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

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

In the spring of 1922, a study of the lake sturgeon (*Acipenser rubicundus* Le Sueur) was commenced in Lake Nipigon. As that lake is one of the last strongholds of the lake sturgeon, it seemed advisable to investigate the possibilities of maintaining this fish in numbers large enough to be of economic value. This necessitates a knowledge of its relations to other fish and to its environment, both of which are inseparably bound up with its rate of growth and with its dietary. The present report gives the results obtained during the season of 1922 regarding these two phases of its life.

Rate of Growth

The otoliths or ear stones were used in determining the ages of the fish. Scales, which among the teleost fishes are generally used for this purpose, were not available, since the surface of the body is covered with bony plates which do not show growth areas. Neither can the vertebral column be used, since it is composed of cartilage, and sections fail to show any indication of concentric layers. The otoliths occur in the sacculi of the internal ears, one on each side of the brain case. The sacculus contains a fluid (endolymph), which in turn contains calcium carbonate, from which the otolith is apparently formed by the accretion of the calcareous particles. The base of the otolith is dark in colour, while the remaining portion of it shows well-marked alternate light and dark areas, indicating periods of rapid and slow growth respectively. Pronounced differences in the rate of growth would naturally be expected in a fish which habitually lives in the shallow water of the bays and shores. In the summer when the water is warm, the metabolic processes of the sturgeon, no doubt, proceed at a relatively rapid pace, and the layers of calcium carbonate that are laid down are quite large. Their edges are consequently far apart, producing light areas on the otolith. On the other hand, during the winter, when the water is cold (at 4.0° C. or less), the metabolic processes are very much slowed down and the layers of calcium carbonate which are laid down are small. As a result the edges of these layers are quite close together, forming dark areas which are very much narrower than the light areas which alternate with them.

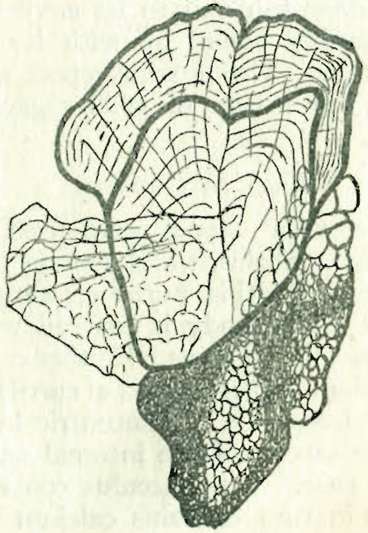

Fig. 1. Otolith from sturgeon No. 18, 19.7 cm. (7.7 in.) in length, second summer. M.×50.

The sturgeon spawns about June 1 in Lake Nipigon, and the eggs hatch probably two weeks later. The fry apparently start out on a period of rapid growth, since all otoliths examined show a clear area before the innermost dark line. Drawings of three ear stones have been made with the aid of a camera lucida. Fig. 1 shows an otolith from

a sturgeon, 19.7 cm. (7.7 in.), 0.1 lb. in weight (the smallest specimen obtained in this season) and estimated to be in its second summer; Fig. 2, an otolith from a sturgeon, 30.0 cm. (11.9 in.), 0.3 lb., third summer; Fig. 3, one from a sturgeon, 56.1 cm. (22.2 in.), 1.7 lb., tenth summer.

The majority of the otoliths used in this study were removed from the fish within a very few hours after capture and were immediately placed in glycerine and preserved in this fluid. In attempting to determine the age of each

Fig. 2. Otolith from sturgeon No. 45, 30.0 cm. (11.9 in.) in length, third summer. M.×33.

fish, the usual difficulties associated with work of this nature were encountered. The otoliths from the larger fish are very thick and the rings often indistinct. Moreover, as they increase in size the eccentricity or irregularity of the layers of the accretion becomes exaggerated and the lines of growth which are continuous in such an otolith as shown in Fig. 3, become very much broken as shown in Fig. 4. Each stone was examined under magnification while mounted in glycerine. Some of the larger were ground down on a very fine grained oil stone and the rings became slightly more evident after such treatment. The ages of all the fish from which otoliths were obtained having been deter-

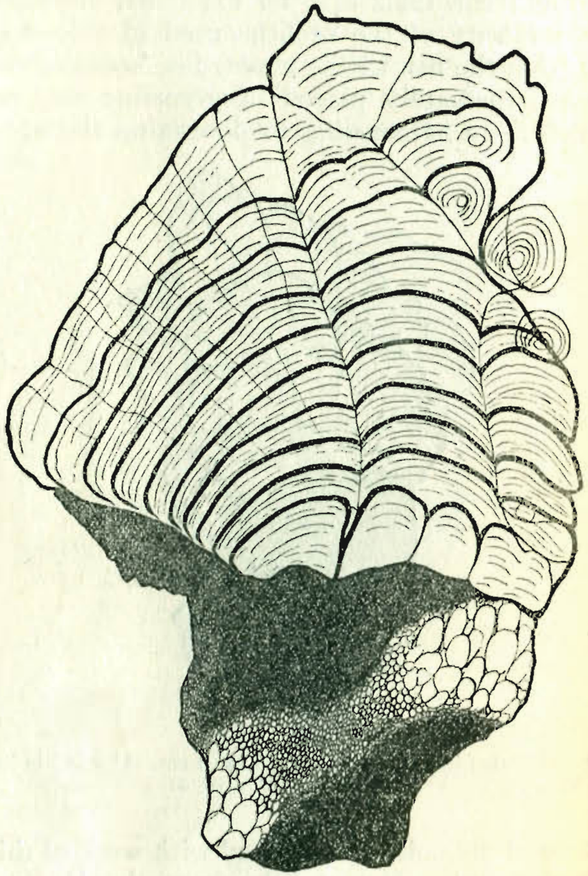

Fig. 3. Otolith from sturgeon No. 34, 56.1 cm. (22.2 in.) in length, tenth summer. M.×27.

mined, the data available for each fish were compiled in Table I. From these data, the graphs in Fig. 5 were constructed with age as ordinate, against length, girth, and weight respectively as abscissa.

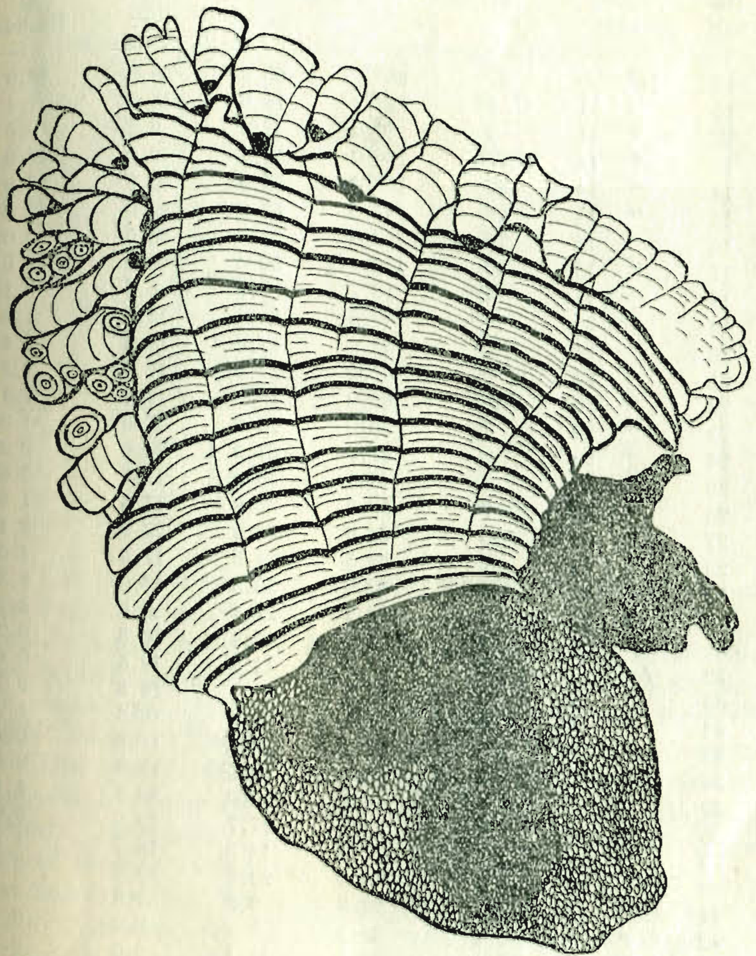

Fig. 4. Otolith from sturgeon No. 60, 78.0 cm. (30.7 in.) in length, sixteenth summer. M.×

TABLE I

No. of the Fish	Date of taking 1922	Age	Length of Fish cm.	Length of Fish in.	Girth in cm.	Weight in Pounds
10	July 6	47	160.5	63.0	59.0	64.0
11	" 11	5	48.2	19.0	15.3	1.1
12	" 11	2	30.0	11.9	9.2	0.3
13	" 14	37	136.0	53.4	49.0	42.0
14	" 14	50	156.0	61.5	53.5	50.0
15	" 14	38	147.5	57.9	49.0	45.0
16	" 15	25	100.0	39.5	33.5	12.0
17	" 15	40	132.4	52.0	48.0	29.0
18	" 11	1	19.7	7.7	6.5	0.1
19	" 24	..	49.0	19.3	16.0	1.3
20	" 24	3	33.0	13.0	10.5	0.4
21	" 24	6	54.0	21.3	17.0	1.5
22	" 26	10	65.0	25.7	17.0	2.1
23	" 29	7	56.0	22.0	17.0	1.9
24	" 29	9	61.0	24.0	20.0	2.2
25	" 29	4	40.3	16.0	12.5	0.6
26	" 30	7	58.0	22.8	17.5	1.8
27	" 30	10	65.6	25.9	22.0	3.1
28	" 31	7	54.5	21.5	17.5	1.6
29	" 31	5	52.0	20.5	17.0	1.3
30	" 31	6	54.2	21.4	19.0	1.7
31	" 31	3	34.0	13.4	10.5	0.3
32	Aug. 1	4	44.3	17.5	13.5	0.8
33	" 2	10	60.8	24.0	19.5	2.7
34	" 2	9	56.1	22.2	16.5	1.7
35	" 2	9	58.8	23.5	18.5	2.1
36	" 3	3	34.7	13.7	11.5	0.4
37	" 3	4	48.4	19.0	15.5	1.1
38	" 4	4	44.9	17.7	16.0	0.9
39	" 4	4	47.0	18.5	14.5	1.1
40	" 4	7	60.2	23.7	19.5	2.2
41	" 5	1	23.5	9.3	7.5	0.1
42	" 5	1	25.3	9.9	8.2	0.2
43	" 5	1	28.1	11.1	9.0	0.2
44	" 5	..	28.0	11.0	9.5	0.2
45	" 5	2	30.0	11.9	9.5	0.3
46	" 5	2	30.0	11.9	10.5	0.3
47	" 5	15	79.6	31.4	26.0	5.7
48	" 5	12	77.2	30.4	25.0	5.1

TABLE I—*Continued*

No. of the Fish	Date of taking 1922	Age	Length of Fish cm.	Length of Fish in.	Girth in cm.	Weight in Pounds
49	Aug. 5	8	60.2	23.7	20.0	2.1
50	" 5	8	60.4	23.8	19.0	2.4
51	" 5	10	66.3	26.1	21.5	3.3
52	" 5	9	62.9	24.8	19.5	2.7
53	" 5	5	50.7	20.0	17.0	1.2
54	" 5	..	62.5	24.7	20.5	2.3
55	" 5	7	60.5	23.8	19.0	2.3
56	" 5	6	55.1	21.8	17.0	1.5
57	" 5	3	36.5	14.4	11.0	0.4
58	" 9	17	87.3	34.4	24.5	6.5
59	" 9	10	74.7	29.4	23.0	4.1
60	" 19	15	78.0	30.7	31.5	5.1
61	" 19	18	89.0	35.1	30.0	6.4
62	" 19	22	89.0	35.1	33.0	8.4
63	" 19	19	90.5	35.7	35.2	9.8
64	" 19	13	74.2	29.3	28.0	4.2
69	" 19	15	76.5	30.0	....	4.0

The number of the fish in column 1 refers to the laboratory tag number of the sturgeon, and the same number is used in both the rate of growth and the food references. The otoliths from sturgeon 1-9, 19, 44, 54, and 65-68 were not examined. All measurements in length are from the tip of the snout and the tip of the dorsal portion of the tail.

The graphs show that during the first five years the sturgeon increase very rapidly in length, but very little in weight. In the next ten years there is a falling off in the rate of growth in length, the total for the ten years being less than that for the first five. At the same time there is a slight increase in the rate at which weight is added, the total gain in weight for the ten years being four times the weight at the end of the fifth year. About the age of twenty the rate of growth in length becomes still slower and more uniform, while after this period the increase in weight becomes more rapid with increasing age (Fig. 6). The

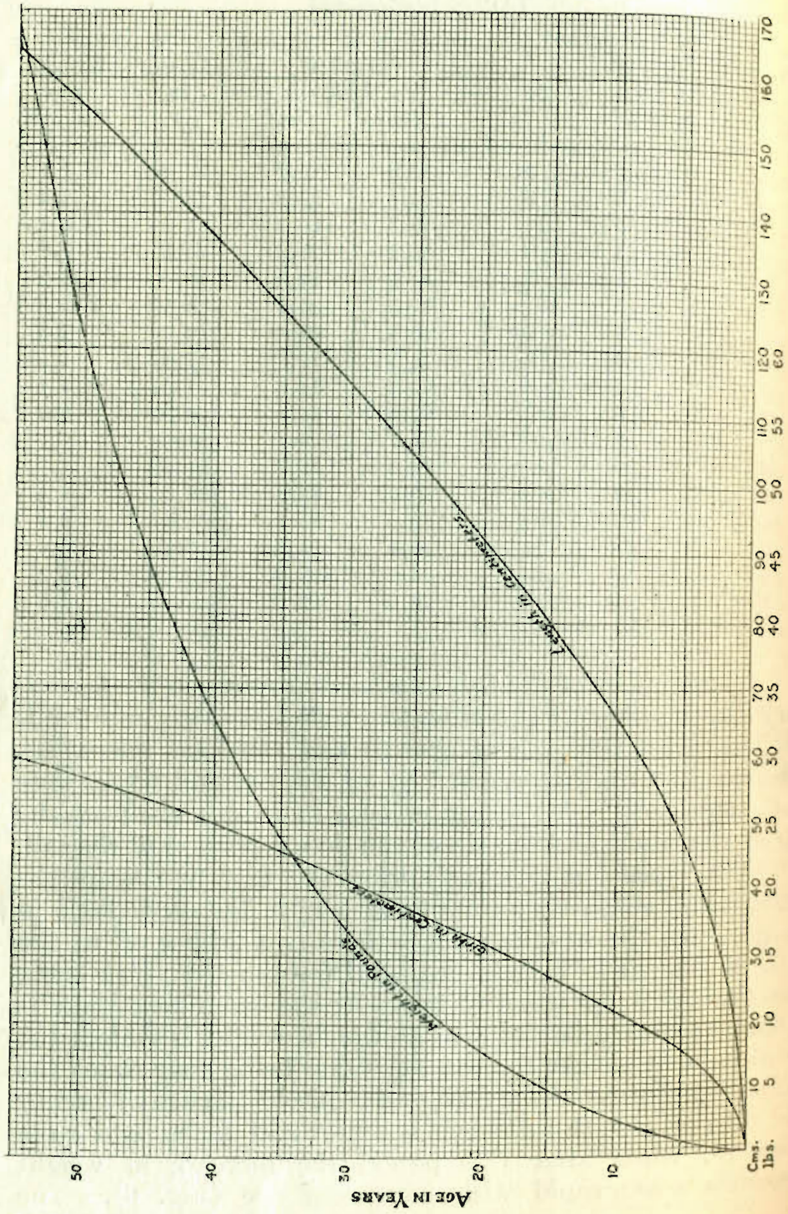

Fig. 5. Graphs showing rate of growth of sturgeon in Lake Nipigon.

girth increases with the ages in approximately the same ratio as the length.

By extending graphs obtained from the data covering Lake Nipigon sturgeon, it is possible to estimate the age of a fish of which we know the length or weight. The largest sturgeon taken from Lake Nipigon was caught in 1919. It weighed 99 pounds and was approximately 180 cm. (6 feet) in length. By reference to the graph, Fig. 5, this sturgeon would appear to have been 63 years old. On June 29, 1922, a large sturgeon measuring 225 cm. (7 feet 6 inches) was taken near Sault Ste. Marie by Mr. La Pointe, fisherman. Unfortunately it was impossible to secure the otoliths of this specimen, but a photograph was obtained of the fish, as well as data regarding size, capture, etc. Although it was taken from Lake Superior, there is little doubt that its rate of growth would be approximately the same as that of a sturgeon in Lake Nipigon. By extending the graph as noted above, it is found that this sturgeon was probably 99 years old.

In all fish which were less than 22 years of age it was impossible to determine the sex by macroscopic examination of the reproductive organs. In older fish the sex was readily determined. It is interesting to note that between the ages of 20 and 25 years great changes occur in the outward appearance of the sturgeon. The snout becomes shorter and blunter; the sharp points of the shields disappear; the shields themselves become smoother, and some apparently are entirely resorbed. Without doubt these changes are associated with the attainment of sexual maturity which is reached apparently at about 22 years of age. Although a female may become sexually mature at this age, it is not until after the age of about 30 years that she begins to produce a large number of eggs. Therefore, the taking of fish of 30 years or less diminishes greatly the production of fry and is likely to result ultimately in the complete depletion of the sturgeon.

Table II gives the rate at which sturgeon increase in weight at different periods of their life.

From a study of Table II it may be seen that until the age of 30 years the sturgeon has increased very little in weight, but thereafter it begins to fill out and form a first-class marketable fish. In dressing a fish for market, it may be noted here, the removal of head and viscera reduces the weight by one-third.

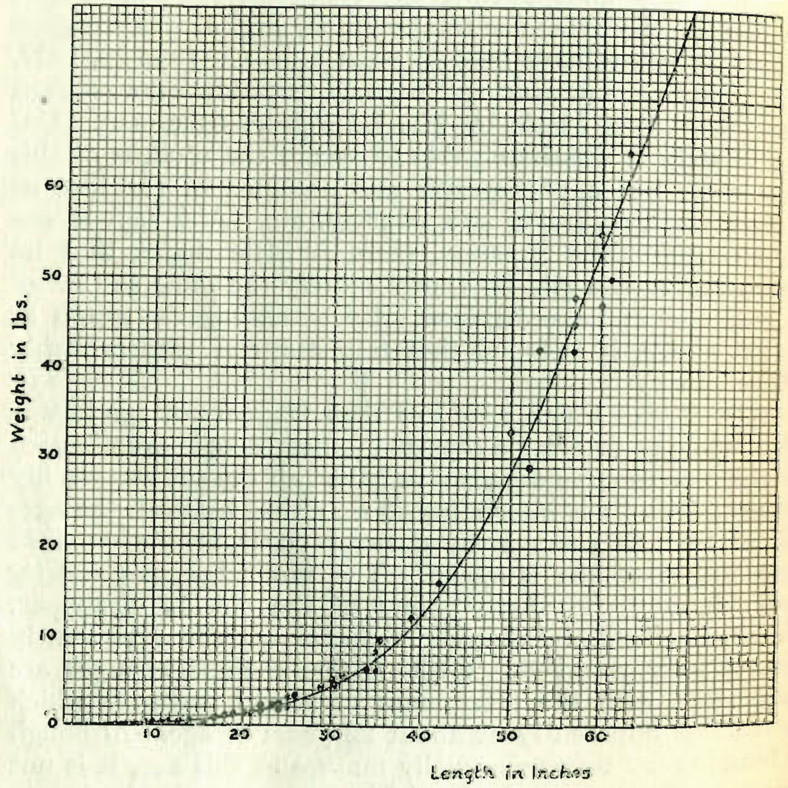

Fig. 6. Graph showing relation of weight to length of sturgeon in Lake Nipigon.

At the present time there is a regulation in Ontario which prohibits the taking of sturgeon under 105 cm. (42 inches) in length. Sturgeon of this length are approximately 27 years of age (Table II). The wisdom of this regulation is

TABLE II

Period of years	Increase in weight in lb.	Increase in length cm.	in.
0-10	0-3	0-66	0-26
10-20	3-8	66-92	26-37
20-30	8-17	92-115	37-46
30-40	17-32	115-136	46-54
40-50	32-60	136-155	54-62
50-60	60-89	155-175	62-70

quite evident, but the data presented in this paper may warrant the enactment of legislation to prevent the taking of even larger sturgeon. It is suggested that the taking of no sturgeon under 127 cm. (50 inches) in length, that is about 35 years of age, would ultimately be in the best interest of the sturgeon fisheries. Such legislation would have the double advantage of allowing an increased number of sturgeon to spawn for eight additional years, and as pointed out above, of enhancing the value of the fish taken.

THE FOOD OF THE STURGEON IN LAKE NIPIGON

Review of the Literature

Ryder (1888) gives a rather full account of the food of the sturgeon (*Acipenser sturio*) at different stages of its development. During the first three months, the food consists of minute plant forms such as diatoms, *Infusoria*, *Rhizopoda*, worms, microscopic shrimps, larvae of aquatic insects, etc. When one to two inches in length the little fish feeds upon *Cladocera*, worms, insect and fish larvae. The mature sturgeon has a dietary consisting of the larger crustaceans, shrimp-like isopods and amphipods, and *Mollusca*, as well as microscopic organisms.

Ehrenbaum (1892?) found in the alimentary tract of eleven-day sturgeon (*Acipenser sturio*) small filamentous algae, and in fish a month old, large numbers of *Daphnia*.

Milner, as quoted by Goode (1884), holds that the sturgeon (*Acipenser rubicundus*) of the lakes, subsists almost entirely on the *Mollusca*, principally the *Gastropoda*. The same author is quoted by Forbes and Richardson as recording that in the vicinity of grain elevators the stomachs of sturgeon are sometimes found well filled with wheat and corn.

Evermann and Latimer (1910) report work done by Woolman, who in 1894 examined 55 sturgeon (*Acipenser rubicundus*), from the Lake of the Woods, for stomach contents. Of these, 22 were empty; 28 contained one or more crayfish; 6 contained *Mollusca*; 6, insect larvae; 1, a fish egg; 1, a fish vertebra; 1, a hazelnut; and 8, gravel. They also report an examination of several Oregon sturgeon, a species related to *Acipenser rubicundus*, which were taken in Snake River, Idaho. Of these a twenty-five inch specimen contained eleven minnows; and some larger specimens contained several suckers, which were about one foot in length.

Prince (1899) records that in sturgeon sent to him from the rivers of British Columbia he found large quantities of a small smelt-like fish, the Oolâchan, which ascends the rivers of British Columbia in great schools at the spawning season. The same writer reports that the alimentary tracts of the sturgeon from the St. John River, N.B., revealed enormous numbers of fresh water *Mollusca*, as well as quantities of mud, and masticated vegetable ooze containing numerous unicellular algae, and leaves and stems of higher aquatic plants.

Clemens and others (1921) examined the stomach contents of 12 individuals (*Acipenser rubicundus*) from Lake Nipigon. Three of these sturgeon were 44, 44 and 53 centimetres in length and were taken off the mouth of Blackwater River in a net of small mesh. The remaining nine were all over 107 centimetres in length, and were taken in commercial pound nets along the east shore of Lake Nipigon. The contents of the alimentary tracts of these fish consisted largely of *Ephemerida* nymphs and *Mollusca*, with a considerable quantity of fish remains and *Chironomidae* larvae and small quantities of other animals and a few plants. These results have been included in Table III, with the results obtained in the present investigation.

Methods

During July and August of 1922, sturgeon (*Acipenser rubicundus*) ranging from 23 centimetres to 160 centimetres in length were taken from as many parts of Lake Nipigon as possible, and the contents of their alimentary tracts were preserved. Various methods were used in taking these fish depending on their size and habitat. The fish from Humboldt Bay were taken in commercial gill nets of 12 inch mesh.[1] These nets were generally set out from a point of land and the sturgeon were caught while rounding the point from thirty to sixty feet from shore. The fish from Sturgeon River were caught in gill nets of 2, 3, and 4½ inch mesh. These nets were set completely across the river always within one-half mile of the mouth. The Blackwater River specimens were taken in gill nets of 3 and 4½ inch mesh, set some distance out from the mouth of the river and at right angles to the shore-line of the lake. The bottom at this place is extremely rocky with sand among the rocks. Some of the fish taken in Gull River were caught in gill nets of 3 and 4½ inch mesh, and set from shore to shore about three quarters of a mile up the river. The larger sturgeon from Gull River were taken on hooks of set lines, stretched across the mouth of the river by Indians. The size of the fish, the locality where taken, and, as far as is known, the depth of water from which they were taken are given in Table III.

The methods used in dealing with the contents of the alimentary tracts were as follows: When possible, the fish was opened almost immediately upon being brought ashore after the nets had been lifted. The material was cleaned from the alimentary tracts and preserved in 70% alcohol, a separate jar being used for the material from each fish. When it was impossible to open the fish for a few hours

[1] The range in size of fish caught by nets of various size of mesh is as follows:

2 inch mesh,—fish from 23 to 30 cm.
3 inch mesh,—fish from 30 to 49 cm.
4½ inch mesh,—fish from 44 to 79 cm.
12 inch mesh,—fish from 100 to 160 cm.

after taking it from the net, a 10% or stronger solution of formalin was forced down the alimentary tract with a syringe. This hardened the walls of the tract and preserved the contents in perfect condition until the fish was opened, when these preserved contents were placed in 70% alcohol. The contents of the alimentary tract of 61 sturgeon were examined, but as the first three and the next two were grouped together, each of these groups is considered as one fish, and the total number examined may be regarded as 58. The reason for thus grouping these first five was that the contents of their alimentary tracts were placed in two jars, no more jars being available at the time. The last eight sturgeon recorded in the tables had formalin forced down their alimentary tracts, all of the fish were then preserved in formalin, and they were not opened until two months after catching. The stomach contents were in good condition, but not so good as those from the fish opened at the lake. In determining the percentage estimates of the food in each fish, the first process was to separate the different groups of organisms. The number of specimens in each group was then counted, and each group was placed in a separate bottle in 70% alcohol. All of the bottles containing the food of one fish were placed side by side and direct measurements were made of the contents of the bottles. From these measurements the percentages were deduced. The data obtained by these methods are presented in the following tables.

In one horizontal column the percentage estimates are given. In the accompanying column is indicated the number of organisms of each group occurring in each sturgeon. Owing to disintegration it was not always easy to determine the actual numbers, as often only half or less of an organism was present. This is indicated by a × sign after the number representing the organisms actually counted. The sign *a* in this column refers to numerous organisms or parts of organisms, usually too much broken up even to estimate their numbers. The sign × in the percentage column indicates an amount estimated to be less than one per cent.

TABLE III—FOOD OF STURGEON

Number	Date, 1922	Length in cm.	Place taken	Depth water (feet)		*Nematoda*	*Hirudinea*	*Amphipoda*	*Decapoda*	*Neuroptera* larvae	*Plecoptera* nymphs	*Ephemerida* nymphs	*Anisoptera* nymphs	*Trichoptera* larvae	*Chironomidae* larvae	*Mollusca*	Fish remains	Fish eggs	Green plants	Dead wood	Spruce needles	Gravel, sand, etc.	Unidentified
4	June 29	107.0	Humboldt	4-5	%	x						95		2	1	2			x			x	
5		143.8	Bay																				
6		152.8			No.	2						222		1	14	4			3			1	
7	June 29	128.5	Humboldt	4-5	%	x			11	5		83			1	x			x				
8		145.0	Bay		No.	9			1x	136		1036			46	10			2				
10	July 6	160.5	Humboldt	4-5	%		1		98	x		1			x	x			x				
			Bay		No.		3		924	2		73			8	12			5				
11	July 11	48.2	Sturgeon R.	10	%	x						4		59	8	8			x	20		x	1
					No.	2						x		14	9	13			1	8x		*a*	x
12	July 11	30.0	Sturgeon R.	10	%							95		5									
					No.							*a*		3									
13	July 14	136.0	Humboldt	4-7	%	x			85			3				12			x				
			Bay		No.	1			1			1				8			*a*				
14	July 14	156.0	Humboldt	6-8	%		6	x	x	x		90		x	1	1		x	2			x	
			Bay		No.		47	1	x	1		1487		1	16	16		3	*a*			5x	
15	July 14	147.5	Humboldt	5-7	%				96			x				3						1	
			Bay		No.				8x			1				8						3	
16	July 15	100.0	Humboldt	6	%	x						96			2				2				
			Bay		No.	1x						211			6				1				

TABLE III—*continued*

Number	Date, 1922	Length in cm.	Place taken	Depth water (feet)		*Nematoda*	*Hirudinea*	*Amphipoda*	*Decapoda*	*Neuroptera* larvae	*Plecoptera* nymphs	*Ephemerida* nymphs	*Anisoptera* nymphs	*Tricoptera* larvae	*Chironomidae* larvae	*Mollusca*	Fish remains	Fish eggs	Green plants	Dead wood	Spruce needles	Gravel, sand, etc.	Unidentified
17	July 15	132.4	Humboldt	6	%	x		x		1		90	1		3	4			1				
			Bay		No.	*a*		4		1		372	1		7	49			*a*				
19	July 24	49.0	Gull River	15	%	x	3					25	68	1	2	x			x	1			
					No.	*a*	1					155	162	1	19	2			1	1			
20	July 24	33.0	Gull River	15	%	x							100		x	x							
					No.	1							47x		1	1							
21	July 26	54.0	Blackwater	10	%			x							14	81		2	x		3		
			River		No.			1							83	513x		6	1		4		
22	July 26	65.0	Blackwater	10	%	x	1								1						98		
			River		No.	3x	6x								1						17		
23	July 29	56.0	Blackwater	10	%									6	2	81			x		11		
			River		No.									4	9	1534			*a*		23		
24	July 29	61.0	Blackwater	10	%									52	4	20				5	18	x	1
			River		No.									149	24	157				40	47	*a*	7
25	July 29	40.3	Blackwater	10	%									46	46					7			1
			River		No.									2	15					2			2
26	July 30	58.0	Mouth of																				
			Blackwater	8	%									55	9	20			x	2	14	x	x
			River		No.									34x	34	14			*a*	5	29	*a*	*a*

TABLE III—*continued*

Number	Date, 1922	Length in cm.	Place taken	Depth water (feet)		*Nematoda*	*Hirudinea*	*Amphipoda*	*Decapoda*	*Neuroptera* larvae	*Plecoptera* nymphs	*Ephemerida* nymphs	*Anisoptera* nymphs	*Trichoptera* larvae	*Chironomidae* larvae	*Mollusca*	Fish remains	Fish eggs	Green plants	Dead wood	Spruce needles	Gravel, sand, etc.	Unidentified
27	July 30	65.5	Mouth of																				
			Blackwater	8	%									85	13							2	
			River		No.									3	3							4	
28	July 31	54.5	Blackwater	12	%	x		15						8	30	1	33	9	3		x	x	1
			River		No.	10		357						24	1390	26	1	14	5		1	*a*	5
29	July 31	52.0	Blackwater	12	%									48	7	43			x	1	1	x	
			River		No.									100x	88	901			1	*a*	1	*a*	
30	July 31	54.2	Blackwater	12	%										5	1	57						37
			River		No.										24	2	16						*a*
31	July 31	34.0	Blackwater	12	%									10	75					15			x
			River		No.									2	97					1			10
33	Aug. 2	60.8	Blackwater	20	%									5	3	85	2			5			x
			River		No.									9	6	876	1			4			3
34	Aug. 2	56.1	Blackwater	20	%									7	10	60				13	9		1
			River		No.									13	100	776				47	12		3
35	Aug. 2	58.8	Blackwater	20	%									60	2	6				10	20	2	
			River		No.									41	10	25				9	19	2	
36	Aug. 3	34.7	Blackwater	20	%									87	10	x				1	2	x	
			River		No.									101	112	1				3	8	*a*	

TABLE III—*continued*

Number	Date, 1922	Length in cm.	Place taken	Depth water (feet)		*Nematoda*	*Hirudinea*	*Amphipoda*	*Decapoda*	*Neuroptera* larvae	*Plecoptera* nymphs	*Ephemerida* nymphs	*Anisoptera* nymphs	*Trichoptera* larvae	*Chironomidae* larvae	*Mollusca*	Fish remains	Fish eggs	Green plants	Dead wood	Spruce needles	Gravel, sand, etc.	Unidentified
37	Aug. 3	48.4	Blackwater	20	%									5	9	80				3	1	1	1
			River		No.									14	40	762				6	1	1	4
38	Aug. 4	44.9	Blackwater	15	%									50	7		42		x	1	x	x	
			River		No.									61	61		1		1	2	1	*a*	
39	Aug. 4	47.0	Blackwater		%									5	30	60			1	1	2	1	x
			River		No.									2	26	23			1	1	1	2	*a*
40	Aug. 4	60.2	Blackwater	15	%									2	1	94				3			
			River		No.									1	1	617				4			
41	Aug. 5	23.5	Sturgeon	15	%							93			5					2			
			River		No.							150			12					3			
42	Aug. 5	25.3	Sturgeon	15	%							97			3								
			River		No.							64			6								
43	Aug. 5	28.1	Sturgeon	15	%							97			2	1							
			River		No.							56			5	1							
44	Aug. 5	28.0	Sturgeon	15	%										100								x
			River		No.										4								*a*
45	Aug. 5	30.0	Sturgeon	15	%	x						95	3		2	x							
			River		No.	3						112	10		9	1							
46	Aug. 5	30.0	Sturgeon	15	%	x						96			4				x				
			River		No.	2						49			8				1				

TABLE III—*continued*

Number	Date, 1922	Length in cm.	Place taken	Depth water (feet)		*Nematoda*	*Hirudinea*	*Amphipoda*	*Decapoda*	*Neuroptera* larvae	*Plecoptera* nymphs	*Ephemerida* nymphs	*Anisoptera* nymphs	*Trichoptera* larvae	*Chironomidae* larvae	*Mollusca*	Fish remains	Fish eggs	Green plants	Dead wood	Spruce needles	Gravel, sand, etc.	Unidentified
47	Aug. 5	79.6	Sturgeon	8	%	x						x	86		x	13			x	1	x	x	x
			River		No.	*a*						2	14		6	265			2	*a*	2	2	*a*
48	Aug. 5	77.2	Sturgeon	8	%							1		1	2	85			1	4		6	x
			River		No.							3		1	9	329			3	20		30	*a*
49	Aug. 5	60.2	Sturgeon	8	%							62	10	8	1	13			2			4	
			River		No.							35	12	2	1	12			2			9	
50	Aug. 5	60.4	Sturgeon	8	%	2		20					20	10	45	3							x
			River		No.	35		47					16	2	174	3							1
51	Aug. 5	66.3	Sturgeon	8	%							42			8	5				34		8	3
			River		No.							58			31	3				63		25x	*a*
52	Aug. 5	62.9	Sturgeon	8	%			28				2		3	63	1	1			1		x 1	
			River		No.			481				18		24	1142	19	1			*a*		*a a*	
53	Aug. 5	50.7	Sturgeon	8	%							70	11	4	10	3							2
			River		No.							71	6	1	30	2							*a*
54	Aug. 5	62.5	Blackwater	10	%										2	94				2		2	
			River		No.										11	640				x		x	
55	Aug. 5	60.5	Blackwater	10	%							8		22	11	41		1		8	2		7
			River		No.							2		10	40	464		1		7	1		8
56	Aug. 5	55.1	Sturgeon	15	%						2	14	79	2	2						1		
			River		No.						1	15	13x	1	6						1		

TABLE III—*continued*

Number	Date, 1922	Length in cm.	Place taken	Depth water (feet)		*Nematoda*	*Hirudinea*	*Amphipoda*	*Decapoda*	*Neuroptera* larvae	*Plecoptera* nymphs	*Ephemerida* nymphs	*Anisoptera* nymphs	*Trichoptera* larvae	*Chironomidae* larvae	*Mollusca*	Fish remains	Fish eggs	Green plants	Dead wood	Spruce needles	Gravel, sand, etc.	Unidentified
57	Aug. 5	36.5	Sturgeon River	15	%						6	69	8	9	6							2	
					No.						1	114	4	2	38							2	
58	Aug. 8	87.3	Gull River	15	%	x						86			5	4				5			
					No.	1						79			15	7				25			
59	Aug. 9	74.7	Gull River	15	%			4		x		42		x	3	x	50		x	1			
					No.			308		2		212x		2	192	8	13		*a*	*a*			
60	Aug. 19	78.0	Gull River	15	%			2				93			4					1		x	
					No.			10				510x			18x					2		*a*	
61	Aug. 19	89.0	Gull River	15	%			1				25			3		70		x	1			
					No.			24				161x			22		25		*a*	4			
62	Aug. 19	89.0	Gull River	15	%			3				83			4		10					x	
					No.			100				800x			46		2					*a*	
63	Aug. 19	90.5	Gull River	15	%	x		2		1		86			5					6		x	
					No.	1		1		1		33x			2					1		*a*	
64	Aug. 19	74.2	Gull River	15	%	x				3		86			2	8			x	1			
					No.	3				4		08x			36	32			2	5			
65	Aug.	50.6	Lake Nipigon		%	x		20		x		41			37					2			
					No.	1		130		1		25x			202					5			
66	Aug.	48.1	Lake Nipigon		%			90							10								
					No.			487							74								
67	Aug.	77.0	Lake Nipigon		%	x					4	80			6		10						
					No.	1					3	75x			14		1						

TABLE IV—SUMMARY

	Nematoda	*Hirudinea*	*Amphipoda*	*Decapoda*	*Neuroptera* larvae	*Plecoptera* nymphs	*Ephemerida* nymphs	*Anisoptera* nymphs	*Trichoptera* larvae	*Chironomidae* larvae	*Mollusca*	Fish remains	Fish eggs	Green plants	Dead wood	Spruce needles	Gravel, sand, etc.
Number of sturgeon stomachs in which found............	19	4	13	5	8	3	34	10	30	55	38	9	4	23	29	16	24
Average percentage stomach contents of sturgeon of preceding column........	0.1	2.8	14.2	58.0	1.3	4.0	57.3	38.3	21,9	11.6	24.6	30.6	3.0	0.5	5.4	11.4	1.2
Total specimens obtained from all sturgeon..............	76	57	1951	934	148	5	6410	285	625	4403	8135	61	24	32	268	168	86
Percentage stomach contents of 58 sturgeon.............		0.2	3.2	5.0	0.2	0.2	33.6	6.6	11.3	11.0	16.1	4.7	0.2	0.2	2.7	3.2	0.5
Percentage stomach contents of 12 sturgeon year 1921.....			3.6				35.6			9.4	31.9	19.0					

Additional Data on the Tables

Only a few of the specimens present in the stomach contents have been identified with certainty. These identifications are as follows:

(4-5-6) EPHEMERIDA Nymphs: *Ephemera simulans* (18); *Hexagenia bilineata* (204).
MOLLUSCA: *Lymnaea stagnalis* (1); *Sphaerium* sp? (1).
ALGAE: *Ulothrix* (1); *Melosira* (1); *Chara*.

(7-8) EPHEMERIDA Nymphs: *Ephemera simulans* (1); *Hexagenia bilineata* (1035).
MOLLUSCA: *Planorbis* sp? (1).
DECAPODA: *Cambarus virilis* (1).

(9) No stomach contents.

(10) EPHEMERIDA Nymphs: *Ecdyurus maculipennis* (3); *Heptagenia canadensis* (2); *Hexagenia bilineata* (67).
MOLLUSCA: *Planorbis parvus* (1); *Amnicola limosa* (3); *Amnicola* sp? (1); *Sphaerium* sp?
DECAPODA: *Cambarus virilis* adult (24), young (900).

(11) ALGAE: *Rivularia* sp? (1).

(13) DECAPODA: *Cambarus virilis* (1).
ALGAE: *Rivularia* sp? (a).

(14) MOLLUSCA: *Planorbis antrosus; Amnicola limosa; Valvata sincera; Pisidium* sp?
AMPHIPODA: *Pontoporeia hoyi*.
ALGAE: *Cladophora* (a); *Rivularia* (a); *Chara* (a).

(15) DECAPODA: *Cambarus virilis* (8).

(17) MOLLUSCA: *Lymnaea galbana; Planorbis parvus; Amnicola limosa; Valvata tricarinata; Pisidium compressum*.
AMPHIPODA: *Pontoporeia hoyi* (3); *Hyalella knickerbockeri* (1).
ALGAE: *Rivularia* (a); *Chara*.
ELODEA.

(18) No stomach contents.

(19) MOLLUSCA: *Planorbis parvus* (1); *Pisidium* sp? (1).
ALGAE: *Rivularia*.

(20) MOLLUSCA: *Pisidium* sp? (1).

(21) MOLLUSCA: *Lymnaea* sp? (500); *Amnicola* sp?; *Planorbis parvus* (12); *Valvata tricarinata* (1).
AMPHIPODA: *Hyalella knickerbockeri* (1).
ALGAE.

(23) ALGAE: *Rivularia; Nostoc*.

(28) AMPHIPODA: *Pontoporeia hoyi* (357).

(29) ALGAE.

(30) FISH: *Pygosteus pungitius* (1).
Unidentified material consists of very small portions of *Cladocera*, *Copepoda*, *Amphipoda* and other invertebrates.

(32) No stomach contents.

(38) FISH: *Pygosteus pungitus* (1).
CLADOCERA (1).
ALGAE.

(45) Ten legs of *Anisoptera* nymphs.

(46) CLADOCERA.
ALGAE.

(49) Twelve parts of *Anisoptera* nymphs.
ALGAE.

(50) Sixteen parts of *Anisoptera* nymphs.
AMPHIPODA: *Pontoporeia hoyi* (a).

(52) One scale of a fish.
AMPHIPODA: *Pontoporeia hoyi* (a).

(53) Six legs of *Anisoptera* nymphs.

(59) One small fish.
Twelve large pieces of fish flesh.
AMPHIPODA: *Pontoporeia hoyi* (a).

(60) AMPHIPODA: *Pontoporeia hoyi* (10).

(61) Twenty-five pieces of fish flesh.
AMPHIPODA: *Pontoporeia hoyi* (8); *Hyalella knickerbockeri* (16).
ALGAE: *Rivularia; Vaucheria; Dichotomosiphon* sp?; *Oedogonium; Spirogyra;* Diatoms.

(62) Two pieces of fish flesh.
AMPHIPODA: *Hyalella knickerbockeri* (1).

(64) ALGAE: *Spirogyra; Chara*.

(65) AMPHIPODA: *Pontoporeia hoyi* (a).

(66) AMPHIPODA: *Pontoporeia hoyi* (a).
(67) One fish vertebra.

A large number of *Trichoptera* larval cases have been opened and a great many of them (over 50%) contained larvae. Among the *Chironomidae* larvae there is a small percentage of *Chironomidae* pupae. Of the *Mollusca*, 140 are *Gastropoda* and 7995 are *Pelecypoda* (*Sphaeridae*).[1]

Discussion

From an examination of the tables and from comparison of the data previously obtained, the following facts are manifest. *Chironomidae* larvae, *Mollusca* and *Ephemerida* nymphs constitute the basic food supply of the sturgeon. *Chironomidae* larvae occur in every locality; *Mollusca* occur almost as frequently and generally in larger numbers; while *Ephemerida* nymphs occur in every locality except that off the mouth of Blackwater River, where the bottom is very rocky and sandy. The *Trichoptera* larvae also form a very staple article of diet and occur in large numbers where the *Ephemerida* nymphs are scarce or entirely wanting. In some areas other organisms may abound and be more readily procured on account of their large numbers, or because of the fact that they are not buried in the mud to the same extent as those organisms forming the sturgeon's regular dietary. The sturgeon may feed almost entirely on these and the amount eaten of the otherwise staple diet articles become practically negligible. Instances of this are seen in the case of the *Decapoda*, *Anisoptera*, *Amphipoda*, and fish remains; in the case of Prince's reference to the Oolâchan of British Columbia; and again in Milner's record of the sturgeon eating large quantities of corn and wheat in the vicinity of grain elevators. From these observations it seems reasonable to conclude that the sturgeon will take anything of food value that it can find; also that the more

[1]The writer is indebted to Professor A. G. Huntsman and to Mr. E. Moss for the identification of *Decapoda* and *Algae* respectively, and to members of the Ontario Fisheries Research Laboratory for assistance in identification of various other organisms.

abundant and more easily obtained food will come first, regardless of its ingredients. If this readily obtained food is not forthcoming, the sturgeon will go in search of some of its regular diet of *Chironomidae* larvae, *Mollusca*, and *Ephemerida* nymphs.

The other organisms which constitute a smaller percentage of the food do not, in this investigation, appear of much importance. It is easy to conceive, however, that in a scarcity of other food, or in an area where some of these organisms are particularly abundant, the sturgeon could make more use of them than it does on the evidence of these records. Even here, when all grouped together, this miscellaneous material constitutes no inconsiderable percentage of the total food.

As far as can be learned from this investigation and from other trustworthy data, the sturgeon does not appear to feed to any extent upon the eggs or fry of fishes. Although there are records of sturgeon taking other fish as food, these records are very few and of a nature which should not cause the sturgeon to be considered a predaceous fish. Evermann (1910) reports finding specimens of adult suckers in sturgeon. As sturgeon are infinitely more valuable than suckers this is not to be deplored. Prince (1899) notes that the sturgeon of British Columbia ascend the rivers during the spawning season of the Oolâchan. These Oolâchan also ascend the rivers in practically solid shoals which are so dense that a sturgeon with its tube-like mouth could hardly avoid taking some in. If some of these fish became injured or sick and settled to the bottom, as is almost certain to be the case where such large numbers are present, they would be still more easily taken. Although the sturgeon does take a large number of these fish, at this period of the year, this number must be an almost infinitesimal percentage of the total number present in one stream.

That an abundance of food suitable for the sturgeon exists in Lake Nipigon, is evident from a survey made by Adamstone and Harkness (1923). This survey indicates a wide and uniform distribution of *Chironomidae* larvae, *Mollusca*, *Ephemerida* nymphs, *Trichoptera*, and *Amphipoda*. From data obtained later it is evident that apart from the uniform distribution of these organisms, there are also beds where the *Decapoda*, and *Anisoptera* nymphs are particularly abundant.

The fish of greatest importance commercially in Lake Nipigon is the whitefish, *Coregonus clupeaformis*. Although the value of the annual catch of sturgeon is not as great as that of the whitefish, yet the sturgeon is economically entitled to no little consideration, both because of its highly esteemed flesh and because of the great demand for caviar made from its eggs. The whitefish feeds largely upon *Chironomidae* larvae, *Mollusca*, and *Amphipoda* (Clemens and others, 1921), which, as has been shown in this investigation, also constitute an important part of the sturgeon's food. Nevertheless, it is unlikely that keen competition exists between the whitefish and the sturgeon, since the whitefish is found chiefly in deep water, whereas the sturgeon lives in the shallower bays and in the mouths of the rivers. In this way their feeding grounds are distributed over different areas, and they do not encroach on each other to any considerable extent.

In so far as this preliminary work on the food of the sturgeon demonstrates the facts of the case, it would appear that the sturgeon is not detrimental to the welfare of other valuable fish either as a predatory agent or as a competitor for food. In view of the economic importance of this fish, and since it has been shown that there is an abundance of food material in Lake Nipigon, it seems advisable that an attempt be made to maintain the sturgeon in Lake Nipigon in numbers equal to or even greater than those now present.

General Summary

1. This investigation has shown that the use of otoliths for determining the age and the rate of growth of the sturgeon is satisfactory.

2. The sturgeon in Lake Nipigon may attain an age of at least 50 years.

3. During the first twenty years, increase in length of the sturgeon is rapid, whereas increase in weight is slow. Subsequently increase in length becomes slower, whereas increase in weight becomes more rapid.

4. It appears that the sturgeon does not become sexually mature until about 22 years of age, when it is approximately three feet in length.

5. It is suggested that the taking of no sturgeon under 35 years of age (50 inches in length, 27 pounds in weight) would result in ultimate benefit to the sturgeon fisheries.

6. The sturgeon is a bottom feeder whose food consists chiefly of *Ephemerida* nymphs, *Chironomidae* larvae and *Mollusca*, with the addition of considerable quantities of *Amphipoda*, *Decapoda*, *Odonata* nymphs, *Trichoptera* larvae, fish and plant stuffs.

7. It does not appear that the sturgeon enters into serious competition with the common whitefish (*Coregonus clupeaformis*) since it obtains its food in shallow water.

8. In view of the facts brought out in this investigation it seems advisable that an attempt be made to maintain the sturgeon fishery in Lake Nipigon.

LITERATURE CITED

Adamstone, F. B., 1923. The Distribution and Economic Importance of Mollusca in Lake Nipigon. University of Toronto Studies: Biological Series, Pub. Ontario Fisheries Research Laboratory, No. 14.

Adamstone, F. B., and Harkness, W. J. K., 1923. The Bottom Organisms of Lake Nipigon. University of Toronto Studies: Biological Series, Pub. Ontario Fisheries Research Laboratory, No. 15.

Clemens, W. A., and others, 1923. The Food of Lake Nipigon Fishes. University of Toronto Studies: Biological Series, Pub. Ontario Fisheries Research Laboratory, No. 16.

Ehrenbaum, E., 1892? Contributions to the Natural History of some Elbe Fish. Marine Scientific Biological Investigation, Heligoland Biological Station.

Evermann, B. W., and Latimer, H. P., 1910. The Fishes of the Lake of the Woods and Connecting Waters. Proc. U.S. Nat. Mus. 39; 121-126, No. 1778.

Forbes, S. A., and Richardson, R. E., 1908. The Fishes of Illinois. Nat. Hist. Survey of Illinois: Vol. 3, Ichthyology. Urbana.

Goode, B., 1884. Fisheries of the United States. Washington.

Prince, E. E., 1899. The Food of the Sturgeon. Annual Report, Department of Marine and Fisheries, Ottawa, IV-IX.

Ryder, J. A., 1888. The Food of the Sturgeon. Bulletin U.S. Fish Commission.

UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE
ONTARIO FISHERIES RESEARCH LABORATORY
No. 19

THE BOTTOM FAUNA OF LAKE NIPIGON

BY

F. B. ADAMSTONE

OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

TORONTO
THE UNIVERSITY LIBRARY
1923