, is likewise a bottom feeder. Three other species, although not marketed at the present time, depend almost entirely upon this source. These are the round whitefish (*Coregonus quadrilateralis*), the common sucker (*Catostomus commersonii*), and the northern sucker (*Catostomus catostomus*). The importance of the evaluation of the bottom fauna in any body of water in any undertaking relating to fish production becomes quite evident when its importance as fish food is taken into consideration.

*The results of the examination of stomach contents of various species of fish are given in another paper in the series.

ORIENT BAY AT MACDIARMID

Series II

										Totals
Dredging	1	2	3	4	5	6	7	8	9	..
Depth (in feet)	7	45	120	162	93	72	60	12	11	..
Character of Bottom	Coarse Grit	Grit on Clay	Clay	Mud	Mud	Sand	Rock	Sand	Sand	..
Distance from Shore (yds.)	10	30	75	175	600	1200	1400	1800	1900	..
Mollusca	16	..	..	..	..	..	..	11	21	48
Chironomidae	12	5	..	1	2	1	..	26	32	79
Ephemeridae	1	..	..	..	..	..	..	..	..	1
Amphipoda	..	3	5	36	25	4	..	..	..	73
Oligochaeta	3	..	..	1	1	..	..	7	47	59
Nematoda	..	..	..	..	..	..	..	1	..	1
Totals	32	8	5	38	28	5	..	45	100	261

SAND POINT BAY			Series III		SANDY RIVER TO N. SHAKESPEARE					Series IV	
											Totals
Dredging	1	2	3	4	1	2	3	4	5	6	..
Depth (in feet)	6	12	21	45	12	21	27	30	48	159	..
Character of Bottom	Gravel	Gravel	Sand	Mud	Clay	Sand	Sand	Sand	Sand	Mud	..
Distance from Shore (yds.)	30	60	120	440	150	250	850	1200	2800	4550	..
Mollusca	6	5	4	..	..	4	..	16	10	..	45
Chironomidae	33	37	14	1	..	2	1	3	..	1	92
Trichoptera	3	1	1	..	..	1	..	..	..	..	6
Ephemeridae	4	..	1	..	..	..	..	..	..	..	5
Amphipoda	13	3	4	4	..	13	..	..	..	6	43
Nematoda	1	..	..	..	..	..	..	..	..	1	2
Oligochaeta	2	3	7	..	..	..	..	1	..	..	13
Hydracarina	1	..	1	..	..	1	..	..	..	..	3
Totals	63	49	32	5	..	21	1	20	10	8	209

SHAKESPEARE ISLAND TO SANDY RIVER

Series V

											Totals
Dredging	1	2	3	4	5	6	7	8	9	10	..
Depth (in feet)	150	150	156	163	80	96	78	45	84	192	..
Character of Bottom	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Gravel	Clay	Mud	..
Distance from Shore	50 yd	100 yd	200 yd	400 yd	800 yd	1 mile	2 miles	3 miles	$3\frac{1}{4}$ miles	6 miles	..
Mollusca	..	..	..	..	..	..	..	8	..	1	9
Chironomidae	3	..	1	3	..	..	1	23	..	..	31
Amphipoda	36	10	25	8	3	13	21	6	28	45	195
Ostracoda	..	..	..	1	..	..	..	..	..	..	1
Oligochaeta	..	..	1	..	..	..	..	..	1	..	2
Nematoda	..	..	..	1	..	..	..	..	..	..	1
Trichoptera	..	..	..	..	..	..	..	2	..	..	2
Totals	39	10	27	13	3	13	22	39	29	46	241

SAND POINT BAY (Off McColeman's Dock) Series VI

										Totals
Dredging	1	2	3	4	5	6	7	8	9	..
Depth (in feet)	6	9	12	14	15	15	15	15	16	..
Character of Bottom	Sand	Sand	Sand	Sand	Sand & Gravel	Sand	Sand & Gravel	Sand & Gravel	Sand & Gravel	..
Distance from Shore (ft.)	75	100	150	175	200	225	250	275	300	..
Mollusca	..	..	3	1	3	1	..	6	15	29
Chironomidae	6	6	8	12	1	..	4	5	18	60
Amphipoda	..	..	..	4	..	..	..	..	12	16
Oligochaeta	..	..	1	4	..	..	..	..	3	8
Ephemeridae	..	..	..	..	..	..	1	1	..	2
Hydracarina	..	..	..	..	..	..	..	..	..	..
Totals	6	6	12	21	4	1	5	12	48	115

SAND POINT BAY (Off McColeman's Dock) — Series VI

									Totals
Dredging	10	11	12	13	14	15	16	17	..
Depth (in feet)	15	21	27	39	53	60	69	75	..
Character of Bottom	Gravel	Gravel	Mud	Clay	Clay	Mud	Mud	Clay	..
Distance from Shore (ft.)	330	375	450	600	750	900	1200	1500	..
Mollusca	6	1	3	..	..	..	..	..	10
Chironomidae	4	4	10	..	..	2	7	5	32
Amphipoda	..	..	..	13	11	7	21	25	77
Oligochaeta	1	1	5	..	..	1	..	..	8
Ephemeridae	..	..	1	..	..	..	..	..	1
Hydracarina	..	..	2	..	..	..	..	..	2
Totals	11	6	21	13	11	10	28	30	130

BAY EAST OF COOKE POINT

Series VIII

Dredging	1	2	3	4	5	6	7	8	9	10	Totals
Depth (in feet)	15	15	18	21	21	18	23	30	33	48	..
Character of Bottom	Sand	Sand	Sand	Sand	Gravel	Rock	Sand & Rock	Sand & Rock	Sand & Gravel	Mud	
Distance from Shore (yds.)	100	150	200	250	325	400	550	880	1100	1800	..
Mollusca	2	3	1	3	1	5	..	3	..	..	18
Chironomidae	7	23	12	40	32	10	..	24	5	14	167
Amphipoda	3	3	..	..	..	..	..	5	1	8	20
Oligochaeta	4	11	1	2	1	1	4	4	2	7	37
Nematoda	..	6	..	1	..	2	..	2	..	5	16
Trichoptera	..	1	1	..	..	..	..	..	..	..	2
Hydracarina	..	..	..	1	1	..	..	..	..	1	3
Ephemeridae	..	..	..	1	..	..	..	..	..	..	1
Totals	16	47	15	48	35	18	4	38	8	35	264

BLACKWATER BAY — Series IX

Dredging	1	2	3	4	5	6	7	8	Totals
Depth (in feet)	8	9	18	21	21	27	30	33	..
Character of Bottom	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	..
Distance from Shore (yds.)	275	300	370	450	525	600	700	880	..
Mollusca	..	..	..	1	..	5	7	2	15
Chironomidae	1	10	..	3	14	4	2	11	45
Amphipoda	..	..	2	2	..	2	10	3	19
Oligochaeta	..	..	..	..	1	..	1	..	2
Nematoda	..	..	..	..	..	..	2	..	2
Ephemeridae	1	..	..	..	..	..	..	..	1
Hydracarina	..	..	..	..	..	1	..	..	1
Totals	2	10	2	6	15	12	22	16	85

BLACKWATER BAY — Series X

									Totals
Dredging	1	2	3	4	5	6	7	8	..
Depth (in feet)	12	21	24	27	29	36	39	39	..
Character of Bottom	Sand	Gravel	Sand	Sand	Sand	Sand	Sand	Sand	..
Distance from Shore (yds.)	50	100	150	200	300	700	900	900	..
Mollusca	..	4	..	1	..	8	..	9	22
Chironomidae	8	19	4	2	1	5	2	5	46
Amphipoda	1	..	1	..	..	..	..	..	2
Oligochaeta	..	2	..	..	..	..	1	..	3
Trichoptera	3	..	..	..	..	..	..	..	3
Totals	12	25	5	3	1	13	3	14	76

SOUTH SHAKESPEARE ISLANDS — Series XI

Dredging	1	2	3	4	5	6	7	8	Totals
Depth (in feet)	3	6	27	48	48	54	51	30	..
Character of Bottom	Rock	Sand	Clay	Ooze	Ooze	Ooze	Ooze	Ooze	..
Distance from Shore (yds.)	5	15	80	200	400	600	800	900	..
Mollusca	4	53	..	..	..	..	..	1	58
Chironomidae	11	13	15	5	..	4	9	..	57
Amphipoda	..	..	20	32	9	63	89	2	215
Oligochaeta	3	2	1	2	1	18	10	1	38
Nematoda	..	1	..	1	..	1	..	..	3
Ephemeridae	1	5	6	3	..	..	..	2	17
Trichoptera	..	3	1	1	..	..	..	1	6
Hydracarina	..	..	..	1	..	..	..	..	1
Totals	19	77	43	45	10	86	108	7	395

EAST SHAKESPEARE ISLANDS

Series XII

								Total
Dredging	1	2	3	4	5	6	7	..
Depth (in feet)	6	15	21	21	21	18	15	..
Character of Bottom	Sand among Rocks	Sand	Mud	Algae	Algae	Sand	Sand	..
Distance from Shore (yds)	15	50	100	200	400	800	1000	..
Mollusca	4	15	6	8	12	25	15	85
Chironomidae	13	30	5	67	45	28	23	211
Trichoptera	1	8	..	..	..	4	..	13
Ephemeridae	4	3	..	1	..	5	4	17
Amphipoda	..	70	16	62	..	96	33	277
Oligochaeta	1	2	..	..	1	7	..	11
Nematoda	..	..	..	..	..	1	..	1
Hydracarina	..	..	..	..	..	6	..	6
Totals	23	128	27	138	58	172	75	621

NORTH SHAKESPEARE—HAT MOUNTAIN

Series XIII

									Totals
Dredging	1	2	3	4	5	6	7	8	..
Depth (in feet)	3	15	18	24	33	57	63	69	..
Character of Bottom	Sand	Ooze	Mud	Ooze	Gravel & Sand	Mud	Mud	Mud	..
Distance from Shore (yds.)	15	80	130	430	530	730	900	1100	..
Mollusca	..	18	15	29	1	1	..	..	64
Chironomidae	3	59	46	98	32	10	28	3	279
Amphipoda	12	3	3	20	5	4	18	2	67
Oligochaeta	1	7	3	3	2	1	..	..	17
Nematoda	..	1	..	1	1	..	5	..	8
Trichoptera	..	2	4	1	..	..	..	..	7
Ephemeridae	..	..	..	1	1	..	..	..	2
Hydracarina	..	2	..	..	..	..	..	..	2
Totals	16	92	71	153	42	16	51	5	446

McL. BAY | Series XIV

Dredging	1	2	3	4	5	6	7	8	Totals
Depth (in feet)	3	3	6	6	9	15	30	36	..
Character of Bottom	Wood Debris & Mud	Mud	Mud	Mud	Mud	Mud	Sand	Clay	..
Distance from Shore (yds.)	15	40	75	150	200	250	350	450	..
Mollusca	4	7	33	15	85	2	..	..	146
Chironomidae	7	..	30	2	49	6	7	3	104
Amphipoda	..	..	3	..	..	..	..	1	4
Oligochaeta	20	..	4	..	27	4	..	3	58
Nematoda	3	..	1	..	..	..	..	..	4
Tabanidae	2	..	..	..	..	..	..	..	2
Ephemeridae	..	3	2	3	2	..	..	..	10
Trichoptera	1	..	..	1	2	..	..	..	4
Hirudinea	1	..	..	..	..	..	..	..	1
Hydracarina	..	..	2	..	..	..	..	..	2
Neuroptera	..	..	1	..	..	..	..	..	1
Acanthocephala	..	..	..	..	..	..	..	7	7
Totals	38	10	76	21	165	12	7	14	343

FOOT OF ORIENT BAY

Series XV

											Totals
Dredging	1	2	3	4	5	6	7	8	9	10	..
Depth (in feet)	12	3	2	5	3	5	9	69	51	27	..
Character of Bottom	Gravel	Sand	Sand	Sand	Sand	Sand	Sand	Mud	Mud	Mud	..
Distance from Shore (yds.)	..	100	200	300	400	550	700	800	900	1000	..
Mollusca	3	..	..	10	11	5	32	5	..	13	79
Chironomidae	..	2	1	3	4	11	11	53	27	15	127
Amphipoda	..	..	..	..	1	..	..	1	1	10	13
Oligochaeta	..	..	..	..	5	2	3	1	2	1	14
Nematoda	..	..	..	..	..	..	2	..	..	1	3
Ostracoda	..	..	..	..	..	..	1	2	..	..	3
Ephemeridae	..	1	..	1	..	1	1	..	..	..	4
Trichoptera	..	2	..	..	1	2	..	..	..	..	5
Totals	3	5	1	14	22	21	50	62	30	40	248

BLACKWATER BAY — Series XVI

										Totals
Dredging	1	2	3	4	5	6	7	8	9	..
Depth (in feet)	12	21	21	21	39	90	117	147	178	..
Character of Bottom	Sand	Mud & Gravel	Mud & Gravel	Mud & Gravel	Mud	Clay	Mud	Mud	Mud	..
Distance from Shore (yds.)	50	150	250	350	450	550	650	750	1000	..
Mollusca	..	1	..	4	7	2	..	..	..	14
Chironomidae	3	8	9	3	8	9	6	6	8	60
Trichoptera	..	..	..	..	1	..	..	..	..	1
Amphipoda	..	..	4	..	..	36	44	19	12	115
Oligochaeta	..	..	..	..	..	3	..	3	3	9
Nematoda	..	..	1	..	..	..	..	2	2	5
Hydracarina	..	..	..	..	..	..	1	..	..	1
Ostracoda	..	..	..	..	..	2	..	3	..	5
Totals	3	9	14	7	16	52	51	33	25	210

SECOND CHANNEL W. OF NIPIGON RIVER — Series XVII

									Totals
Dredging	1	2	3	4	5	6	7	8	..
Depth (in feet)	18	18	12	12	12	3	27	28	..
Character of Bottom	Mud	Mud	Mud	Mud	Mud	Sand	Gravel	Mud & Sand	..
Distance from Shore (yds.)	25	75	150	250	350	550	750	1150	..
Mollusca	5	12	19	26	15	7	33	1	118
Chironomidae	35	37	55	17	18	154	9	12	337
Ephemeridae	6	4	5	6	2	8	4	..	35
Trichoptera	..	1	7	..	..	1	3	2	14
Amphipoda	3	..	9	6	..	..	6	2	26
Oligochaeta	4	8	4	..	8	9	1	7	41
Ostracoda	..	..	..	..	3	1	..	..	4
Hirudinea	..	1	1	..	..	1	1	..	4
Hydracarina	..	..	1	..	..	2	..	..	3
Neuroptera	..	..	1	1	..	..	..	..	2
Coleoptera	..	..	..	1	..	1	..	..	2
Totals	53	63	102	57	46	184	57	24	586

SOUTH BAY (West Shore)			Series XVIII		SOUTH BAY (West Shore)			Series XIX	
									Totals
Dredging	1	2	3	4	1	2	3	4	..
Depth (in feet)	1½	3	6	6	2	4	5	5	..
Character of Bottom	Sand	Sand	Mud & Gravel	Mud & Gravel	Mud & Sand	Mud	Mud	Mud	..
Distance from Shore (yds.)	25	50	75	200	15	25	40	65	..
Mollusca	..	..	24	10	45	15	24	6	124
Chironomidae	50	3	22	40	35	2	25	10	187
Trichoptera	..	..	..	..	2	..	2	..	4
Amphipoda	..	1	3	5	..	..	2	1	12
Ostracoda	..	..	4	..	..	..	..	..	4
Oligochaeta	5	..	7	9	14	1	5	5	46
Nematoda	1	..	..	..	..	..	..	..	1
Hirudinea	..	..	2	..	..	..	..	1	3
Hydracarina	..	..	6	1	..	..	..	..	7
Cladocera	1	..	..	..	..	..	..	..	1
Coleoptera	..	..	..	..	..	..	..	1	1
Tabanidae	1	..	..	..	1	1	..	..	3
Totals	58	4	68	65	97	19	58	24	393

SECOND BAY WEST OF NIPIGON RIVER

Series XX

Dredging	1	2	3	4	5	6	7	8	9	Totals
Depth (in feet)	5	18	18	33	33	33	12	6	5	..
Character of Bottom	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud	..
Distance from Shore (yds.)	15	50	150	250	300	350	400	450	550	..
Mollusca	23	2	2	..	..	..	11	11	..	49
Chironomidae	159	24	38	41	31	23	47	28	12	403
Ephemeridae	5	1	..	..	..	..	9	9	1	25
Trichoptera	1	..	..	..	..	..	2	..	..	3
Amphipoda	10	3	16	36	42	34	2	2	..	145
Ostracoda	4	..	..	..	1	..	..	..	..	5
Oligochaeta	12	5	..	5	7	2	1	4	1	37
Nematoda	1	..	..	4	2	..	..	..	..	7
Hirudinea	3	..	..	..	1	..	..	..	..	4
Hydracarina	7	1	..	..	..	..	..	1	..	9
Coleoptera	1	..	..	..	..	..	..	..	..	1
Totals	226	36	56	86	84	59	72	55	14	688

BEAR CREEK — Series XXI

							Totals
Dredging	1	2	3	4	5	6	..
Depth (in feet)	18	9	9	9	9	9	..
Character of Bottom	Mud	Mud & Debris	Sand & Debris	Sand	Sand	Sand	..
Distance from Shore (yds.)	20	300	600	900	1300	1700	..
Mollusca	1	2	..	..	..	1	4
Chironomidae	5	2	..	..	7	1	15
Ephemeridae	..	..	..	..	..	1	1
Trichoptera	..	1	1	..	1	..	3
Ostracoda	..	..	..	..	4	..	4
Oligochaeta	..	..	..	..	12	1	13
Totals	6	5	1	0	24	4	40

NORTH SHAKESPEARE BAY — Series XXII

										Totals
Dredging	1	2	3	4	5	6	7	8	9	..
Depth (in feet)	4	18	18	36	24	15	9	6	$2\frac{1}{2}$	..
Character of Bottom	Mud	Mud	Mud & Gravel	Mud	Mud	Mud	Mud	Sand	Sand	..
Distance from Shore (yds.)	10	60	110	210	610	710	760	810	840	..
Mollusca	47	5	2	6	..	3	8	36	..	107
Chironomidae	15	27	13	2	8	26	15	6	46	158
Trichoptera	2	2	..	..	..	..	..	..	..	4
Ephemeridae	8	3	2	..	1	6	4	9	1	34
Amphipoda	1	3	3	1	11	2	..	1	..	22
Oligochaeta	4	3	1	..	1	..	3	..	2	14
Nematoda	..	..	2	..	..	..	..	..	1	3
Hirudinea	2	..	..	..	..	..	..	1	..	3
Hydracarina	..	..	..	1	1	1	2	..	..	5
Odonata	..	..	..	..	..	1	..	..	..	1
Tabanidae	..	..	..	..	..	..	..	..	1	1
Totals	79	43	23	10	22	39	32	53	51	352

NORTH SHAKESPEARE ISLANDS — Series XXIII

									Totals
Dredging	1	2	3	4	5	6	7	8	..
Depth (in feet)	5	17	21	21	15	9	42	42	..
Character of Bottom	Gravel among Rocks	Sand	Sand	Sand	Sand	Sand	Mud	Mud	..
Distance from Shore (yds.)	10	40	40	60	100	130	230	380	..
Mollusca	2	15	1	..	..	60	..	3	81
Chironomidae	5	16	9	12	3	7	4	13	69
Ephemeridae	9	6	1	..	1	6	..	..	23
Trichoptera	1	1	..	2	..	6	..	..	10
Coleoptera	..	..	..	1	..	..	1	1	3
Neuroptera	..	1	..	..	..	..	..	..	1
Oligochaeta	1	1	1	1	..	..	3	..	7
Hirudinea	..	..	6	1	..	1	..	..	8
Hydracarina	..	..	1	..	..	2	..	..	3
Amphipoda	1	2	6	5	..	13	7	8	42
Totals	19	42	25	22	4	95	15	25	247

ORIENT BAY (At Macdiarmid) — Series XXIV

										Totals
Dredging	1	2	3	4	5	6	7	8	9	..
Depth (in feet)	6	39	90	150	87	69	63	11	9	..
Character of Bottom	Sand	Mud	Mud	Mud	Mud	Mud	Clay	Sand & Clay	Mud	..
Distance from Shore (yds)	10	30	60	160	800	1000	1100	1500	1700	..
Mollusca	9	2	..	..	..	2	5	15	7	40
Chironomidae	8	3	1	5	2	13	5	7	7	51
Ephemeridae	3	1	..	..	..	..	..	..	..	4
Amphipoda	..	4	67	61	32	21	28	..	..	213
Oligochaeta	7	..	..	6	2	5	3	8	10	41
Nematoda	..	1	..	1	..	2	1	..	..	5
Hirudinea	1	..	..	..	..	..	..	..	..	1
Hydracarina	..	..	1	..	..	..	..	..	..	1
Totals	28	11	69	73	36	43	42	30	24	356

NAONAN IDS.	Series I	NIPIGON HOUSE		Series VII	MACDIARMID HARBOUR			Series XXV
								Totals
Dredging	1	1	2	3	1	2	3	..
Depth (in feet)	150 (?)	144	36 (?)	..	9	8	5	..
Character of Bottom	Mud & Shells	Clay	Mud	..	Mud	Mud	Mud	..
Distance from Shore (yds.)	800	800	125	..	100	75	25	..
Mollusca	..	..	3	..	37	3	2	45
Chironomidae	3	11	10	..	42	39	9	114
Trichoptera	..	..	..	..	1	..	..	1
Ephemeridae	..	..	8	..	..	..	..	8
Amphipoda	13	47	9	..	7	..	2	78
Oligochaeta	3	..	..	..	28	17	6	54
Nematoda	..	..	1	..	..	1	..	2
Hirudinea	..	..	..	..	1	..	..	1
Cladocera	..	..	..	..	..	..	1	1
Hydracarina	..	..	..	..	..	1	..	1
Totals	19	58	31	..	116	61	20	305

ORIENT BAY AND NORTHWARD (East Shore) Series XXVI

Dredging	1	2	3	4	5	6	7	8	9	Totals
Depth (in feet)	9	18	8	12	18	24	27	48	129	..
Character of Bottom	Sand	Sand	Sand	Sand	Gravel	Sand	Sand	Sand	Mud	..
Distance from Shore (yds)	30	60	85	130	230	280	330	380	430	..
Mollusca	8	6	1	..	..	..	1	4	..	20
Chironomidae	9	6	46	4	2	2	6	6	5	86
Trichoptera	..	1	..	..	..	..	..	..	..	1
Amphipoda	..	..	..	2	..	..	..	..	45	47
Ostracoda	..	..	2	..	..	..	..	..	..	2
Oligochaeta	8	14	22	..	1	3	2	8	14	72
Nematoda	..	..	..	..	..	..	1	..	..	1
Totals	25	27	71	6	3	5	10	18	64	229

VIRGIN ISLANDS — Series XXVII

										Totals
Dredging	1	2	3	4	5	6	7	8	9	..
Depth (in feet)	6	12	15	15	15	12	9	5	3	..
Character of Bottom	Sand	Sand	Sand	Sand	Sand	Mud on Sand	Mud on Sand	Mud on Sand	Mud	..
Distance from Shore (yds)	10	50	100	150	200	300	400	500	600	..
Mollusca	96	14	1	3	10	12	10	31	213	390
Chironomidae	48	1	9	..	15	28	32	49	43	225
Trichoptera	2	1	..	..	..	2	..	..	1	6
Ephemeridae	7	..	..	..	1	1	..	7	..	16
Amphipoda	..	..	..	..	1	..	..	..	..	1
Ostracoda	..	..	..	..	..	..	..	1	..	1
Oligochaeta	21	3	2	3	5	2	10	5	12	63
Nematoda	..	..	..	..	..	..	..	..	3	3
Hirudinea	7	..	..	..	..	..	..	..	2	9
Hydracarina	2	..	..	1	..	1	..	1	4	9
Totals	183	19	12	7	32	46	52	94	278	723

McINTYRE BAY (South End) Series XXVIII

Dredging	1	2	3	4	5	6	7	8	9	Totals
Depth (in feet)	1	3	9	12	15	18	21	24	24	..
Character of Bottom	Sand	Mud on Sand	Mud & Gravel	Mud & Sand	Mudon Sand	Mud	Mud	Mud	Mud	..
Distance from Shore (yds)	25	75	125	175	225	325	425	525	625	..
Mollusca	4	1	17	12	6	6	6	3	8	63
Chironomidae	8	21	3	2	..	14	1	2	16	67
Trichoptera	..	1	1	1	..	..	1	..	..	4
Ephemeridae	..	1	2	3	..	3	1	1	..	11
Amphipoda	1	..	2	5	12	9	27	5	1	62
Oligochaeta	1	2	..	..	2	..	7	3	2	17
Hirudinea	..	..	..	..	1	..	..	..	..	1
Hydracarina	..	..	..	..	..	..	..	..	2	2
Odonata	..	..	..	..	2	..	..	..	..	2
Totals	14	26	25	23	23	32	43	14	29	229

McINTYRE BAY (East Side among Islands) — Series XXIX

									Totals
Dredging	1	2	3	4	5	6	7	8	..
Depth (in feet)	3	6	12	18	18	21	21	15	..
Character of Bottom	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud	..
Distance from Shore (yds.)	10	60	110	160	210	260	310	360	..
Mollusca	16	8	3	3	6	10	5	9	60
Chironomidae	14	11	23	22	38	40	100	4	252
Trichoptera	2	..	..	..	..	..	..	1	3
Ephemeridae	2	2	2	2	7	7	6	6	34
Coleoptera	..	1	..	..	..	..	..	..	1
Neuroptera	..	..	..	1	2	1	2	..	6
Amphipoda	3	..	3	10	9	31	12	2	70
Oligochaeta	6	..	4	1	..	6	6	1	24
Nematoda	..	..	..	2	..	..	1	..	3
Ostracoda	..	..	..	..	..	1	9	..	10
Hydracarina	..	..	..	..	1	..	..	..	1
Totals	43	22	35	41	63	96	141	23	464

McINTYRE BAY (North End) Series XXX

							Totals
Dredging	1	2	3	4	5	6	..
Depth (in feet)	6	9	9	21	45	48	..
Character of Bottom	Mud	Mud	Mud	Mud	Mud	Mud	..
Distance from Shore (yds.)	30	80	130	180	230	280	..
Mollusca	47	17	9	2	2	..	77
Chironomidae	6	15	5	2	9	1	38
Trichoptera	2	3	..	..	..	..	5
Ephemeridae	10	7	3	5	1	..	26
Amphipoda	3	7	4	1	105	30	150
Oligochaeta	6	3	..	1	3	9	22
Ostracoda	..	1	..	..	..	..	1
Odonata	..	4	1	..	1	..	6
Hydracarina	1	1	..	..	..	..	2
Hirudinea	1	..	..	..	..	..	1
Cladocera	..	1	..	..	..	..	1
Coleoptera	..	..	1	..	..	..	1
Neuroptera	..	1	..	..	..	..	1
Totals	76	60	23	11	121	40	331

GROS CAP	Series XXXI					ALEXANDER ID. Series XXXII				
										Totals
Dredging	1	2	3	4	5	1	2	3	4	..
Depth (in feet)	3	9	15	24	30	1	4	6	9	..
Character of Bottom	Mud	Mud	Mud	Mud	Mud	Mud	Sand	Sand	Sand	..
Distance from shore (yds.)	10	35	60	110	210	10	25	50	100	..
Mollusca	38	38	5	5	..	3	50	52	20	211
Chironomidae	18	38	121	24	5	15	40	44	26	331
Trichoptera	1	3	3	..	..	..	..	2	..	9
Ephemeridae	6	1	1	2	1	..	2	3	3	19
Amphipoda	1	7	10	..	2	..	..	10	6	36
Ostracoda	1	..	6	..	..	..	..	2	2	11
Oligochaeta	3	3	5	3	1	2	4	21	5	47
Nematoda	..	..	..	..	..	..	6	..	..	6
Hydracarina	..	..	..	..	..	..	..	2	1	3
Hirudinea	..	..	..	..	..	..	..	..	1	1
Neuroptera	..	..	..	..	..	..	..	1	..	1
Cladocera	..	..	..	..	..	..	1	..	..	1
Coleoptera	2	..	..	..	..	..	..	..	..	2
Totals	70	90	151	34	9	20	103	137	64	678

UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 16

THE FOOD OF LAKE NIPIGON FISHES

BY

WILBERT A. CLEMENS
JOHN R. DYMOND
N. K. BIGELOW
F. B. ADAMSTONE
AND
W. J. K. HARKNESS
OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

TORONTO
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THE FOOD OF LAKE NIPIGON FISHES

In conjunction with the various studies dealing with the food supply of fish in Lake Nipigon as well as with the studies of the distribution and rates of growth of the fish themselves, examinations of the contents of a considerable number of alimentary tracts of several species of fish have been made. The results, as far as it has been possible to bring them together at the present time, are given in the following tables. In the cases of the larger predaceous fish (lake trout, yellow pike perch, and ling), the numbers in the columns give the actual number of fish eaten and a + sign indicates material disintegrated beyond identification and no attempt made to count individuals. In the tables dealing with the other species an attempt has been made to estimate the percentages of the most abundant organisms found, and the numbers in the tables give these estimates. A + sign in these tables indicates occurrence in amounts not estimated, usually representing less than one per cent. The results of the examination of 455 fish are given, distributed as follows:—sturgeon 12, northern sucker 16, common sucker 33, minnows 27, round whitefish 29, common whitefish 65, ciscoes 89, lake trout 42, trout perch 23, small mouth black bass 6, yellow pike perch 20, yellow perch 14, ling 79.

STURGEON. *Acipenser rubicundus*

No.	Date 1921	Length in cm.	*Ephemeridae* nymphs	*Chironomidae* larvae	*Mollusca*	Fish remains	Miscellaneous
1	July 12	44.0	+	+	..	98	Misc. 2 (*Ephemeridae* nymph, *Trichoptera* larva, Dytiscid larva, *Chironomidae* larvae and pupae, Tabanid larva).
1	June 24	44.0	24[1]	+	+	75	Misc. 1 (*Trichoptera* larva, *Chironomidae* larvae, *Mollusca*, *Clado phora*).
1	June 24	54.0	..	65	1	1	*Pontoporeia hoyi* 30; misc. 3 (*Hydracarina*, *Corixa*, *Trichoptera* larvae and pupa, *Coleoptera*).
1	June 23	large	..	..	100	..	
1	" 23	"	2[2]	2	85	3	Misc. 8 (*Pectinatella* statoblast, *Amphipoda*, *Odonata* nymph, *Corixa*, *Trichoptera* larvae, *Chironomidae* adult, *Nostoc*, *Ulothrix*, *Cladophora*, *Chara*, *Bryophyta*, higher plant tissues).
1	" 23	"	5	40	50	..	Misc. 5 (*Amphipoda*, *Trichoptera* larvae).
1	" 23	"	..	+	70	30	*Cyclops*.
1	July 9	"	4	1	75	20	
1	Aug. 26	"	98[3]	+	2	..	
1	" 26	"	99	+	+	..	*Cladophora*.
1	" 26	"	95	4	..	..	*Cladophora*.
1	" 26	"	99	+	..	..	*Bosmina longirostris*, *Diatoms*, *Ulothrix*, *Cladophora*.

[1]*Ephemera simulans*.
[2]*Hexagenia bilineata, Ephemera simulans, Heptagenia tripunctata*.
[3]*Ephemera simulans*.

NORTHERN SUCKER. *Catostomus catostomus*

No.	Date 1921	Length in cm.	*Pontoporeia hoyi*	*Trichoptera* larvae	*Chironomidae* larvae	*Chironomidae* pupae	*Mollusca*	Miscellaneous
6	July 28	12–16	..	10	50	5	10	Misc. 25 (*Bryozoa, Canthocamptus, Bosmina longirostris, Camptocercus, Acroperus harpae, Alona affinis, A. quadrangularis, Chydorus sphaericus, Alonella nana, A. rostrata, Ostracoda, Hyallela knickerbockerii, Hydracarina, Thysanura*).
1	July 15	17.0	15	..	70	10	1	Misc. 4 (*Difflugia, Plumatella, Canthocamptus hiemalis, Alona affinis, Chydorus sphaericus, Ostracoda, Hydracarina, Diatoms*).
1	June 14	22.5	90	..	9	..	1	
1	" 28	24.5	96	..	1	..	2	Misc.1 (*Bosmina*, etc.).
1	" 24	27.0	90	10	..	..	..	*Diatoms.*
1	" 28	29.0	..	..	..	..	..	Filamentous *Algae* 60; *Diatoms* 30; Insecta fragments 10.
1	July 4	34.2	30	..	5	5	+	*Hyallella knickerbockerii* 10; other forms 50 (*Arcella, Centropyxis, Cyclops, Ostracoda, Hydracarina,* filamentous *Algae, Diatoms*).
1	July 21	40.5	15	..	85	+	..	
1	June 24	42.2	80	..	18	..	+	Misc. 2 (*Hydracarina,* two *Plecoptera* nymphs, *Chironomidae* adult, *Diatoms*).
2	July 15	?	..	+	70	+	20	Misc. 10 *Rhizopoda, Cyclops, Chydorus sphaericus, Ostracoda, Corixa, Ulothrix, Cladophora, Diatoms*).

COMMON SUCKER, *Catostomus commersonii*

No.	Date 1921	Length in cm.	*Pontoporcia hoyi*	*Trichoptera* larvae	*Chironomidae* larvae	*Chironomidae* pupae	*Mollusca*	Miscellaneous
1	June 11	13.2	..	45	35	5	1	*Ostracoda* 2; *Hydracarina* 5; other forms 7 (*Cyclops*, *Canthocamptus*, *Alona affinis*, *Chydorus sphaericus*, *Hyallela knickerbockerii*, *Diatoms*).
2	July 12	13.0-13.5	..	..	82	2	10	Misc. 6 (*Canthocamptus*, *Eurycercus lamellatus*, *Acroperus harpae*, *Alona affinis*, *Chydorus sphaericus*, *Ostracoda*, *Hydracarina*, *Corixa*, *Ulothrix*, *Bulbochaete*, *Diatoms*).
1	July 21	15.0	..	45	20	..	30	Misc. 5 (*Centropyxis*, *Canthocamptus*, *Alona quadrangularis*, *Chydorus sphaericus*, *Ostracoda*, *Hydracarina*, *Diatoms*).
5	June 11	25-30	..	5	40	3	12	*Hyallela knickerbockerii* 35; other forms 5 (*Cyclops*, *Canthocamptus*, *Plecoptera* nymphs, *Ephemeridae* nymphs, *Corixa*, *Diatoms*).
1	July 12	26.0	1	55	35	+	5	Misc. 4 (*Canthocamptus*, *Bosmina*, *Eurycercus lamellatus*, *Alona affinis*, *Ostracoda*, *Hydracarina*, *Corixa*, *Chironomidae* pupae, *Ulothrix*, *Diatoms*).
8	July 28	26.0 app.	50	1	30	10	5	*Hydracarina* 4; *Ephemeridae* nymph (*Caenis*).
2	Aug. 4	37-41	90	..	5	+	4	Misc. 1 (*Hydracarina*, *Chironomus* pupa).

The stomach contents of a large number of small suckers have been examined. The following list of organisms found in 13 specimens, averaging 2.8 cm. in length, taken July 27 in a seine, will illustrate the type of food and the variety of forms found:

Algae—Oscillatoria, Melosira, Pinnularia, Navicula, Stauroneis, Amphora, Cocconema, Achnanthes, Surirella, Epithemia, Desmidium, Closterium, Docidium, Staurastrum, Micrasterias, Euastrum, Cosmarium, Oöcystis.

Protozoa—Arcella, Centropyxis, Lecquereusia, Difflugia, Cyphoderia, Sphenoderia, Euglypha.

Rotatoria—Keratella cochlearis, Euchlanis, Lecane luna, Lecane leontina, Lecane sp., *Monostyla lunaris, Trichocera, Gastropus stylifer.*

Oligochaeta—podal spines.

Copepoda—Cyclops.

Cladocera—Latona setifera, Daphnia, Bosmina longirostris, Eurycercus lamellatus, Kurzia latissima, Acroperus harpae, Alona guttata, A. affinis, Graptoleberis testudinaria, Rynchotalona falcata, Pleuroxus denticulatus, Chydorus sphaericus, Alonella nana, A. excisa, A. exigua, Monospilus dispar.

Ostracoda—several species.

Hydracarina—

Insecta—Ephemeridae nymph, *Chironomidae* larvae, dipterous pupae.

MINNOWS—(*Cyprinidae*)

Spot-tail minnow, *Notropis hudsonius*

Twelve individuals, 5 to 7 cm. in length, were taken, on July 20, in a seine close to the dock at the village of Macdiarmid.

Bryozoa—one statoblast, probably of *Pectinatella.*

Cladocera—a few *Bosmina longirostris, Acroperus harpae, Alona* sp., many *Chydorus sphaericus*, a few *Polyphemus pediculus.*

Ostracoda—fragments.

Arachnida—one water-mite and two spiders.

Insecta—one mayfly nymph, one mayfly subimago, a few *Corixa* nymphs, several chironomid pupae and adults.

Mollusca—Snail shell fragments.

Couesius plumbeus

Fifteen individuals, 4.2 to 7.4 cm. in length, were taken on July 20, in a seine close to the dock at the village of Macdiarmid.

Cladocera—considerable numbers of *Chydorus sphaericus*.

Insecta—one ephemerid or plecopteran nymph, corixids, one beetle, one chironomid larva, one chironomid adult, one *Lucillia caesar*, several ants.

ROUND WHITEFISH. *Coregonus quadrilateralis*

No.	Date 1921	Length in cm.	*Trichoptera* larvae	*Chironomidae* larvae	*Chironomidae* pupae	*Mollusca*	Miscellaneous
2	Aug. 4	5.0–5.3	1	1	95	..	*Corixa* nymphs 1; *Ephemeridae* nymphs 1.
1	June 28	16.0	..	20	10	5	*Mysis relicta* 30; *Pontoporeia hoyi* 10; *Corixa* 15; other forms 10 (*Ostracoda, Hydracarina*, small beetle, filamentous *Algae*).
1	July 15	16.5	35	20	20	20	*Chironomidae* adults 5; *Ostracoda*.
1	June 14	17.5	4	30	65	1	
1	" 24	18.0	..	35	65	..	
1	July 15	18.3	85	..	7	8	
3	Aug. 5	18.0 app.	10	80	5	..	*Ostracoda* 5; small *Homoptera; Algae*.
18	" 8	17–19	95	1	+	1	Other forms 3 (*Cyclops, Daphnia pulex, Bosmina, Drepanothrix, Alona affinis, A. quadrangularis, A. costata, Eurycercus lamellatus, Acroperus harpae, Chydorus sphaericus, Ostracoda, Hydracarina, Trichoptera* pupa, filamentous *Algae, Diatoms*).
1	June 24	21.1	65	11	..	20	*Ephemeridae* nymphs (*Ephemerella*) 2; *Odonata* nymph 1; *Hemiptera* 1.

COMMON WHITEFISH, *Coregonus clupeaformis*

No.	Date 1921	Length in cm.	*Ostracoda*	*Pontoporeia hoyi*	*Hydracarina*	*Trichoptera* larvae	*Chironomidae* larvae	*Chironomidae* pupae	*Mollusca*	Miscellaneous
2	Aug. 4	4.8-5.8	..	..	25	10	5	..	..	*Chironomidae* adults 50; other forms 15 (*Cyclops*, *Bosmina longirostris*, *Acroperus harpae*, *Arachnida*, *Hemiptera Coleoptera*, *Formicina*).
1	July 6	14.0	+	..	+	..	80	10	6	Misc. 4 (*Bosmina longirostris Corixa*).
1	" 15	14.3	..	..	7	..	80	3	5	Misc. 5 (*Plumatella*, *Amphipoda*, *Plecoptera* nymph, *Melosira*).
3	" 28	15.0 app.	..	..	10	..	20	20	20	*Hemiptera* 5; *Ephemeridae* nymphs (*Caenis*) 5; *Chironomidae* adults 20.
3	Aug. 27	15.0 app.	1	..	3	..	2	2	1	*Mysis relicta* 90; other forms 1 (*Diaptomus*, *Cyclops*, *Canthocamptus*, *Latona setifera*, *Bosmina longirostris*).
1	June 14	16.0	98	..	+	..	..	2	+	
1	Aug. 5	16.0 app.	+	..	2	..	95	+	2	Misc. 1 (*Hemiptera*, dipterous adult).
4	Aug. 8	16.2 app.	..	..	4	1	1	1	93	*Bosmina longirostris*.
1	July 4	16.5	100	..	..	..	..	..	..	
1	" 15	17.5	+	..	30	..	45	..	25	
18	" 21	15-18	+	+	+	15	10	5	10	*Ephemeridae* nymphs (*Hexagenia*, *Caenis*) 45; *Corixa* 5; *Trichoptera* pupae 5; other forms 5 (*Cyclops*, *Bosmina*, *Insecta* fragments, *Cladophora*, *Diatoms*).
1	" 4	25.7	..	15	..	..	80	..	5	

No.	Date 1921	Length in cm.	*Ostracoda*	*Pontoporeia hoyi*	*Hydracarina*	*Trichoptera* larvae	*Chironomidae* larvae	*Chironomidae* pupae	*Mollusca*	Miscellaneous
6	July 28	25-27	..	2	+	..	2	50	+	One *Leucichthys* (cisco) 45; Misc. 1 (*Canthocamptus; Corixa*).
1	June 30	28.0	..	30	..	..	70	..	..	*Coleoptera* adult, *Chironomidae* adult.
10	July 26	34.0 app.	..	35	+	..	60	..	1	Misc. 4 (*Mysis relicta, Formicina*).
1	June 14	35.3	..	..	1	2	2	..	15	One *Pygosteus pungitius* (nine-spined stickleback) and other fish remains 75; other forms 5 (*Plumatella, Ephemeridae* nymph, *Corixa, Cladophora, Diatoms*).
1	" 24	36.5	..	80	1	..	4	..	15	*Canthocamptus hiemalis, Diaptomus sicilis.*
1	July 12	36.5	..	52	1	..	5	..	40	*Algae* and higher plants 2.
1	June 20	37.2	..	50	..	..	40	..	10	
1	July 12	38.5	..	25	3	..	25	3	40	*Ephemeridae* nymphs (*Heptagenia*) 4.
1	Aug. 12	39.3	..	..	..	..	..	..	5	Four *Pygosteus pungitius* (nine-spined sticklebacks) and other fish remains 95.
1	Aug. 4	40.0	..	..	..	..	+	..	+	Two Miller's Thumbs and one other fish unident. 98; *Ephemeridae* nymphs 1.
1	June 20	42.0	..	..	..	..	..	..	17	*Hemiptera* 4; *Coleoptera* 45; *Diptera* 4; *Formicina* 30.
1	July 15	45.0	..	..	+	..	..	..	99	Misc. 1 (*Rotatoria, Bosmina longirostris, Plecoptera* nymph, *Ephemeridae* nymphs (*Heptagenia*) *Corixa*, dipterous adult, *Diatoms*).
1	July 15	?	..	..	+	..	+	..	99	*Diatoms.*
1	Aug. 6	?	..	4	..	..	92	..	..	*Coleoptera* 4.

CISCOES, *Leucichthys*

No.	Date 1921	Length in cm.	*Limnocalanus macrurus*	*Leptodora kindtii*	*Mysis relicta*	*Chironomidae* larvae	*Chironomidae* pupae	Miscellaneous
12	July 6	12-17	..	..	55	25	10	Misc. 10 (*Cyclops*, *Amphipoda*, *Hydracarina*, *Ephemeridae* (*Ephemerella* nymphs, *Heptagenia* subimago), *Corixa*, *Trichoptera* adult, dipterous adult.
1	" 6	14.5	..	..	99	1	..	
1	Aug. 12	14.5	..	55	1	..	..	*Diaptomus* 10; *Cyclops* 30; other forms 4 (*Daphnia longispina*, *Bosmina longirostris*, *Chydorus sphaericus*, *Hydracarina*, dipterous adults).
1	June 11	14.8	..	..	..	..	97	Misc. 3 (*Hydracarina*, Chalcid, *Formicina*).
1	" 30	14.8	..	..	95	..	..	Misc. 5 (*Bryozoa*, *Hymenoptera*, *Mollusca*, *Diatoms*).
1	" 11	15.2	..	..	..	..	100	
1	" 30	15.2	..	..	100	..	..	
14	July 26	16.0 app.	..	..	100	..	..	
2	Aug. 4	16.0 app.	..	90	..	5	5	*Cyclops*.
1	June 20	16.1	5	..	95	..	..	
1	July 4	16.5	..	..	99	1	..	
5	" 21	15-21	..	..	85	15	..	*Cyclops*.
20	" 20	16-25	..	..	99	1	..	*Mollusca*.
1	June 30	19.8	..	..	99	..	..	*Ostracoda* 1.
1	July 15	20.7	..	..	..	..	..	Fragments winged terrestrial insects 100 (*Ephemeridae*, *Hemiptera*, *Trichoptera*, *Lepidoptera*, *Coleoptera*, *Diptera*, *Hymenoptera*).
1	June 30	25.0	..	..	100	..	..	
1	" 30	26.0	..	..	100	..	..	
3	Aug. 21	28.5 app.	50	..	50	..	..	*Diaptomus*.
1	June 30	29.8	5	..	95	..	..	One small caterpillar.
4	July 4	28-31	98	..	2	+	..	
2	" 21	29.3-30.5	90	..	5	5	..	
1	June 30	30.0	75	..	25	..	..	
1	July 4	31.0	50	..	50	..	..	
11	" 26	31.0 app.	5	..	95	..	..	
1	June 30	45.0	10	..	90	..	..	

LAKE TROUT, *Cristovomer namaycush*

No.	Date 1921	Length in cm.	Ciscoes	Nine-spined stickle-backs	Trout perch	Miller's Thumbs	Ling	Fish remains
1	June 14	20.0	1 (6.5 cm.)	..	..	..	..	..
1	"	22.0	4 (6.5 cm.)	..	..	..	..	..
1	"	23.0	1 (6.5 cm.)	..	..	..	..	..
1	" 28	31.2	..	..	..	..	..	+
1	July 4	36.0	6 (6-10 cm.)	..	..	..	..	..
1	June 14	36.5	..	4	..	..	..	..
1	" 24	48.5	3 (7-10 cm.)	..	..	..	..	..
1	July 4	50.0(?)	1 (10 cm.)	..	..	..	..	..
1	Aug. 12	53.0	..	1	..	..	..	..
1	" 10	60-80	1 (37 cm.)	..	..	..	..	..
1	"	"	2	1	..	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	1	1	..	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	1 (23 cm.)	..	..	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	..	..	..	2	..	..
1	"	"	2	..	..	..	..	..
1	"	"	1 (13 cm.)	..	..	..	..	..
1	"	"	1 (30 cm.)	..	..	..	..	..
1	"	"	1 (30 cm.)	..	..	..	..	..
1	"	"	3	..	..	..	..	..
1	"	"	..	..	..	..	1	..
1	"	"	1	..	..	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	2	..	..	..	..	..
1	"	"	1 ..	1	..	..	..	..
1	"	"	..	..	1	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	1 (23 cm.)	..	..	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	1	..	..	..	..	..
1	"	"	1	..	..	..	..	..
2	"	"	..	..	..	..	..	+
1	Aug. 22	90.0	..	..	..	..	1(37cm)	..
1	" 10	100.0	..	..	..	..	1(42cm)	..

TROUT PERCH, *Percopsis omisco maycus*

Food of 23 individuals 6.0-9.5 cm. in length were taken July 20 in a trap net set in the Pustagone river.

No.	*Ostracoda*	*Amphipoda*	*Ephemeridae* nymphs	*Trichoptera* larvae	*Chironomidae* larvae	*Chironomidae* pupae	Miscellaneous
1	..	..	1	45	45	..	*Corixidae* 9.
1	..	..	95	..	..	5	
1	..	..	95	5	..	..	
1	..	1	50	48	1	..	
1	..	..	100	..	..	..	
1	1	..	65	3	25	..	*Cladocera* (*Ophryoxus gracilis*, *Chydorus sphaericus*) Gyrinid larvae 1; Haliplid beetles 5.
1	..	..	100	..	..	..	
1	5	..	80	..	15	..	Algal filaments.
1	..	4	25	..	35	35	1 Dipterous larva.
1	..	..	75	..	25	..	
1	..	10	50	..	25	10	Algal filaments; *Cladocera* (*Alona* sp.?).
1	..	..	60	..	40	..	
1	..	..	60	..	5	..	*Plecoptera* nymphs 35.
1	..	..	50	..	50	..	
1	..	5	60	..	35	..	
1	..	..	50	50 (pupae)	..	..	
1	25	..	25	..	25	25	*Diatoms* (*Surirella*, *Navicula*).
1	..	..	45	..	45	10	*Diatoms* (*Surirella*, *Epithemia*).
1	10	..	30	30	15	15	
1	..	..	75	..	25	..	
1	..	..	75	..	..	25	
1	..	..	50	..	50	..	
1	..	..	50	..	50	..	
6 App.	+	+	+	+	+	+	*Cladocera* (*Eurycercus lamellatus*).

Two genera of *Ostracoda* were represented, namely, *Cypria* and *Candona*. Three genera of *Ephemeridae* were represented, namely *Ephemera*, *Heptagenia* snd *Tricorythus*. All small dipterous pupae have been considered as *Chironomidae*, although in some cases the fragmentary state made identification uncertain.

SMALL MOUTH BLACK BASS, *Micropterus dolomieu*

No.	Date 1921	Length in cm.	*Copepoda*	*Cladocera*		*Insecta*				Fish remains
			Epischura lacustris	*Sida crystallina*	*Eurycercus lamellatus*	*Ephemeridae* nymphs	*Corixidae*	*Chironomidae* larvae	*Chironomidae* pupae	
1	July 19	2.6	95	..	5	..	..	..	..	..
1	"	2.6	66	2	..	..	16	8	8	..
1	"	2.8	2	2	..	15	65	16	..	..
3	" 27	3.3	..	80	..	3	10	..	1	6

YELLOW PIKE PERCH, *Stizostedion vitreum*

No.	Date 1921	Length in cm.	Ciscoes	Nine-spined sticklebacks	Miller's Thumbs	Fish remains
1	Aug. 4	5.3	..	..	..	+
1	July 20	5.6	..	..	..	+
1	" 20	6.8	..	..	..	+
1	" 28	14.0	..	..	..	+
1	" 12	15.0	..	4	..	..
8	" 28	17.0	..	6	..	+
1	" 12	18.0	..	5	..	+
1	" 12	29.5	..	1	1	..
1	Aug. 8	43.7	..	2	..	+
1	" 12	44.0	..	1	..	..
1	July 28	47.3	..	3	..	..
2	" 15	50.0 (?)	1(7.0 cm.)	1	..	+

YELLOW PERCH, *Perca flavescens*

No.	Date 1921	Length in cm.	*Copepoda*			*Cladocera*					*Insecta*						
			Epischura	*Diaptomus*	*Cyclops*	*Daphnia*	*Bosmina*	*Chydorus*	*Leptodora*	*Ostracoda*	*Ephemeridae* nymphs	*Corixidae*	*Chironomidae* larvae	*Chironomidae* pupae	*Chironomidae* adults	Dipterous pupae	Fish
1	Aug. 15	3.0	..	..	15	..	50	..	..	..	..	..	..	..	..	35	..
5	June 27	3.4	10	75	1	1	1	..	2	..	..	..	..	..	10	..	..
7	July 30	4.7-5.6	..	..	..	..	..	..	..	..	62[1]	37	..	1	..	..	..
1	" 20	7.8	..	+	+	..	..	+	..	+	..	..	+	+	..	..	99[2]

[1]The *Ephemeridae* nymphs were *Callibaetis* sp.?

[2]The fish were the nine-spined stickleback (*Pygosteus pungitius*).

LING, *Lota maculosa*

No.	Date 1921	Length in cm.	Suckers	Ciscoes	Nine-spined sticklebacks	Trout Perch	Miller's Thumbs	Fish remains	*Mysis relicta*	*Pontoporeia hoyi*	*Chironomidae* larvae
1	July 26	20.0	..	..	1	1	..	..	..	..	..
1	" 4	35.5	..	..	1	..	..	..	..	..	..
1	" 4	35.5	..	..	..	..	..	3%	95%	+	2%
1	Aug. 8	35-42	..	..	1	..	..	..	..	..	..
1	" 8	"	..	..	..	..	1	..	..	..	..
1	" 23	35-42	..	..	1	..	..	..	..	..	..
1	" 23	"	..	..	2	..	..	..	..	..	..
1	" 10	35-55	..	2	..	..	1	..	..	..	..
1	"	"	..	1	..	..	..	..	..	..	..
1	"	"	..	..	1	..	5	..	..	..	..
1	"	"	..	1	..	..	1	..	..	..	..
1	"	"	..	1	..	..	..	..	..	..	..
1	"	"	..	2	..	..	1	+	..	..	..
1	"	"	..	8	..	..	..	..	..	..	..
1	"	"	..	9 {one 30.5 cm.}	..	..	..	..	..	..	..
1	"	"	..	4	..	..	..	..	..	..	..
1	"	"	..	2 {10 and 30 cm.}	..	..	..	..	..	..	..
1	"	"	..	2	..	..	..	..	..	..	..
1	"	"	..	2	..	..	1	..	..	..	..
1	"	"	..	1 (25 cm.)	..	..	..	..	..	..	..
1	"	"	..	5	..	..	..	..	..	..	..
1	"	"	..	5	..	..	..	..	..	..	..
1	"	"	..	2	2	..	1	..	..	..	..
1	"	"	..	3	..	..	..	..	..	..	..
1	"	"	..	1 (30 cm.)	..	..	..	..	..	..	..
1	"	"	..	..	..	..	1	+	..	..	..
1	"	"	..	1	..	..	..	..	..	..	..
1	"	"	..	1	..	..	..	..	..	..	..
1	"	"	..	1	..	..	..	..	..	..	..
1	"	"	..	2 {30 and 40 cm.}	..	..	..	..	..	..	..
1	"	"	..	4	..	..	..	..	..	..	..
1	"	"	..	2	..	..	..	+	..	..	..
2	"	"	..	..	..	..	..	+	..	..	..

LING, *Lota maculosa* (continued)

No.	Date 1921	Length in cm.	Suckers	Ciscoes	Nine-spined sticklebacks	Trout Perch	Miller's Thumbs	Fish remains	*Mysis relicta*	*Pontoporeia hoyi*	*Chironomidae* larvae
1	Aug. 22-23	35-55	..	1 (23 cm.)	..	..	..	..	..	..	..
1	"	"	..	1 (20 cm.)	..	..	..	..	..	..	..
1	"	"	..	2	..	..	..	..	..	..	..
1	"	"	..	5	..	..	..	..	..	..	..
1	"	"	..	1	..	..	..	..	..	..	..
1	"	"	..	1	..	..	..	..	..	..	..
1	"	"	..	3	..	..	1	..	..	..	..
1	"	"	1	3	..	..	1	..	..	..	..
1	"	"	..	2	..	..	..	+	..	..	..
1	"	"	..	4	..	..	..	..	..	..	..
1	"	"	..	4	..	..	..	+	..	..	..
1	"	"	..	3	..	..	5	..	..	..	..
1	"	"	..	1	..	..	..	+	..	..	..
1	"	"	..	1	..	..	..	+	..	..	..
1	"	"	..	1	..	..	1	+	..	..	..
1	"	"	..	6	..	..	..	+	..	..	..
1	"	"	..	2	1	..	..	+	..	..	..
1	"	"	..	..	..	..	3	+	..	..	..
1	"	"	..	..	5	..	1	+	..	..	..
1	"	"	..	..	..	..	1	+	..	..	..
1	"	"	..	..	..	..	1	+	..	..	..
1	"	"	..	..	..	..	1	+	..	..	..
28	"	"	..	..	..	..	..	+	..	..	..
3	"	"	..	..	..	..	..	..	100%	..	..
1	"	48.3	..	..	..	..	..	10%	75%	10%	3%
1	July 4	large	..	3 (11 cm.)	..	..	..	..	..	..	..

Little need be added in amplification of the data given in the tables, but mention may be made of a few outstanding points.

1. Gill net records show that the northern sucker inhabits deeper water than does the common sucker. The food studies substantiate this fact, in that, as a rule, higher percentages of *Pontoporeia* occurred in the northern sucker than in the common. It appears also that the older individ-

uals of the common sucker feed at greater depths than do the younger.

2. Somewhat similar conclusions may be drawn respecting the whitefishes. According to the gill net records, the round whitefish does not extend to as great depths as does the common whitefish, and its food, according to the table, is obtained in comparatively shallow water. The data do not show definitely that the older individuals of the common whitefish feed altogether at greater depths than do the younger. This would be expected where the data is not extensive, because large individuals are often taken in shallow water. It is evident that the common whitefish has serious competitors for food in the suckers, since the latter are bottom feeders and are very abundant in the lake.

3. The ciscoes, although very abundant, come into very little competition with other fish as regards food, in that they are open water plankton feeders, subsisting largely upon *Mysis relicta* and *Limnocalanus*. On the other hand they are fed upon extensively by the lake trout.

4. The outstanding item of food of the lake trout is ciscoes. In Lake Nipigon, where the operation of gill nets of 4½ inch mesh only is permitted, the number of ciscoes taken is relatively small, and those which are taken are at present sent to the market as whitefish. In view of this fact and since the lake trout is of such great commercial importance, the feeding of the latter upon the ciscoes is not to be deplored. It has been a matter of some surprise that no whitefish have as yet been found in the lake trout stomachs, and if further investigation substantiates this condition, a very fortunate state of affairs will be shown to exist.

5. The food of the trout perch was evidently obtained in the river.

6. The importance of the nine-spined stickleback (*Pygosteus pungitius*) in the food of the yellow pike perch is interesting and is possibly correlated with the small numbers of minnows occurring in the lake.

7. The chief competitor of the lake trout is no doubt the ling, since it apparently feeds largely upon ciscoes. The

absence of fish of commercial value in its diet is important. It is interesting to note that five individuals had fed upon *Mysis relicta.* The amounts of the latter were so large as to preclude the possibility of their having been contained in cisco stomachs and, in fact, in three cases no other material could be detected.

8. The fish examined fall more or less definitely into the following groups as regards food:—(1) predaceous—lake trout, yellow pike perch, ling; (2) bottom feeders—sturgeon, northern sucker, common sucker, round whitefish, common whitefish; (3) open water plankton feeders—ciscoes; (4) shallow water plankton and insect feeders—young common suckers, minnows, young small mouth black bass, young yellow perch; (5) insect feeders—trout perch.

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No. 23: A MUSKOX SKULL FROM IROQUOIS BEACH DEPOSITS AT TORONTO: *OVIBOS PROXIMUS*, SP. NOV., BY B. A. BENSLEY

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A MUSKOX SKULL

FROM IROQUOIS BEACH DEPOSITS AT TORONTO:

OVIBOS PROXIMUS, SP. NOV.

BY

B. A. Bensley

Professor of Zoology in the
University of Toronto

A MUSKOX SKULL FROM IROQUOIS BEACH DEPOSITS AT TORONTO: *OVIBOS PROXIMUS*, SP. NOV.

The following description refers to a well-preserved though incomplete skull, consisting of the brain case and horn cores virtually entire, but lacking the face except its upper or naso-frontal portion. The specimen was secured by foreman J. Quinn of the York Sand and Gravel Co., East Toronto, and was brought to the Royal Ontario Museum by Mr. H. G. Barter. It appears to merit description because of its relative completeness and characteristic nature as compared with most specimens, usually fragments, from the Toronto Pleistocene deposits; further because it fills a hitherto disconcerting gap in the faunal record of the Toronto beds; and finally because it exhibits some noteworthy differences of form as compared with previously described types.

The area from which the skull was taken is part of the gravel bar formation of the Iroquois Beach deposit as it passes through Toronto. This deposit has been extensively studied by Coleman ('13). It is estimated as late glacial or postglacial and is relatively the youngest of the three characteristic Pleistocene beds, Don, Scarborough, and Iroquois, as differentiated at Toronto. Mammalian remains are scarce, though the fine exposures of the Iroquois Beach to the west of Hamilton, Ont., have yielded at least a number of fragments of caribou antlers.

The sand and gravel pit mentioned is situated at a point immediately to the east of the present city limit of Toronto, about one-third of a mile south of Danforth Ave. and about half a mile east of Blantyre Ave. It is an excavation of perhaps twenty-five feet in depth, the extent of which is being constantly increased by the removal of material from the sides. An effort was made by Professor Coleman and the writer to determine the precise level at which the specimen was found, but without success. It was apparently blasted out of the cliff-like wall of the pit, picked up, fortunately without damage, in the hoisting scoop, and was only discovered after having rolled off the sand separator screen together with gravel, boulders, and other course material. The edges and more delicate portions of the skull show some chipping as a result of the rough treatment, and the tip of the right horn core had been broken off and lost. Otherwise the skull appears to have been deposited originally much as at present shown, and bears no signs of having been imbedded in any deposit previous to its enclosure in the Iroquois.

The specimen bears a general resemblance to the existing *O. moschatus*. It appears to differ, however, in a more compact and transversely quadrate shape. This is due in part to the very flat condition dorsally of the medial portions of the horn cores, and the fact that the posterolateral borders of the bases of these structures are filled out or buttressed out so that they are flush with the nuchal and lateral surfaces of the skull. The basal exostoses are further concrescent in the median plane, concealing entirely the sloping portion of the back of the skull, and showing an apparent depth externally in the median plane of about 34 mm. The basal plane of the skull seems to be relatively broader, flatter or less compressed. The compact quadrate contour of the skull is best shown in the view of the occipital surface shown in Plate II, Fig. 3. The appearance is, however, unduly exaggerated by the imperfect condition of the mastoids, the edges of which, doubtless at least slightly convex in life, were apparently broken or worn off on each side before deposition.

There is a resemblance in some respects to *O. yukonensis* as described by Gidley ('08), especially the dorsal contours of the horn core bases, the suggestion of a modified area on the dorsal surface of the skull in front of and more or less connecting the medial portions of the horn bases, and the general aspect at least of the attachments of the horn cores at the back of the skull, though Gidley does not describe the condition of the exostoses on this plane. On the other hand, the more expanded appearance of the basal plane in the present specimen, especially the shield-like form and parallel arrangement of the sides of the basioccipital in comparison with Gidley's excellent figure, seems to indicate a greater deviation from *O. yukonensis* than is shown by *O. moschatus* itself.

The characters of this specimen are obviously very close to those of *O. moschatus* and *O. yukonensis*, which latter is considered by Allen ('13) as possibly falling within the limits of *O. moschatus*. The postglacial occurrence would suggest a form immediately antecedent to the existing species. On account of the difference noted above, it appears advisable as a provisional arrangement at least, to recognize the specimen as the type of a species for which the name *proximus* is proposed. It is impossible at the present time, however, to obtain measurements that will place the type in proper position with reference to *O. moschatus*, the difficulty being mainly that no ratios appear to be available that can be exactly applied to the specimen and at the same time will give explicitly defined proportional measurements in the three principal axes.

Concerning the general affinities of American species Gidley has pointed out that while *Ovibos yukonensis* is distinctly ovibovine rather than symbovine, it possesses some features reminiscent of *Symbos* as re-defined by Osgood ('05), namely a rugosity of the frontal portion of the skull suggesting the anterior median extension of the exostoses characteristic of *Symbos*, and further a narrowing of the middle and anterior portions of the basioccipital as in the latter genus. In the present specimen an intermediate condition is suggested in a faint way by the appearance of the frontal area as described by Gidley, and by the posterior concrescence of the horn exostoses in the median plane which feature might be ascribed to *O. yukonensis* from the appearance of Gidley's figure though he does not describe a concrescence as actually present. On the other hand, the shield-like form of the basioccipital is extreme in the present specimen, and thus apparently is relatively more removed from the existing *Ovibos* than the latter from *Symbos*. Further, in the present specimen the horn cores, as they leave the skull, appear to be more depressed than in *O. yukonensis*, *i.e.*, they lie more nearly in a lateral position, not rising in a graceful curve from the dorsolateral surface of the skull.

Referring to the relative depth of the skull as compared with other forms, the available measurements give the impression of dorsoventral compression. The present mastoid width, 160 mm., has reference to a surface from which both mastoid angles and the paroccipital processes have been broken off. The original width, which was probably not less than 197 mm. The height of the back of the skull, to any point above the nuchal (occipital) crest, cannot be exactly stated, because the area is filled in with the horn exostoses. There is evidently a considerable variation in the ratio occipital depth to mastoid width in modern *Ovibos* skulls, but Allen in his extensive memoir does not compare them. His measurements for single specimens of *O. moschatus* and *Symbos cavifrons* do not define the occipital height, but being doubtless comparable *inter se* establish depth ratios of .66 for *O. moschatus* and .90 for *S. cavifrons*, supporting his contention that the skull of *Symbos* is relatively deeper and narrower than that of *Ovibos*.* Speaking of *Symbos* apparently as a genus, however, he overlooks Osgood's figures for *Symbos tyrelli* (*loc. cit.*, p. 184), which indicate a much lower occiput than in *S. cavifrons*. Osgood states explicitly the limits of his occipital measurements. They may not be comparable with Allen's, but are again doubtless comparable *inter se*. Expressed as ratios the height of the occiput in one-hundredths of the mastoid width are *O. moschatus* .68, *Symbos cavifrons* .85, *S. tyrelli* .59. Gidley (*loc. cit.*, p. 683) refers to these measurements, adding for *O. yukonensis* figures yielding a ratio of .626. In the specimen at hand measurements as defined by Osgood yield a ratio of .61, the points of uncertainty being the extent of the exostosis of the back of the skull and the rela-

* A similar proportion is indicated by measurements of a skull of *S. cavifrons* described by Case ('15).

tive accuracy of the width measurement of the mastoid as reconstructed. There is at least some ground for the view that the present specimen has the skull relatively broad and shallow, like *O. yukonensis* in this respect, and that the breadth if not relatively greater than in modern *Ovibos* is at least towards the extreme of the latter.

Concerning the horn cores, Allen (*loc. cit.*, p. 170) appears to have established that in *O. moschatus* the bases become approximated, but do not meet in even old animals. There is always a median portion of the skull left exposed. Further, as viewed from the occipital surface the horn cores, even if unsymmetrical to a slight extent, rise naturally from the top of the skull. In the specimen at hand the basal contour of the horn core is obscured and the whole surface squared off by the extended exostosis which not only fills up the natural concavity of the lateral borders but forms a bridge across the median line, interrupted only on its surface by the median furrow separating the horn cores in the mid dorsal line. Thus the two horn cores are perfectly distinct and separate in front, but the median extension of the exostosis apparently increases in depth posteriorly, until at the posterior end of the median groove it has a thickness of about 34 mm. The groove at this point is 26 mm. deep. The downward deflection of the horn cores is as in older males of *Ovibos moschatus*. Their original length is doubtful, since even the apparently intact one may have been worn down at the tip. The anteroposterior diameter near the median dorsal line shows nothing unusual as compared with modern Ovibos as described by Allen.

The basal plane of the skull appears broad and flat. Comparison with a male *Ovibos moschatus* skull kindly loaned me from the collection of the Victoria Memorial Museum* shows several points of difference. Especially in the form of the basioccipital element, the specimen at hand shows a shield-like contour, accentuated by the parallel arrangement of the two sides rather than a convergence of them

* The writer is indebeted to Director McInnes and Dr R. M. Anderson for the loan of this specimen.

when traced anteriorly. Doubtless the width of the basioccipital cannot be properly expressed in terms of the transverse width of the skull at the same level since any expansion of the one is likely due to the same circumstances as have brought about transverse expansion of the other. It is noteworthy, however, that on a line cutting the basilar tubercles the ratio of the width of the basioccipital to the width of the skull measured to the borders of the zygomatic processes of the temporal bones is .36 in the specimen as opposed to .31 in the specimen of *O. moschatus*. Allen gives some measurements for the anterior and posterior widths of the basioccipital in *O. moschatus*, but those of the width anteriorly are so small as to indicate that they were taken not on, but in front of, the sphenoccipital synchondrosis. The posterior tuberosities of the basioccipital are massive, separated by a deep median groove or pit; replaced forwards by a conspicuous ridge in the manner described by Allen as characteristic of *O. moschatus*. The basilar tubercles representing the attachment of M. longus capitis are conspicuously triangular, with their bases forming a straight line transversely raised above the surface of the bone.

On account of the absence of the facial region and nearly all of the zygomatic arch, there is a little suggestion of the width of the basal portion of the skull in relation to the palatal aspect of the face. The external borders of the zygomatic processes of the temporal bones suggest a parallel arrangement as between two sides or a direct continuation forwards with less divergence than in *Ovibos* and much less than in *Symbos*, as described by Allen. Certain differences which may or may not be distinctive appear in the comparison of the specimen with the *Ovibos moschatus* skull of the Victoria Memorial Museum already mentioned. In the latter of the basis cranii is almost straight while in the Toronto specimen the basisphenoid turned upward at a considerable angle. In the latter also the pterygoid lamina meets the base of the bone at a much sharper angle, so far as the posterior border of the process is concerned. The osseous bulla appears to be more compressed, and the alae vomeris extend not only over the front of the basisphenoid, as described by Gidley for *O. yukonensis*, but pass upward and backward over a considerable portion of the medial surface of the pterygoid lamina.

Partial concrescence of the horn cores posteriorly in the specimen described, if we presume that no concrescence of the horn cores exists in modern muskoxen, suggests either that the definition of *Ovibos* should not be based upon existing forms alone, or that forms showing concrescence should be generically separated. An interesting possibility is that *O. proximus* (and possibly *O. yukonensis*) are intermediate stages leading from the full concrescence of *Symbos* to the complete separation of modern *Ovibos*. There appear to have been two principal mechanical types of horn support, one in which the horn deflection is upward as in *Bison*, the other in which the deflection is downward as in the *Bootherium*, *Symbos* and *Ovibos* group. Females and younger males of modern *Ovibos* suggest the stages of a downward deflection, which, from the point of view of apical leverage begins with a condition looking towards the mechanical type of the horn bases in *Symbos* where there is full concrescence. But in *Ovibos* this type is modified and finally replaced by a hook or S-shaped arrangement by which the mechanical stress, both of leverage and direct support, is at points or in a plane parallel to the top of the skull. Thus the separation of the horn cores in modern *Ovibos* may be a reduction phase following complete concrescence of the *Symbos* kind.

PRINCIPAL MEASUREMENTS

Nuchal plane:

Height, ventral border foramen magnum to nuchal crest	94 mm.
Height, dorsal border foramen magnum to nuchal crest	75 "
Height, ventral surface of condyle to nuchal crest	106 "

Height, ventral surface of condyle to top of exostosis	169 mm.
Breadth, condyles	110 "
Breadth, mastoid (imperfect)	160 "
Breadth, mastoid (estimated)	197 "

Horn cores:

Anteroposterior diameter near median plane	174 "
Anteroposterior diameter at point of leaving skull	126 "
Length, along dorso lateral surface in groove	275 "
Length, along dorso lateral surface, posterior margin	300 "
Height, exostosis, from level nuchal crest to median groove	45 "
Height, exostosis, ventral edge to median groove	34 "
Height, bottom of groove posteriorly to top of core	26 "
Breadth, average, of median groove	7 "

Basal plane:

Length, basioccipital	81 "
Breadth, basioccipital, at posterior protuberances	66 "
Breadth, basioccipital, at basilar tubercles (maximum)	56 "
Breadth, skull at basilar tubercles, to lateral margins of zygomatic processes of temporal	156 "

Dorsal plane:

Breadth, skull, postorbital	146 "

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Plate I

Both figures x $\frac{1}{3}$

Fig. 1. *O. proximus*, skull, left profile

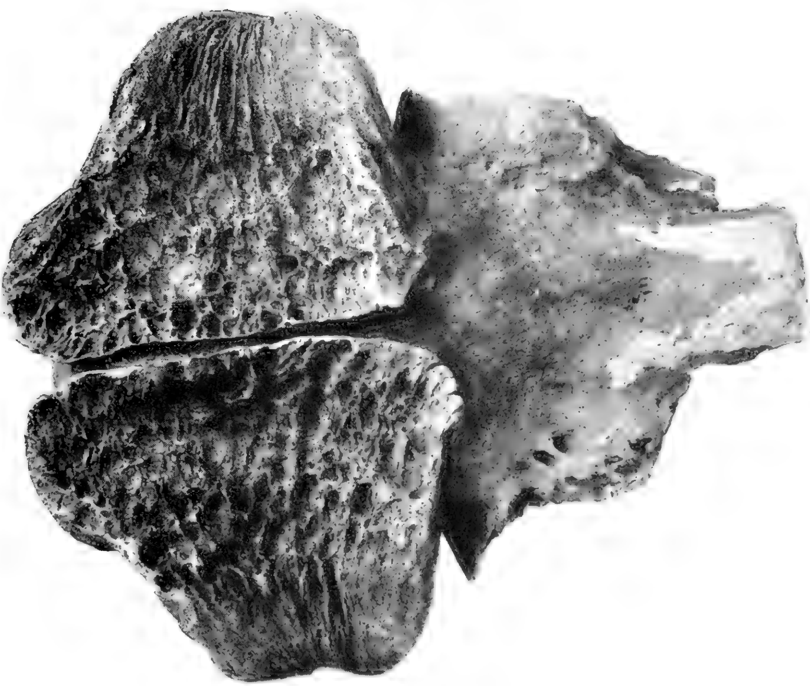

Fig. 2. *O. proximus*, skull, dorsal surface

PLATE II

Both figures x $\frac{1}{3}$

Fig. 3. *O. proximus*, skull, nuchal surface

Fig. 4. *O. proximus*, ventral surface