

which Richardson had given the name *tullibee*. Examination of the specimens here described makes it evident that *L. nipigon* is quite distinct from *L. tullibee*. The Department of Biology collection of fishes includes several specimens from Manitoba which are not referable to either *L. nipigon* or *L. tullibee*, but our material is not yet sufficient to say how many species of this genus are included in the fish fauna of this area.

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A PRELIMINARY STUDY OF THE GENUS *LEUCICHTHYS* IN THE CANADIAN WATERS OF LAKE ONTARIO

BY

ANDREW L. PRITCHARD

OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

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A PRELIMINARY STUDY OF THE GENUS LEUCICHTHYS IN THE CANADIAN WATERS OF LAKE ONTARIO

INTRODUCTION

The freshwater fishes of the genus *Leucichthys*, popularly known as lake herrings or ciscoes, are of considerable commercial importance. They represent several species differing from one another as regards habits, size attained, rate of growth, spawning time, and quality of flesh. They have not as yet been studied extensively from these points of view, and consequently there has been very little constructive information available upon which either understanding of the situation or control could be based. The present study of the case represents a preliminary step to a more complete survey.

The genus *Leucichthys* includes several closely related species, common in the Great Lakes and in the lakes of northwestern Canada. In order to give an idea of the standing of these fishes in comparison with other commercial species of Lake Ontario, the yearly catches for 1907, 1915, 1919, 1920, 1923 and 1925, as recorded in the Annual Reports of the Department of Game and Fisheries of Ontario, are set forth in table 1.

The statistics recorded above show that until 1920 the herring were one of the most important commercial assets in the fisheries of the Canadian waters of Lake Ontario. About that time the catch began to decline in spite of an increase in the yardage of gill nets used and has gradually fallen off up to the present time. Whitefish and trout have taken

TABLE 1.—GIVING IN POUNDS THE ANNUAL CATCH OF HERRINGS IN COMPARISON WITH THE OTHER MORE IMPORTANT COMMERCIAL SPECIES OF FISH TAKEN IN THE CANADIAN WATERS OF LAKE ONTARIO IN 1907, 1915, 1919, 1920, 1923 AND 1925.

	1907	1915	1919	1920	1923	1925
Herring, including						
ciscoes.....	(2) 1,010,010	(2) 1,801,341	(2) 1,720,342	(2) 1,291,530	(2) 256,279	(2) 294,107
Whitefish.....	(3) 343,690	(3) 817,618	(3) 1,593,558	(3) 2,027,008	(3) 2,566,110	(3) 1,926,367
Trout.....	105,790	555,369	554,013	462,013	754,950	1,063,304
Pike.....	296,200	366,988	246,095	311,432	280,800	191,842
Pickarel.....	72,390	85,965	40,459	36,551	167,985	70,982
Sturgeon.....	7,080	1,521	.....	500	2,948	6,033
Eels.....	20,400	219,703	167,186	91,932	123,940	159,325
Perch.....	168,920	119,310	158,802	107,383	82,703	90,423
Catfish.....	297,300	267,698	247,840	170,215	180,761	122,414
Carp.....	(1)	112,518	139,471	65,674	102,989	29,635
Mixed or coarse fish	283,140	438,684	603,014	413,841	377,544	382,171
Gill nets, yards.....	485,208	887,685	1,139,100	1,057,962	1,467,364	1,677,035

(1) Not separated from mixed or coarse fish.

(2) These figures include the fresh herring and salted herring which have been calculated at 200 pounds per barrel when the statistics give the amount in barrels. The poundage of tullibees and smoked herrings is included also when it is given separately.

(3) These figures include the fresh whitefish and salted whitefish. The latter when given in barrels are calculated as before.

their place at the top of the list. Reckoning on the basis of five cents per pound, as is done in the Department of Game and Fisheries' annual reports, this decrease in the herring catch as between 1915 and 1925 represents a difference of about \$75,000 in revenue.

MATERIAL

Specimens for this study were secured from commercial fishermen as follows: from Port Credit, February 1926, from a depth of 250 feet; March 1926, from depths of 250 and 350 feet; and from Bronte in November 1926, from a depth of 75 feet. Other fish were obtained from gill net settings made for the purpose in September and October 1926 and in the summer of 1927 in different depths of water off Port Credit. For these settings a gang of nets was used, made up of eleven pieces, each fifty yards in length, and each of different size mesh. The meshes of the sections were $1\frac{1}{2}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3, $3\frac{1}{2}$, 4, $4\frac{1}{2}$, $4\frac{3}{4}$ and 5 inches stretched mesh, as manufactured. Specimens were also procured from the gill net settings made by the Ontario Department of Game and Fisheries off Winona in November 1925. Other individuals were taken from the pound nets set in the Bay of Quinte off Belleville by the Department of Game and Fisheries of Ontario during the whitefish spawning run of 1926.

ACKNOWLEDGMENTS

To Professor John R. Dymond of the Department of Biology, University of Toronto, I am greatly indebted for direction, aid, and advice during the course of this research. My thanks are also due to Dr. Walter Koelz of the U.S. Bureau of Fisheries, for the identification of some of the fish and advice on matters connected with them. All the commercial fishermen have extended every courtesy, especially Mr. Louis Joyce of Port Credit, who allowed us to use as much of his equipment as was necessary.

STATUS OF SPECIES

The latest publication dealing with this genus in the Great Lakes from the taxonomic viewpoint, is that of Jordan and Evermann (1911) in which the following three species are listed from Lake Ontario: *Leucichthys ontariensis*, Jordan and Evermann; *L. artedi* (LeSueur), and *L. prognathus* (H. M. Smith).

For some time, however, Dr. Koelz has been engaged in a revision of the coregonine fishes of the Great Lakes. The results of his studies have not yet been published, but he has been kind enough to identify some of our material and advise us thereon. In addition, reference has been made to original papers on a number of new species which he described as a result of his intensive studies. At the present time Dr. Koelz recognizes in Lake Ontario the following four species: *Leucichthys artedi* (LeSueur), which he regards as the same as *L. ontariensis* Jordan and Evermann; *L. reighardi* Koelz; *L. hoyi* (Gill), and *L. kiyi* Koelz. A fifth species *L. nigripinnis* (Gill), which formerly supported a considerable fishery, he now believes to be extinct.

The fishermen divide the members of this genus into two groups which they designate "herrings" and "ciscoes". The term "herring" to them implies a shallow water fish with dry flesh, while the term "cisco" conveys the idea of a deep water form with fat or oily flesh. Thus they include in the first group *L. artedi* and in the second *L. reighardi*, *L. kiyi*, and *L. hoyi*.

The great variability of the fishes in this genus necessitated measuring a considerable number of individuals of both sexes, and of as many sizes as possible, in order to obtain descriptions of the four existing species. Measurements of individuals of the same species from different portions of the lake furnish data on which to form opinions as to the existence of races within a given species. It was found impossible to work over the fish when fresh so that all the descriptions are based on measurements of preserved fish. The specimens were first placed in a 6 per cent. formalin

solution for about a week. At the end of this time they were removed, washed for about a day in water, and finally placed in 66 per cent. alcohol in which they were kept permanently. Averages of these measurements for each species are given in table 1 of the appendix. The method of indicating body proportions used by Dymond (1926) has been employed in the following descriptions.

DESCRIPTIONS OF SPECIES

LEUCICHTHYS ARTEDI (Le Sueur)LAKE HERRING, SHOAL WATER HERRING, BLUE BACK,
QUINTE HERRING

The body is slender without much rise at the nape as compared with the jumbo herring of Lake Erie; width 7.0-9.4; depth 3.6-4.9; head short 4.2-4.9; snout usually longer than eye; eye 3.8-4.6 in head; interorbital 3.4-4.4; maxillary short 2.6-3.1; caudal peduncle of moderate length, about 2 in head, its depth greater than that in other species averaging about 1.5 in its own length. The fins are comparatively short, the height of the dorsal 5.8-7.5 in total length. Lateral line scales 67-79. Gill rakers 27+15 to 33+19.

The colour is usually dark blue above and silvery below. The ventral fins in most cases have no pigment, but the outer edges of the others are slightly pigmented.

The blue back herring, which grows to at least sixteen and three quarters inches in length and three pounds in weight, is of considerable commercial importance in the eastern end of Lake Ontario, but in the west it is at present quite scarce. It has generally been regarded as a shoal water form, but the opinion that it is somewhat pelagic is becoming more prevalent. In Lake Nipigon, surface settings showed its presence in the upper six feet of water in the open lake. It is most commonly taken in Lake Ontario at depths of from 80 to 125 feet, but larger individuals are taken at all depths down to 400 feet. In the Bay of Quinté it is often taken in water of 10 feet in depth during the spawning run.

Spawning occurs usually early in November, the exact time varying somewhat from year to year, due to temperature and other conditions. There is also evidence that it comes at slightly different dates in different parts of the lake in the same season. For instance, on October 29, 1926, at Port Credit the fish taken by the fishermen were either ripe or had spawned. In the Bay of Quinte, deposition of eggs had scarcely commenced during the latter part of the whitefish run about November 8, 1926. Most of the females were just ripe, but no spent individuals were taken. Evidently, then, the run is later in this area than at Port Credit.

Nearly all the spawning males of this species in the Bay of Quinte had a quite evident spawning dress, similar to that reported by Bensley (1915) in the case of *Coregonus clupeaformis* in the Georgian bay. Along the sides on every row of scales, extending in most cases to several above the lateral line, is a series of lumps of yellowish thickened slime material. These appear on every scale, but are not horny outgrowths of the scale. This condition is more prevalent on the larger males than on the smaller ones. These structures are not similar to the horny pearl organs and tubercles reported by Reighard (1908, 1910) to be present at spawning time in suckers and minnows, especially the horned dace (*Semotilus atromaculatus*).

LEUCICHTHYS REIGHARDI Koelz

REIGHARD'S CISCO

Body less compressed than in the other species of the lake; width 6.3-7.5; depth 3.6-4.4; head short 4.4-5.0; snout slightly longer than eye; eye 4.0-4.5 in head; interorbital comparatively wide 3.4-3.9; maxillary short 2.6-2.9; caudal peduncle slender, its depth 1.4-1.8 in its own length. The fins are shorter than in any other species of the genus in the lake, the height of the dorsal 6.8-8.7 in total length. Lateral line scale 68-78. Gill rakers always less than 40, 20+12 to 25+13.

The colour is light greenish straw-coloured above, shading into silvery below.

Reighard's cisco, which attains a size of about fourteen inches in length and one pound three ounces in weight, is the most important and valuable of the forms in the deeper portions of the lake. Because its flesh is of a higher quality than any of the other species, being preferred by some to the whitefish, fishermen regard it as the best of the "ciscoes". It is found in depths of 75 to 300 feet, but comparatively few occur in water shallower than 200 feet off Port Credit and Bronte. It is most abundant at a depth of approximately 250 feet. This is in direct contrast to its occurrence in Lake Nipigon, where maximum abundance is from 90 to 100 feet (Dymond, 1926).

According to the fishermen, spawning takes place at a depth of 250 feet from about April 15 to May 15, although a spent female has been taken as early as January. The height of the run usually occurs during the first week in May.

LEUCICHTHYS HOYI (Gill)

BLOAT; HOY'S CISCO

Body usually slender, often badly bloated when removed from the nets; width 8.6-9.6; depth 4.4-4.8; head longer than in any of the other species here described, 3.8-4.3; snout slightly longer than the eye; eye 3.7-4.4 in head; interorbital narrower than in the other species, 4.1-5.0; maxillary 2.6-2.9; lower jaw usually longer than the upper with a tubercle at its tip; caudal peduncle slender, its depth 1.5-1.8 in its own length. The fins are very long, the height of the dorsal 5.4-6.3 in the length of the fish. Lateral line scales 60-75. Gill rakers 27+15 to 28+17.

This species is silvery in colour with a slightly greenish tinge above the lateral line. The caudal and dorsal fins are dark edged. The scales are easily removed so that specimens often lack scales when taken from the nets.

The "bloat" is the smallest and least valuable of the

one which should be investigated because of its economic significance.

Local races have been discovered and described in the case of a number of species of fish. Kendall (1920) has found in some lakes two distinct sizes of mature smelts (*Osmerus mordax*), each having well-defined breeding seasons, and each living on different kinds of food. According to Crawford (1921), "there are apparently two races of herring (*Clupea pallasii*), one of which resides in the bays and waterways along the coast from Puget Sound, northward to British Columbia and southeastern Alaska. The other, which is composed of larger individuals passes along the outer coasts, where it is taken off Vancouver Island in June, July and August".

"The smaller race of herring is found to be sexually mature in the summer, but no milt or roe is found during the winter. Sexually mature individuals vary from 6 to 10 inches. The probable spawning time is late summer or early fall. The larger race of herring reaches sexual maturity in the fall and winter, the individuals varying in size from 9 to 12 inches or longer. The probable spawning time is winter or early spring."

The evidence secured from our investigation as to whether the Quinté herring differ from those of open water is based on proportionate measurements. Table 2 of the appendix gives the proportionate measurements of 25 specimens of *L. artedii* from each of the following localities: Winona, Bronte, Port Credit, and the Bay of Quinté.

The figures in this table show that the specimens from Winona, Bronte, and Port Credit resemble each other more closely than any one of them resembles the Bay of Quinté fish. The main differences between the Bay of Quinté herring and those from the other regions is that the former are considerably shallower and much more compressed, and the scales and gill rakers are slightly more numerous. Besides these evident differences in proportionate measurements preliminary studies reveal a definite difference in growth rate. These groups show too a difference in time of spawning

somewhat similar to that exhibited by the races of herring described by Crawford.

As to the meaning of such differences between localized races, the following statement by Regan (1924) is of interest, "My own work on the structure, classification and geographical distribution of fishes including monographs on several subfamilies has led me to certain conclusions. I believe that the first step in the origin of a new species is not a change of structure but the formation of a community either through localization, geographical isolation or habitual segregation".

It seems quite possible that in the Bay of Quinté there is a race of lake herrings (*L. artedii*) isolated by habit from those of the open water, an incipient species according to Regan. The fact that the requirements of life in this bay are different from those in open water, may have resulted in the selection of a slightly different set of characters from those suitable for life in the exposed parts of the lake. If such is the case, Bay of Quinté herring may be less adapted to the conditions in the open lake than those forms which are native to that habitat.

Spawn for the propagation of this species (*L. artedii*) in Lake Ontario is taken largely, if not entirely, from the Bay of Quinté fish. It is possible then, that these fish are not suitable for conditions in the open lake, and should not be planted anywhere but in their natural habitat in the Bay of Quinté or in localities where conditions of life are similar.

RELATION OF MESH OF NETS TO SIZE OF FISH TAKEN

It has not yet been possible to obtain sufficient information on the various species at spawning time to enable us to make a definite statement as to the size at which each species normally begins to spawn in Lake Ontario. Until such studies have been thoroughly carried out, it will be impossible to offer a suggestion as to the minimum size at which the various species should be taken in commercial fishing. In the meantime, data are accumulating as to the

relation between the mesh of nets used and the size of fish taken.

Koelz (1926) has drawn attention to the relatively great difference in the numbers of fish taken in nets of slightly different sizes. He set nets of $2\frac{1}{2}$ and $2\frac{3}{4}$ inch mesh off Braddock Point Light and off Wilson, N.Y., in July, 1921, and found that in the $2\frac{1}{2}$ inch net the catch was more than

TABLE 2—GIVING THE PERCENTAGE OF LAKE HERRING OF ALL SPECIES UNDER 6 OUNCES IN WEIGHT AND THE PERCENTAGE OF FISH OVER 6 OUNCES IN WEIGHT TAKEN IN NETS OF VARIOUS SIZED MESH AT DIFFERENT DEPTHS OFF PORT CREDIT DURING SEPTEMBER AND OCTOBER, 1926.

Depth of water in feet	Mesh of net in inches	Number of fish taken	Percentage	
			Under 6 oz. in weight	6 oz. and over in weight
125	$1\frac{1}{2}$	4	100	..
	2	2	100	..
	$2\frac{1}{4}$	3	66	33
	$2\frac{1}{2}$	9	55	45
	$2\frac{3}{4}$	2	..	100
275	$1\frac{1}{2}$	20	95	5
	2 & $2\frac{1}{4}$	42	94	6
	$2\frac{1}{2}$	22	36	63
	$2\frac{3}{4}$	16	..	100
	3	6	..	100
300	$1\frac{1}{2}$	28	100	..
	2	32	78	22
	$2\frac{1}{4}$	18	50	50
	$2\frac{1}{2}$	9	11	89
	$2\frac{3}{4}$	5	20	80
	3	3	..	100

double that in the larger mesh. In 1926 nets set in connection with our work off Port Credit showed in all cases that the catch in a $2\frac{1}{2}$ inch net was almost double that taken in the $2\frac{3}{4}$ inch. The difference of one quarter of an inch in the size of mesh may mean to the fishermen either a profitable or a "starvation" industry.

Considered from the opposite point of view, however, this

same apparently slight change in the size of mesh may be for the fish the deciding point between survival and extinction, either commercially or absolutely. A study of table 2 will give some idea of the situation.

While the numbers of fish taken may not be sufficient to warrant any final conclusions, it is very striking to notice that with the exception of one small fish which was caught by the mouth and not gilled, the $2\frac{3}{4}$ inch mesh took no specimens under 6 ounces in weight, while nearly 50 per cent. of those taken in the $2\frac{1}{2}$ inch mesh were under that weight. If then, the regulations were to call for a minimum weight of 6 ounces, the smallest net which should be allowed is $2\frac{3}{4}$ inches.

In deep water fewer undersized fish are taken in the $2\frac{1}{2}$ inch net, but in shallow water large numbers of the shoal water form, *L. artedi*, are taken. In 125 feet nearly 50 per cent. of the fish caught in the $2\frac{1}{2}$ inch net were under 6 ounces in weight, while at 275 feet only 36 per cent. and at 300 feet only 11 per cent. were under that limit. The difference is probably due to the larger size of *L. artedi* frequenting the deep water and to the higher percentage of *L. reighardi*. Accordingly, a smaller mesh than that used in shallow water, might be allowed in deep water.

SUMMARY

1. There are at the present time in Lake Ontario four species of the genus *Leucichthys*,—*L. artedi*, *L. reighardi*, *L. kiyi* and *L. hoyi*.

2. Each of these four species inhabits, in the main, a definite range of depths. *L. artedi* has a wider range than the others, going from about 10 to 400 feet, but being most numerous at depths of less than 150 feet. The optimum depth for each of the other species is as follows: *L. reighardi* 250 feet, *L. hoyi* 275 feet, *L. kiyi* 400 feet to deeper.

3. The species differ in the quality of their flesh, the fishermen dividing them into *herrings* and *ciscoes*. Ciscoes are deep water fish with fat or oily flesh and include *L.*

reighardi, *L. kiyi* and some of the fatter individuals of the species *L. hoyi*. Herrings are shallow water fish with a dry or less oily flesh, viz., *L. artedi*.

4. *L. reighardi* spawns in the spring while the other three species spawn in the autumn.

5. In the case of *L. artedi*, at least, there are indications of the existence of geographical or ecological races.

6. The different species become sexually mature at different sizes.

7. A comparatively small difference in the size of mesh of net used has a relatively great influence on the size of fish caught. For instance, 36 per cent. of the fish taken in a $2\frac{1}{2}$ inch mesh at a depth of 275 feet were under 6 ounces in weight, whereas a $2\frac{3}{4}$ inch took no fish under that weight at the same depth.

APPENDIX

TABLE 1—COMPARATIVE MEASUREMENTS OF *Leucichthys artedi*, *L. reighardi*, *L. hoyi* AND *L. kiyi* FROM LAKE ONTARIO.

	<i>Leucichthys artedi</i>			<i>Leucichthys reighardi</i>			<i>Leucichthys hoyi</i>			<i>Leucichthys kiyi</i> 9♀
	51♂	49♀	Average	25♂	15♀	Average	6♂	16♀	Average	
Length.....	241	240	240	238	240	239	177	182	180	225
Scales.....	73	72	72	73	75	74	68	69	69	73
Gill rakers.....	30+17	30+17	30+17	22+13	23+13	23+13	27+16	27+16	27+16	29+16
Head length.....	224	224	224	213	211	212	249	247	247	238
Body depth.....	232	250	240	246	257	250	208	211	210	229
Body width.....	118	127	122	144	150	147	106	103	104	124
Caudal Peduncle										
Length.....	119	118	118	118	118	118	113	117	116	116
Depth.....	81	81	81	74	73	73	69	69	69	72
Eye.....	54	54	54	51	49	50	63	61	61	58
Snout.....	57	57	57	56	56	56	65	65	65	63
Interorbital.....	57	58	57	60	56	58	54	53	53	58
Maxillary.....	76	79	78	78	77	77	93	91	92	88
Snout to Occiput.....	158	157	158	158	157	157	176	167	170	166
Ventral to Pectoral.....	324	333	328	356	373	363	332	329	330	356
Pectoral length.....	158	155	157	136	134	135	185	176	179	175
Ventral length.....	156	153	155	139	133	136	182	172	175	174
Dorsal height.....	154	153	154	132	130	131	178	172	173	172
Dorsal base.....	107	107	107	98	98	98	107	102	103	101
Anal height.....	101	100	100	91	90	91	110	111	111	113
Anal base.....	104	102	103	103	104	103	104	100	101	96
Adipose length.....	57	59	58	64	64	64	61	61	61	65
Adipose base.....	34	36	35	..	..	..	34	33	33	37

APPENDIX

TABLE 2—COMPARATIVE MEASUREMENTS OF *Leucichthys arctedi* FROM DIFFERENT LOCALITIES IN LAKE ONTARIO.

	Winona			Bronte			Port Credit			Bay of Quinté			Total		
	17 ♂	8 ♀	Average	7 ♂	18 ♀	Average	7 ♂	18 ♀	Average	20 ♂	5 ♀	Average	51 ♂	49 ♀	Average
Length.....	221	225	222	240	254	250	241	230	234	257	245	255	241	240	240
Scales.....	70	70	70	71	72	72	74	73	73	75	72	74	73	72	72
Gill rakers.....	29+17	30+17	29+17	30+17	30+17	30+17	30+17	29+16	29+16	31+17	31+17	31+17	30+17	30+16	30+17
Head length.....	227	223	226	226	222	223	218	226	224	222	229	223	224	224	224
Body depth.....	243	260	248	247	258	255	217	242	235	222	224	224	232	250	240
Body width.....	119	118	118	136	139	138	117	122	121	112	115	112	118	127	122
Caudal Peduncle															
Length.....	120	118	119	116	117	116	117	119	118	120	117	119	119	118	118
Depth.....	84	85	85	85	82	83	73	78	77	79	82	79	81	81	81
Eye.....	54	55	55	52	52	52	54	55	54	56	57	56	54	54	54
Snout.....	58	56	57	59	56	57	56	59	58	56	58	56	57	57	57
Interorbital.....	58	57	58	62	60	60	53	58	57	55	56	55	57	58	57
Maxillary.....	81	78	80	82	79	79	74	80	78	74	78	75	76	79	78
Snout to Occiput.....	160	157	159	158	156	156	151	157	155	159	164	160	158	157	158
Ventral to Pectoral	333	324	330	318	332	328	332	340	338	317	321	318	324	333	328
Pectoral length.....	161	156	159	161	153	155	156	157	157	156	157	156	158	155	157
Ventral length.....	160	155	158	160	151	154	152	154	154	153	155	154	156	153	155
Dorsal height.....	158	155	157	162	153	156	146	149	148	154	160	156	154	153	154
Dorsal base.....	107	107	107	109	110	109	103	105	105	106	103	106	107	107	107
Anal height.....	101	101	101	103	98	100	98	100	100	100	103	101	101	100	100
Anal base.....	103	103	103	111	102	105	105	101	102	103	100	102	104	102	103
Adipose length.....	58	60	59	61	60	60	58	59	59	55	52	55	57	59	58
Adipose base.....	36	37	37	36	36	36	33	30	32	34	36	35

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