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.

UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 17

THE LIMNOLOGY OF LAKE NIPIGON IN 1922

BY

WILBERT A. CLEMENS
OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

TORONTO
THE UNIVERSITY LIBRARY
1923

THE LIMNOLOGY OF LAKE NIPIGON IN 1922

The limnobiological study of Lake Nipigon, begun in 1921, was continued during the summer of 1922. The general plan of investigation has been the same as in the preceding year, although certain modifications and extensions have been followed. While the operations of the first season were confined largely to the south-eastern portion of the lake, those of the second season were extended into the south-western and north-western sections, although a considerable amount of work was again carried out in the south-eastern area. It is planned to study the remaining north-western section during the summer of 1923. Until the whole lake has been covered, no attempt will be made to summarize or correlate the results.

Two stations were maintained for the taking of temperature records, water samples, and plankton, and were as follows: station 2 was that of the preceding year, located in Pijitawabic Bay (Orient Bay) directly opposite the village of Macdiarmid, depth 57 yards; and station 4 was off the mouth of the Blackwater river, in water 100 yards in depth. One series was obtained on August 17 at a point about 2½ miles south of Livingstone Point, where a depth of 125 yards was obtained, and this series has been included in the Station 4 records.

The temperature records and the results of the oxygen and carbon dioxide determinations are given in Tables 1 and 2, and the temperatures at Station 4 are represented by the graphs in Fig. 1. In general, the record for 1922 was essentially the same as that for 1921. The season of 1922 was somewhat cooler than that of 1921, and as a consequence the upper waters of the lake did not warm up quite so rapidly. In the previous year a severe storm at the end of July sent the warm surface water downward to a considerable depth. In 1922 no storm of like severity

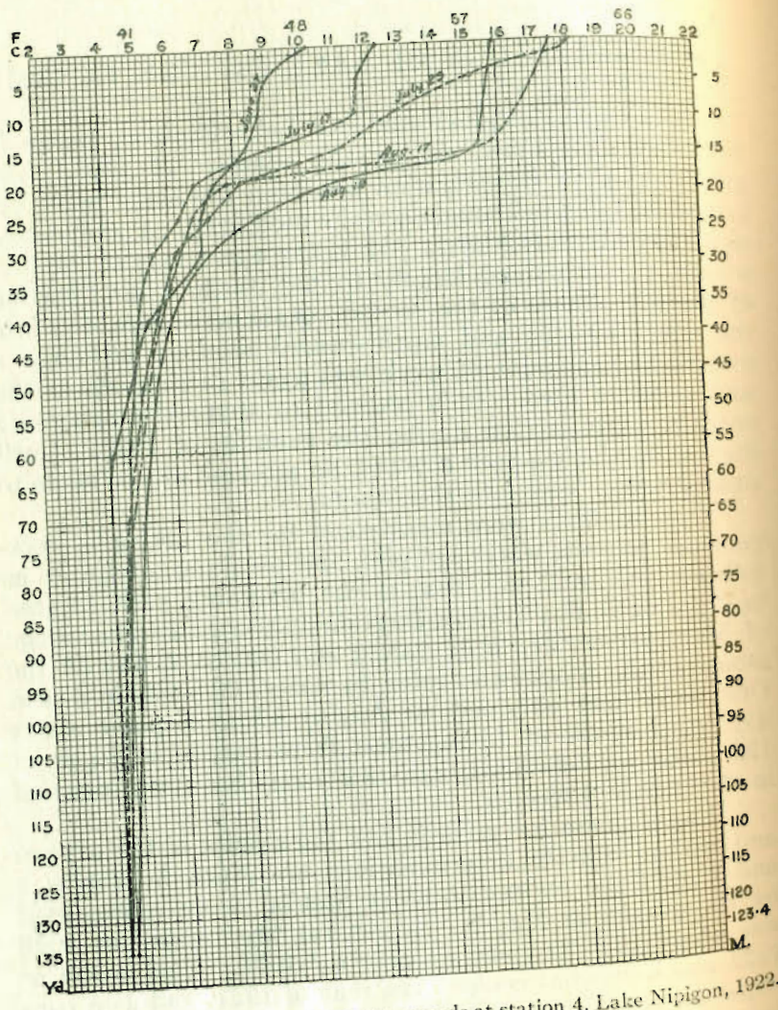

Fig. 1. Curves illustrating temperature records at station 4, Lake Nipigon, 1922.

occurred until August 17, when again the deeper water acquired considerable heat. The mid-summer period, therefore, was 18 days later than in 1921.

On August 14 it was planned to take a series of records at Station 2 at definite intervals throughout 24 hours.

One series was obtained on this date between 8 and 9 A.M. There was a very slight south breeze at the time, but it increased to such an extent during the morning that it was impossible to complete the second series between 1 and 2 P.M. The next day the wind had dropped, and had shifted to a very slight north breeze. Five series were obtained during the following 24 hours. The seven series of temperature records taken on August 14 and 15 are given in Table 3.

TABLE 1

STATION 4

Depth in yards	June 27					July 17				
	T. F.	T. C.	Ox.	% Sat.	CO_2	T. F.	T. C.	Ox.	% Sat.	CO_2
Surface	50.5	10.3	7.71	97	1.0	54.3	12.4	7.4	97	1.0
5	48.2	9.0	7.8	95	.5	53.2	11.8			
10	47.8	8.8	7.81	95	1.0	53.1	11.7	7.8	100	1.0
15	47.1	8.4				48.4	9.1	7.8	95	1.0
20	45.3	7.4				44.2	6.8	7.8	90	1.0
25	44.6	7.0				43.3	6.3			
30	44.6	7.0	7.81	91	1.5	41.9	5.5	8.4	94	1.0
35										
40	41.5	5.3	7.9	88	1.5	41.0	5.0			
45										
50	40.5	4.7				40.6	4.8			
60	39.4	4.1				40.3	4.6	8.5	93	1.0
70			8.0	87	1.5	40.3	4.6			
75										
80						40.1	4.5			
90						39.9	4.4	7.9	86	1.0
100	39.2	4.0	8.1	87	1.5					
125										

TABLE 1—*continued*

STATION 4

Depth in yards	July 29					August 17					August 19	
	T. F.	T. C.	Ox.	% Sat.	CO_2	T. F.	T. C.	Ox.	% Sat.	CO_2	T. F.	T. C.
Surface	64.8	18.2	6.7	99	1.0	63.7	17.6	7.0	102	.5	60.6	15.9
5	59.4	15.2				61.5	16.4?					
10	55.2	12.9				61.9	16.6					
15	52.3	11.3	7.2	92	1.0	60.4	15.8	7.3	102		59.7	15.4
20	46.8	8.2	7.4	89	1.0	46.0	7.8	7.7	91		52.3	11.3
25	45.0	7.2				44.1	6.7				47.7	8.7
30	43.2	6.2	7.5	86	1.5							
35						42.8	6.0					
40	42.1	5.6										
45						41.7	5.4					
50	41.2	5.1						8.1	91			
60												
70	40.1	4.5	7.9	86	2.0							
75						40.1	4.5					
80												
90												
100	39.4	4.1	7.9	86	1.5	40.3	4.6?	8.4?		1.0	40.8	4.9
125						39.4	4.1	8.8?	95?	1.0		

TABLE 2

STATION 2

Depth in yards	July 3					August 14				
	T. F.	T. C.	Ox.	% Sat.	CO_2	T. F.	T. C.	Ox.	% Sat.	CO_2
Surface	52.2	11.2	8.3	106	.5	61.0	16.1	6.5	92	.5
5	52.0	11.1	8.3	106	.5	58.5	14.7	7.0	96	.5
10	51.8	11.0				47.3	8.5	7.8	94	.5
15	51.4	10.8				45.1	7.3	7.8	91	.5
20	51.3	10.7	8.5	107	.5	43.2	6.2	7.8	89	.5
25	50.5	10.3				42.1	5.6	8.0	90	.5
30	47.8	8.8	8.6	104	.5	41.9	5.5	8.4	94	.5
35						41.7	5.4	8.2	92	.5
40	43.5	6.4	8.7	100	.5	41.4	5.2	7.9	88	.5
45								8.1		.5
50	43.0	6.1				41.0	5.0	8.5	94	
55						40.8	4.9			
57	42.6	5.9	8.7	99	.5					

TABLE 3

TEMPERATURE RECORDS, STATION 2

Depth in yards	August 14		August 15				
	8-9 a.m.	1-2 p.m.	8-9 a.m.	1-2 p.m.	8-9 p.m.	12-1 a.m.	5-6 a.m.
0	16.1° C	15.8° C	16.2° C	17.6° C	19.3° C	18.5° C	17.4° C
5	14.7	11.7	12.9	15.6	17.0	16.8	16.7
10	8.5	8.1	11.9	13.7	16.1	16.0	15.5
15	7.3	7.1	10.2	8.2	14.3	15.2	13.6
20	6.2	6.4	8.3	7.2	12.6	12.4	8.0
25	5.6	5.8	6.4	6.8	10.3	9.0	7.2
30	5.5	5.7	5.9	6.6	9.1	7.7	7.0
35	5.4	?	5.8	6.2	7.4	6.7	6.8
40	5.2	?	5.4	6.0	7.1	6.6	6.6
50	5.0	?	5.2	5.8	6.4	6.0	6.0

It will be recalled that Station 2 was located in Pijitawabic Bay (Orient Bay), which is a southerly extension in the south-eastern corner of the lake. The bay is 9 miles long with a maximum width of about 1½ miles. The banks are high on both sides. Strong north winds cause the water to rise considerably in the bay, and strong south winds produce a slight lowering. The results given in Table 3 were not anticipated, and so no record was obtained as to water levels and no accurate measurements made of current. On the morning of August 15 there was a strong surface current from the north, estimated to be at least 2 feet per second. There was still considerable current in the same direction at 2 P.M. The results indicate that on the first day the surface waters were carried out of the bay, and that during the following day there was a large inflow of warm water from the open lake, with possibly an outward movement of the deeper cooler water of the bay. The results are interesting in illustrating the effect of winds in shifting the waters and producing considerable temperature changes in certain regions down to depths of 25 yards in relatively short periods of time. The effect of this movement of the water in relation to the distribution of plankton organisms will be dealt with in later papers.

TABLE 4

TEMPERATURES—STATION 4

Depth m.	June 27		July 29		August 17		August 19	
	Temp. C.	Av. Temp. per 5m. L	Temp. C.	Av. Temp. per 5m. L	Temp. C.	Av. Temp. per 5m. L	Temp. C.	Av. Temp. per 5m. L
0	10.3		18.2		17.6		15.9	
5	8.95	9.63	14.9	16.55	17.1	17.35	15.7	15.80
10	8.72	8.84	12.6	13.75	16.45	16.78	15.55	15.63
15	8.10	8.41	10.5	11.55	15.1	15.78	15.1	15.33
20	7.20	7.65	7.8	9.15	7.2	11.15	10.0	12.55
25	7.00	7.10	6.7	7.25	6.5	6.85	8.0	9.00
30	6.62	6.61	6.2	6.45	6.05	6.28	6.85	7.43
35	5.60	6.11	5.68	5.94	5.8	5.93	6.15	6.50
40	5.05	5.33	5.4	5.54	5.5	5.65	5.85	6.00
45	4.78	4.92	5.1	5.25	5.3	5.40	5.55	5.70
50	4.45	4.62	4.95	5.03	5.1	5.20	5.35	5.45
55	4.10	4.28	4.8	4.88	4.95	5.03	5.20	5.28
60	4.0	4.05	4.65	4.73	4.8	4.88	5.08	5.14
65	4.0	4.00	4.48	4.57	4.6	4.70	4.95	5.02
70	4.0	4.0	4.4	4.44	4.5	4.55	4.90	4.93
75	4.0	4.0	4.32	4.36	4.45	4.48	4.85	4.88
80	4.0	4.0	4.28	4.30	4.42	4.44	4.80	4.83
85	4.0	4.0	4.2	4.24	4.40	4.41	4.70	4.75
90	4.0	4.0	4.15	4.18	4.35	4.38	4.65	4.68
95	4.0	4.0	4.15	4.15	4.30	4.33	4.60	4.63
100	4.0	4.0	4.10	4.13	4.25	4.28	4.50	4.55
105	4.0	4.0	4.10	4.10	4.20	4.23	4.45	4.48
110	4.0	4.0	4.05	4.08	4.15	4.18	4.40	4.43
115	4.0	4.0	4.03	4.04	4.10	4.13	4.30	4.35
120	4.0	4.0	4.01	4.02	4.05	4.08	4.25	4.28
123.4	4.0	4.0	4.00	4.00	4.00	4.03	4.20	4.23

DISTRIBUTION OF HEAT

As in 1921, the distribution of heat and the direct work expended have been calculated for a column of water one square centimetre in area extending from surface to bottom. The calculations are given in Tables 4, 5 and 6. The results indicate that the summer heat income in 1922 and the work involved in its distribution were approximately the same as in 1921.

TABLE 5

CALORIES ABOVE 4° C.—STATION 4

Depth m.	June 27		July 29		August 17		August 19	
0-5	2815		6275		6675		5900	
5-10	2420		4875		6390		5815	
10-15	2205		3775		5890		5665	
15-20	1825		2575		3575		4275	
20-25	1550	10815	1625	19125	1425	23955	2500	24155
25-30	1305		1225		1140		1715	
30-35	1055		970		965		1250	
35-40	665		770		825		1000	
40-45	460		625		700		850	
45-50	310	3795	515	4105	600	4230	725	5540
50-55	140		440		515		640	
55-60	25		365		440		570	
60-65	0		285		350		510	
65-70	0		220		275		465	
70-75	0	165	180	1490	240	1820	440	2625
75-80			150		220		415	
80-85			120		205		375	
85-90			90		190		340	
90-95			75		165		315	
95-100			65	500	140	920	275	1720
100-105			50		115		240	
105-110			40		90		215	
110-115			20		65		175	
115-120			10		40		140	
120-123.4			0	120	15	325	115	885
		14775		25340		31250		34925

TABLE 6

DIRECT WORK—STATION 4

Depth m.	June 27	July 29	August 17	August 19
0-5	36.15	168.30	189.00	149.70
5-10	72.00	278.00	464.00	387.20
10-15	97.50	276.25	646.75	599.30
15-20	93.60	182.70	344.70	486.00
20-25	86.25	95.45	73.60	220.80
25-30	75.60	65.80	57.40	128.80
30-35	57.75	49.50	49.50	80.85
35-40	28.50	36.10	41.80	60.80
40-45	15.05	27.95	34.40	49.45
45-50	7.20	19.20	28.80	40.80
50-55	2.65	18.55	21.20	37.10
55-60		11.60	20.30	31.90
60-65		6.30	12.60	25.20
65-70		3.40	8.50	24.80
70-75		3.65	7.30	23.70
75-80		3.90	5.85	23.40
80-85			4.15	18.65
85-90			4.40	17.60
90-95			4.65	15.35
95-100			4.90	12.25
100-105				10.30
105-110				8.00
110-115				5.65
115-120				5.90
120-123.4				0
	572.25	1246.65	2023.80	2463.50

DISSOLVED GASES

The supply of dissolved oxygen was abundant at all depths throughout the summer, never going below 86% of saturation. The content thus was considerably higher than in 1921, especially in the deeper water, although if determinations had been made several weeks later it is possible that a decided decrease in the oxygen content of the deep water would have been found.

The amount of free carbon dioxide was small at all depths, and practically the same as in 1921.

BICARBONATE

The results of the bicarbonate determinations in 1921 and 1922 are given below for Station 3 and Station 4 respectively. N/50 H_2SO_4 with methyl orange as indicator was used, and the results are given in parts per million.

STATION 3, 1921

	June 23	July 9	August 2	August 29
Surface	107	118	115	118
Bottom	118 (38 yd.)	118 (46 yd.)	116 (63 yd.)	128 (100 yd.)

STATION 4, 1922

	June 27	July 17	July 29	August 17
Surface	110	107	110	108
Bottom	111 (100 yd.)	108 (93 yd.)	111 (100 yd.)	114 (125 yd.)

These results may be slightly high throughout because of the difficulty in determining the end points in the titrations, but they indicate a bicarbonate content well over 100 parts per million.

ACIDITY

The total acidity of the water during the summer of 1922 varied from 2 to 5 parts per million of Ca CO_3.

OTHER ANALYSES

Through the kindness of Mr. A. V. De Laporte, chemist in charge of the Experimental Station, Division of Sanitary Engineering, Provincial Board of Health of Ontario, the following results of the analyses of a sample of water collected at Station 2, on August 24, 1922, are available. The analyses were carried out in the laboratory at Toronto, and all results are expressed in parts per million.

Total Solids	Loss on Ignition	SiO_2	Al_2O_3+ Fe_2O_3	CaO	MgO	Na_2O+ K_2O	Cl	SO_3
114.5	45.1	3.0	4.8	37.5	6.2	13.9	2.5	0.0

Hardness			Nitrogen as				Oxygen
Total	Temp.	Perm.	Free NH_3	Alb. NH_3	Nitrite	Nitrate	Consumed
84	65	19	10	60	0	0	4.3

The bicarbonate alkalinity is low in this case, because of the interval between the time of collection of the sample and the time of analysis. The high albuminoid ammonia content is probably the result of contamination by decomposing fish offal on the west side of Orient Bay, not far from Station 2.

UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 18

THE RATE OF GROWTH AND THE FOOD OF THE LAKE STURGEON (*ACIPENSER RUBICUNDUS* LE SUEUR)

BY

W. J. K. HARKNESS
OF THE DEPARTMENT OF ZOOLOGY
UNIVERSITY OF ALBERTA

TORONTO
THE UNIVERSITY LIBRARY
1923