UNIVERSITY OF TORONTO STUDIES

PUBLICATIONS OF THE

ONTARIO FISHERIES RESEARCH LABORATORY

No. 41

TAXONOMIC AND LIFE HISTORY STUDIES OF THE CISCOES OF LAKE ONTARIO

BY

ANDREW L. PRITCHARD
OF THE DEPARTMENT OF BIOLOGY
UNIVERSITY OF TORONTO

TORONTO
THE UNIVERSITY OF TORONTO PRESS
1931

CONTENTS

TAXONOMIC AND LIFE HISTORY STUDIES OF THE CISCOES OF LAKE ONTARIO

INTRODUCTION

The ciscoes are an important group of freshwater fishes, characteristic of the larger lakes of the northern parts of North America, Asia and Europe. In all these regions, but more especially in Canada, they are of considerable economic importance, and in common with many others of our commercial species, measures for their conservation are being sought.

Because in most lakes there are several species, each differing from the others in such respects as habit, habitat, size attained, quality of flesh and time of spawning, an understanding of the steps necessary for their protection is more difficult than in the case of many other fishes. A number of studies, therefore, have been carried out within recent years with a view to reaching some understanding of the taxonomic relations and the life histories of the various members of this group (Clemens, 1922; Van Oosten, 1929; Koelz, 1929). The studies reported in the present paper had as their object the discovery of such information for the species of this group in Lake Ontario.

The ciscoes have usually been included in the family Salmonidae, but Jordan (1923) and most recent American ichthyologists follow Cope (1872) in placing them with the whitefishes and their relatives (*i.e.*, with the genera *Core gonus*, *Prosopium* and *Stenodus*) in a separate family, the Coregonidae. This is the arrangement followed by Koelz (1929) in his recent monograph on the Coregonid fishes of the Great Lakes.

There is a similar divergence between European and

American workers in their generic grouping of these fishes. Regan (1914) includes the ciscoes with the whitefishes in the genus *Coregonus*, whereas in America they have been regarded as generically distinct since Agassiz in 1850 created the genus *Argyrosomus* for the fishes of this group. Jordan and Evermann (1911) substituted Dybowski's (1874) name *Leucichthys* for *Argyrosomus* on the grounds that the latter was preoccupied, and divided the genus into three subgenera, *Thrissomimus*, *Cisco* and *Allosomus*. We follow Koelz (1929) in disregarding this subgeneric differentiation. In view of the fact that Koelz (1929) has recently discussed the taxonomic history of this group, it is considered unnecessary to go into further detail here.

Regan (1914) has drawn attention to the fact that in the group to which these fishes belong (*Coregoninae*) the parietals meet in the middle line and the teeth are in several series, when present, whereas in the group to which the salmon and trout belong, the parietals do not meet in the midline and the teeth are on the jaws, vomers and palatines and in a double series on the tongue.

Superficially the genus *Leucichthys* is easily separable from the whitefishes (*Coregonus* and *Prosopium*) by their premaxillaries which are longer than wide and oblique in position (*i.e.*, forming an angle of thirty degrees or more with the vertical). In addition the former possess a greater number of longer, more slender gill rakers. This character may be correlated in general with the smaller-sized organisms taken by the ciscoes as food.

The species of the genus *Leucichthys*, but more especially the shoal-water *L. artedi*, are often popularly referred to as herrings. The name originated, no doubt, from their superficial resemblance to the marine herring (*Clupea* spp.). In this connection, it is interesting to note that these freshwater fishes occupy an analogous position in the ecology of the waters where they occur to that held by the true herring in the sea. Both feed largely on plankton and smaller nekton, and are in turn eaten by larger, more valuable food fishes,—the marine forms by cod, salmon, etc., and the freshwater ones by the lake trout. To avoid confusion it is better to confine the term herring to marine fishes of the genus *Clupea* and to use the term cisco for the freshwater fishes of the genus *Leucichthys*. This is the practice followed in the present paper except in connection with certain discussions (pp. 11-22) where it seemed necessary to adopt the fishermen's term "herring" for the shoal water species *L. artedi* when speaking of this species in contrast with the fat-fleshed, deep-water species (*L. reighardi*, *L. kiyi* and *L. hoyi*) to which the fishermen restrict the term "ciscoes."

SOURCE OF MATERIAL

Field work was carried on during portions of the years 1926, 1927 and 1928. Specimens were procured in February, March and November. 1926, from the nets of commercial fishermen at Port Credit and Bronte. Beginning in the autumn of 1926, most of the material was obtained by the use of a special gang of nets, consisting of eleven pieces, each fifty yards in length and each of different sized mesh. These measured 1½, 2, 2¼, 2½, 2¾, 3, 3½, 4, 4½, 4¾, and 5 inches, stretched mesh as manufactured. In the spring of 1927, a section of 1¼ inch mesh was added. During the autumn of 1926 and the spring, summer and autumn of 1927, the gang was set in the western end of the lake at various depths from the shore to four hundred and fifty feet. A small gang of nets was used during the spawning run of *L. artedi* in the Bay of Quinte, near Belleville in 1926, and at Big island in 1927. In the early spring and summer of 1928, settings were made in the mouth of the Bay of Quinte, and in deep water off the Main Duck islands.

Fish were examined from the pound nets set near Belleville, Ontario, by the Ontario Department of Game and Fisheries during the spawning run of *L. artedi* in 1926. In addition, access was given to a collection made by the same department off Winona in 1925.

Stomachs and scales were taken from a large number of these fish for use later in a study of their food and rates of growth.

Opportunities were afforded through the kindness of many fishermen to examine the catches of other fish taken in the lake in order to establish the ecological relation of the ciscoes.

ACKNOWLEDGMENTS

This research was carried out under the auspices of the Ontario Fisheries Research Laboratory, Department of Biology, University of Toronto, to whose members the author is indebted for much assistance.

It is also a pleasure to acknowledge the sympathetic help and support of fishermen from all parts of the lake. Special credit is due to Joyce Brothers at Port Credit, Thompson and Lobb at Main Duck islands, and Mr. Aylesworth Cole of Pleasant point, Bay of Quinte.

I am grateful for the assistance of the Ontario Department of Game and Fisheries in permitting me to examine specimens taken in their nets and for facilities afforded in their hatcheries.

Thanks are also due to the following for their identifications and advice on matters connected therewith—Dr. Walter Koelz, who checked my early identifications of ciscoes; Dr. Charles B. Wilson, who identified the parasitic copepods; the zoologists of the Bureau of Animal Industry, United States Department of Agriculture, who identified the Platyhelminthes, Nematoda and Acanthocephala; Dr. D. S. Rawson, who helped in a portion of the food studies; and Mr. F. P. Ide, who identified the insect material.

Especially am I indebted to Professor J. R. Dymond, of the Department of Biology, University of Toronto, for his supervision and guidance throughout the whole course of the work, and to Mr. John L. Hart, for his co-operation while he was working on the whitefish.

HISTORY AND STATUS OF THE FISHERY

The commercial catch of ciscoes in Canada for the five years between 1923 and 1927 ranged from 11,447,400 to 18,496,500 pounds, the average being 15,350,460. Of this

amount, the Great Lakes produced from 5,466,269 to 13,001,716 pounds with an average of 8,518,103 or 55.5 per cent. of the average for the Dominion.

The catch in the Canadian waters of each of the Great Lakes for each of the years 1923 to 1927, as well as the average annual catch for that period is given in the table below. The table also gives the percentage of the total constituted by the catch of each of the lakes.

TABLE 1. The catch of ciscoes for the years 1923-1927 in the Canadian waters of each of the Great Lakes.

Year	Lake Ontario incl. lower Niagara r. and St. Lawrence r.		Lake Erie incl. upper Niagara r.		Lake Huron incl. North Channel, Georgian bay		Lake Superior		Total
	Pounds	% of total	Pounds	% of total	Pounds	% of total	Pounds	% of total	
1923	256,279	2.3	9,241,168	82.9	437,376	3.9	1,097,558	9.8	11,151,393
1924	263,135	2.0	10,907,928	83.9	496,151	3.8	1,050,532	8.0	13,001,716
1925	294,107	5.4	2,839,625	51.9	670,692	12.3	1,147,007	21.0	5,466,269
1926	638,168	11.4	1,573,093	28.0	980,808	17.7	1,818,559	32.4	5,609,244
1927	733,371	10.0	2,308,686	31.4	1,263,879	17.1	2,460,558	33.4	7,361,892
Aver.	437,012	6.2	5,374,100	55.6	769,777	10.9	1,514,843	20.9	8,518,103

As shown by this table the quantity of ciscoes taken in Lake Ontario is usually less than that in any of the other Great Lakes; nevertheless, being from 2 to 11.4 per cent. of the total, this catch is worth consideration. In 1923 and 1924, the percentages in this lake were very low, due no doubt chiefly to the fact that large quantities were taken in those years in Lake Erie. In 1925, however, catches began to decline in the latter and this resulted in a corresponding increase in the proportion of the whole produced by other lakes. To what extent this represents an increased number of fish in these lakes and to what extent it is caused by a more vigorous exploitation due to a lack of Lake Erie fish is difficult to decide.

The area of each of the Great Lakes and the percentage which that area constitutes of the whole is given in the following table.

TABLE 2. The area of each of the Great Lakes and the percentage which that area constitutes of the whole of the Great Lakes

Lake	Area in square miles*	Percent of total area
Ontario	7,540	10.4
Erie	9,940	13.8
Huron	23,010	31.8
Superior	31,810	44.0
Total area	72,300	

*Canada Year Book, 1928, Department of Trade and Commerce, Ottawa.

The areas in Canadian territory will be about one-half of those submitted above. Lake Ontario, then, constituting about ten per cent. of the total area, produces on the average about six per cent. of the ciscoes. Lake Erie with less than fourteen per cent. of the area, is responsible for more than fifty-five per cent. of the total ciscoes taken in the Great Lakes. Production, therefore, is not dependent solely upon the area of the body of water, but upon some other factor or factors. It may be that it is in some way dependent within limits on depth, as has been shown to be the case with bottom organisms in Lake Simcoe (Rawson, 1930).

TABLE 3. The weight in pounds and the value in dollars of the catch of ciscoes, whitefish and lake trout in the Canadian waters of Lake Ontario for the period 1923 to 1927.

Year	Ciscoes		Whitefish		Lake trout	
	Weight in lbs.	Value in dollars	Weight in lbs.	Value in dollars	Weight in lbs.	Value in dollars
1923	256,062	10,381.87	2,566,114	307,933.68	754,950	83,042.50
1924	263,135	10,525.40	2,653,810	318,457.20	938,994	103,289.34
1925	294,107	11,764.28	1,926,367	231,164.04	1,063,304	116,963.44
1926	638,168	25,526.72	1,822,444	194,693.28	784,333	86,276.63
1927	733,371	44,027.75	1,503,272	195,425.36	713,497	92,754.61

In 1923 and 1924, ciscoes in Lake Ontario ranked fifth among the commercial species of the lake, being less in value than whitefish, trout, pike and eels. From 1925 until late years, they were superseded only by whitefish and lake trout. Below are given the catches and values for ciscoes, whitefish and lake trout for the years 1923 to 1927.

As a guide to the history of the fishery which follows, table 4 presents the catches of ciscoes for each county, in the Canadian waters of Lake Ontario for the years from 1899 to 1922. These are calculated from the statistics given in the reports of the Ontario Department of Game and Fisheries. The totals for each year from 1923 to 1927 are given in table 1. Data for the individual counties for this period are not available in the reports of the Ontario Department of Game and Fisheries.

In the early days of settlement in the Lake Ontario region, Atlantic salmon (*Salmo salar*, Linn.) were very plentiful, migrating to spawn in the summer and early autumn into most of the streams along the northern shore. The few records which have come down to us from those early times indicate that these fishes were exploited to a considerable extent as food. David William Smyth (1799) reports that "the whitefish are taken here" (*i.e.*, the Niagara river) "in great abundance and are reckoned a delicacy. They are, however, as useful as delicate, serving the new settlers for constant food as salmon do on the north side of the lake."

Between 1830 and 1840 the numbers of salmon fell off rapidly. As a result of this decrease and the rapid increase in human population, attention was focused on the whitefish (*Coregonus clupeaformis* (Mitchill)) and the lake trout (*Cristivomer namaycush* (Walbaum)). The fishery for these species was prosecuted at first mainly by seining when they came inshore to spawn. In 1853 gill nets were used for the first time in the deeper waters. These were employed most extensively when the fish were not inshore spawning.

As long as whitefish and lake trout were plentiful, little notice was taken of the ciscoes, although there is no doubt

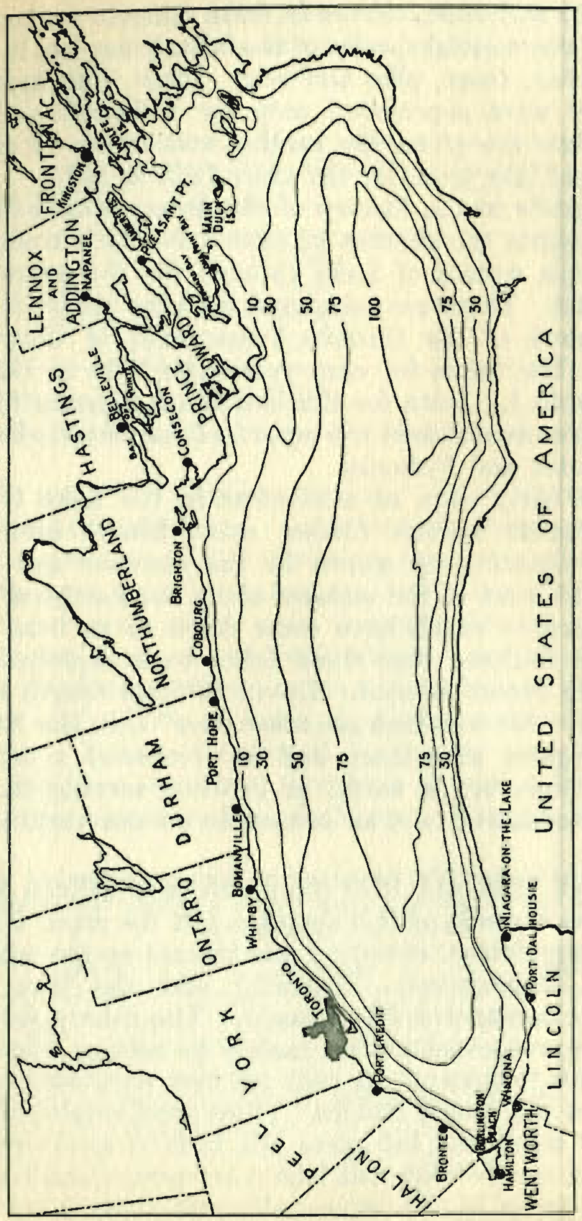

Fig. 1. Illustrating the location of the various counties fronting on Lake Ontario, the fishing ports therein, and the approximate depths of the water in fathoms.

TABLE 4. nd the portions of the catch

	Linc	Total	Value	
			Salted per bbl.	Fresh per lb.
1899	370,	1,315,811	$ 4.00	2c.
1900	240,	1,095,875	4.00	2c.
1901	869,	2,322,475	4.00	2c.
1902	1,133,			
		2,232,919	4.00	2c.
1903	495,	1,088,400	8.00	4c.
1904	450,	886,600	....	5c.
1905	436,	1,390,440	10.00	5c.
1906	309,	....	....	....
1907	450,	1,008,660	10.00	5c.
1908	270,	1,321,984	10.00	5c.
1909*	429,	1,057,843	10.00	5c.
1910*	303,	997,868	10.00	5c.
1911*	247,	950,694	10.00	5c.
1912	285,	673,860	10.00	5c.
1913	147,	811,211½	10.00	5c.
1914	380,	1,174,298	10.00	5c.
1915	627,	1,801,341	10.00	5c.
1916	596,	1,621,590	10.00	5c.
1917	598,	1,938,386	10.00	5c.
1918	423,	1,801,502	.10††	5c.
1919	106,	1,720,342	.05††	5c.
1920*	98,	1,291,230	.05††	5c.
1921	45,	1,016,605	.05††	5c.
1922	17,	345,830	.06††	4c.

TABLE 4. The catch of ciscoes in the Canadian waters of Lake Ontario for each county during the years 1899 to 1922 (inclusive), the total catch in pounds, and the portions of the catch which were smoked, salted and sold fresh, with the average values received.

	Lincoln	Went-worth	Halton	Peel	York	Ontario	Durham Northum-berland	Prince Edward	Bay of Quinte	Lennox and Addington	Amherst Island	Wolfe Island	Sub-totals: Smoked (lbs.)	Sub-totals: Salted (bbls.)	Sub-totals: Fresh (lbs.)	Total	Value: Salted per bbl.	Value: Fresh per lb.
1899	370,119	261,331	443,000	500	149,800	16,000	15,400	16,391	20,100	15,570	6,500	300	....	48	1,306,211	1,315,811	$ 4.00	2c.
1900	240,450	123,331	544,000	1,300	141,000	23,800	12,250	419	5,000	2,025	1,700	....	....	7	1,094,475	1,095,875	4.00	2c.
1901	869,453	437,830	603,763	6,750	339,200	18,800	13,000	17,613	5,000	2,900	6,166	....	....	20	2,318,475	2,322,475	4.00	2c.
1902	1,133,887	231,800	428,990	20,705	66,880	33,314	90,158	18,000	4,000	....	207,185 (1,000 bbl.)	....	....	1,000	2,032,919	2,232,919	4.00	2c.
1903	495,300	142,600	148,500	6,000	112,000	16,800	96,100	55,200	10,000	....	5,900	....	....	5	1,087,400	1,088,400	8.00	4c.
1904	450,700	178,500	101,000	10,000	41,000	16,100	31,200	37,600	9,000	....	11,400	....	....	....	886,600	886,600	....	5c.
1905	436,500	564,340	116,000	7,000	58,700	15,200	29,500	24,300	72,740	3,800	8,360	....	....	3,131	764,240	1,390,440	10.00	5c.
1906	309,100	148,000	280,000	25,000	44,600	20,500	32,900	21,500	41,700	....	9,900	1,600	....	No report		....	....	....
1907	450,340	79,380	209,000	10,000	40,000	6,140	28,520	22,800	55,720	....	6,680	....	....	476	913,460	1,008,660	10.00	5c.
1908	270,270	404,250	380,000		24,800	7,498	26,090	2,023	203,914	....	3,139	....	....	906	1,140,784	1,321,984	10.00	5c.
1909*	429,775	76,180	362,875		13,200	6,455	22,214	5,586	151,558	....	....	....	....	93	1,049,243	1,057,843	10.00	5c.
1910*	303,252	140,177	361,200		16,110	5,445	34,413	5,787	112,657	18,147	....	680	....	1,148	768,268	997,868	10.00	5c.
1911*	247,481	184,900	278,250		23,252	3,086	98,680	15,587	91,492	6,800	....	1,184	....	30	944,694	950,694	10.00	5c.
1912	285,400	97,788	194,100	15,000	16,600	4,157	31,213		39,602	....	....	....	123,900	51	539,760	673,860	10.00	5c.
1913	147,547	88,100	156,500	8,002	12,613	820½	44,870	27,000	325,759	....	....	....	88,900	182½	685,811½	811,211½	10.00	5c.
1914	380,831	108,500	230,950	41,500	26,635	1,150	61,900	142,761	178,971	....	....	1,100	120,192	313½	991,406	1,174,298	10.00	5c.
1915	627,857	376,500	292,050	86,400	25,602	817	36,987	131,272	223,856	....	....	....	75,800	95¾	1,706,391	1,801,341	10.00	5c.
1916	596,528	181,341	329,500	25,901	12,759	300	55,169	201,024	292,568	....	....	300	....	55½	1,601,490	1,621,590	10.00	5c.
1917	598,573	150,200	306,650	10,868	1,650	1,060	49,162	178,607	640,416	....	....	1,200	....	41	1,930,186	1,938,386	10.00	5c.
1918	423,936	33,100	253,900	5,480	781	4,050	105,326	279,044	691,585	....	....	4,300	....	6,450†	1,795,052	1,801,502	.10††	5c.
1919	106,238	46,100	129,400	9,000	5,600	2,716	56,695	289,092	1,071,451	....	....	4,050	....	10,930†	1,709,412	1,720,342	.05††	5c.
1920*	98,724	26,000	79,200	38,000	13,400	500	30,550	271,582	730,765	....	....	14,909	....	3,650†	1,287,580	1,291,230	.05††	5c.
											Frontenac							
1921	45,470	25,400	64,023	6,000	16,166	961	11,805	272,352	563,210	7,909	3,309		....	2,186†	1,014,419	1,016,605	.05††	5c.
1922	17,220	24,843	35,767	5,000	1,700	3,007	9,484	115,506	112,974	7,120	13,209		....	3,222†	342,608	345,830	.06††	4c.

*Given in the report of the year following.

†Weight in pounds, not in barrels.

††Price per pound.

that some of the early settlers took by seining the shallow-water species, *L. artedi* and used it as food, either fresh or salted. S. Wilmot, Fishery Officer in charge of fish breeding operations at Newcastle, Ontario, said in his report to the Minister of Marine and Fisheries of Canada for 1867 that these "herring" had been at one time very numerous along the shores of Lake Ontario, but were then very scarce. The reason for this decrease had been the same as in the case of the whitefish (*i.e.*, destruction by seining during the spawning season). This of course refers to conditions in the eastern end of the lake. For the western end, King (1866) reported that "at Burlington Beach during 1856, 1,900,000 herring and 86,400 whitefish were taken. At Port Credit 470,000 fish were captured, two-thirds of them salmon and at other fishing stations on Lake Ontario 200,000 to 300,000 fish."

On account of the wasteful methods then in vogue, the supply of whitefish and lake trout declined to such an extent that it was soon found profitable to fish for ciscoes. As indicated above *L. artedi* was first exploited. About 1860, however, after the introduction of the gill net, deep-water forms, popularly styled "ciscoes" in contrast to the shoal-water "herring", began to be caught. Mr. Jonathan Corey, of Burlington Beach, in giving evidence before the Dominion Fisheries Commission in December 1892, replied to the question as to when he had first heard of the cisco as follows: "Thirty-three or thirty-four years ago[1] my father was the first one who caught ciscoes. He was fishing for whitefish and trout then and he used to get ciscoes in the whitefish net." At the time of the enquiry (1892) the former were being taken six to eighteen miles offshore from Burlington Beach, in water from one hundred to three hundred feet in depth.

That the fishermen recognized the difference between the shoal-water "herring" and the deep-water "cisco" is evidenced by Daniel McGwyn's answer to the Commission mentioned above, when questioned about the spawning of ciscoes. "Ciscoes do not go near our shore at all. They

[1]This and similar numbers on succeeding pages are referred to in tables 6 and 7.

spawn in deep water." He went on to describe them as too soft to be sold fresh. As a consequence they had to be salted or smoked. In contrast, the herrings were drier, firmer and could be sold fresh, thus saving the cost of curing. Both herrings and ciscoes were said to be of about the same size, although an occasional large herring about three pounds in weight was taken. From these statements and a detailed description of the cisco supplied (March 1929) by Robert Montgomery who fished for them between 1885 and 1892, it is almost certain that the fish taken at that time under the name cisco, were, in the main, *L. reighardi*.

This distinction between shoal-water "herrings" and deep-water "ciscoes" is still recognized by fishermen and since the following sketch of the history of the fishery is based so largely on information gathered from fishermen, it has seemed advisable to adopt their use of the term "herring" and "cisco" in discussing it.

Some idea of the fluctuations in the deep-water cisco fishery may be gleaned from the following testimonies. Wm. Montgomery of Toronto, in testifying before the Royal Commission of 1892, about fishing conditions off Toronto, stated that he had been fishing for 26 years. At first ciscoes were plentiful, but fifteen or sixteen years previously (1876 and 1877)[2] "they fell off just to nothing, the same as they have done this while back here" (before 1892)[3] "and then came on as thick as they could be".[4] Mr. Robert Montgomery told the author (March 1929) that about 1885[5] and for a few years after, seven or eight thousand ciscoes were taken commonly in 2100 yards of net, but a rapid decrease had been apparent about 1891.[6] In the spring of that year, four thousand to forty-seven hundred ciscoes had been taken in the same yardage, but in the autumn, twenty-one hundred was the largest number caught. After this time decrease was rapid.

That the same situation held in part for these species in the Burlington beach area is shown by the testimony of Wm. Depew to the Royal Commission. "At one time ten or twelve boats were fishing for ciscoes off Burlington Beach", but when he was speaking (1892)[7] only four were participating actively. Supporting this, Frederick Corey[8] maintained that they used to obtain three to four hundred ciscoes in three hundred feet of net and that he had known as many as eight to nine hundred to be caught, but "of late years they have fallen off very much; if we get fifty to a net we do well to the hundred yards". Daniel McGwyn[9] at the same time said that the "ciscoes have fallen off considerably during the last four or five years."

Very little information has been obtained as to the condition of the shoal-water '"herring" fishery during the same period, up to 1892. At one time these fish were very plentiful in the Bay of Quinte,[10] but by 1867 according to the report of Samuel Wilmot[11] given above, they were very scarce. Whether they increased and declined again before 1892[12] is not known, but according to Mr. Larue, a fisherman of long standing in that area, they were very scarce about that time.

In 1872,[13] in the Department of Marine and Fisheries report, bluebacks (*i.e.*, *L. artedi*) were mentioned as abundant at Toronto. Wm. Montgomery[14] maintained, however, that they had fallen off here in the years previous to 1892, just as the ciscoes had. At Burlington beach, they were very plentiful in the beginning but here the intensive fishing told and they declined. In 1868,[15] Kerr, the fishery overseer, said "for herring alone which frequent the bay in the month of November to spawn in unprecedented numbers of millions". In 1892, they were slightly more numerous than the ciscoes.

Of the period between 1892 and the present, little definite reliable information is available because the reports of the various fishery officers are very incomplete and sketchy. From the reports which we have, from statistics which are procurable, and from questioning the older fishermen, now living, it is possible to indicate the general trend of the fisheries, even though we cannot fix absolutely the exact date at which increase or decrease occurred.

In the Bay of Quinte region, where the catch is almost wholly "herring" the following conditions have been pieced together from the statements of Mr. Larue, who has fished for many years in that region, and from the reports of fishery inspectors. In the late nineties (1892-1897)[16] herring were very scarce. In 1903 phenomenal numbers were reported by "Salmo" in Forest and Stream (1903)[17] as follows:

"Within the last two or three years ciscoes (*Argyrosomus artedi*) have made their appearance at the eastern end of Lake Ontario in phenomenal numbers. In the words of the fishermen 'tons and tons of them are caught there'. They seem to be increasing in numbers also every year. Off 'the Ducks' a small group of islands about twenty-five miles southwest of Cape Vincent lighthouse (Tibleths Point light) and in the Bay of Quinte near the Canadian shore, enormous quantities of these fish were caught last summer and the summer before."

The catch in that area fell off during the next two years (1903 and 1904)[18] and then began to rise steadily with minor fluctuations. From 1909 until 1918 herring were extremely plentiful.[19] Decrease followed until they were again at a low ebb in 1922.[20] About 1925 increase resulted and it did not appear in 1927[21] as if the maximum had been attained.

As far as herring are concerned, the history for the rest of the lake for this period is obscure. In the region between Brighton and Toronto, these fish never constituted a large item and are thus seldom mentioned. At Toronto, they increased in 1899 and 1900[22] but fell off in 1902.[23] From then until the present, they have not appeared in large quantities.

This species in the western end of the lake (Port Credit to the Niagara river) had the same history, increasing through 1899 to 1901,[24] and declining again thereafter while the ciscoes were increasing. Overseer Kerr of Hamilton in 1907[25] reports a great decrease. In 1910,[26] the gain was very noticeable culminating in the large catch of 1915.[27] Of late years[28] there has been a serious decrease.

In 1899[29] the inspector at Brighton reported the presence of "bloaters" offshore, and recommended that these be fished since they would be very valuable. In 1902, the catch in

this area did increase, but it is impossible to tell whether that was the result of the catching of these fish which we may also include under the term ciscoes.

At Port Credit and Bronte, in the nineties, ciscoes were very scarce. Following the year 1903, they began to increase. At this time,[30] Overseer Sargent of Bronte reports that sometimes fully ninety per cent. of the catch was ciscoes. This increase continued through 1904, but evidently a decrease followed, since they were not mentioned again until 1911[31] when Overseer Walker at Port Credit maintained that they were gaining, but that the fishermen had to go farther out to get them. In 1925 and 1926[32] large numbers were taken. In these years and even up till 1928, they constituted the bulk of the catch in that area of the lake.

At the present time in Lake Ontario, fishing is carrried on mainly out of the following ports: Niagara-on-the-Lake, Port Dalhousie, Winona, Burlington beach, Bronte, Port Credit, Toronto, Bowmanville, Cobourg, Brighton, Consecon, Long Point bay, Pleasant point, Main Duck islands, Amherst island, Wolfe island, and in the autumn in the inside of the Bay of Quinte. The catches by counties for 1927, which

TABLE 5. The catch of ciscoes (all species) in pounds in 1927 for each of the counties fronting on Lake Ontario.

County	Port	Catch in lbs.
Lincoln	Niagara-on-the-lake, Port Dalhousie	73,160
Wentworth	Winona, Burlington Beach	7,505
Halton	Bronte	96,001
Peel	Port Credit	60,276
York	Toronto	30,600
Ontario		4,845
Durham	Bowmanville	74,891
Northumberland	Cobourg, Brighton	33,925
Prince Edward	Consecon, Pleasant point, Long Point bay	37,674
	Bay of Quinte	250,382
	Wellers bay	49,989
Lennox	Amherst island	8,574
Frontenac	Wolfe island	3,000
Total		730,822

are given below, give some conception of the quantities taken at the various places, but, of course, they give no inkling of what species were handled.

In considering the present commercial status of these fishes, the lake may be divided conveniently into three parts; the eastern end including the waters off Frontenac, Lennox and Addington, and Prince Edward counties, taking in the Bay of Quinte; the so-called middle area including those off Northumberland, Durham, Ontario and part of York counties; and the western including all other ports in the western region. In each of these divisions, uniform fishing methods are used and similar conditions tend to prevail.

In the Bay of Quinte area at the present time, the fishery centres around the so-called "herring" (*L. artedi*). Since however, there are large numbers of lake trout and whitefish in the region, the herring fishery is not prosecuted intensively at all seasons of the year. In late November, during the spawning run of *L. artedi*, large numbers are taken in the Bay of Quinte proper. At this season, however, the herring bring a relatively low price, since the market is glutted with whitefish, which have run to the same spawning grounds only about two weeks previously. Outside the bay, around such islands as the Main Duck, Amherst and Wolfe, and off Long point, attention is focused, as noted, on whitefish and lake trout, even though the herring are very numerous. In 1928, however, one or two fishermen at Long point in Prince Edward county, turned to the latter. Due to the abundance of the herring, these men were able to carry on quite a successful fishery in spite of the low price. Fishing began here in May and closed in November. How long such success will continue, cannot be predicted.

In the middle area, at the present time, the catch is constituted mainly of the deep-water cisco, although in previous years many "herring" were taken on the spawning beaches. In July and August, off Cobourg and Bowmanville, fishermen capture in depths of 200 to 350 feet, considerable numbers of *L. hoyi* and *L. reighardi*. They also

report the presence of the other cisco, *L. kiyi*. The deep water fishery here continues principally for the summer months.

In the western area, some herring are taken, especially off Lincoln, Wentworth and Halton counties where the waters are comparatively shallow for some distance offshore. These are procured in small quantities throughout the year, but are more numerous during the spawning period in late November and early December.

The chief fishery of this area is that which is carried on for the deep water forms out of Port Credit, and to some extent out of Bronte and the other ports. The depth of water in which sets are made varies from 250 to over 450 feet. All the deep water species are taken, *L. hoyi*, *L. kiyi* and *L. reighardi*. From February to June, the mainstay of the catch is *L. reighardi*, taken in about two hundred and fifty feet of water, when it is on the bottom in preparation for, and in the act of spawning. From June to September, the depth of setting varies, and with it, of course, the species obtained. In the main, however, sets are made in depths of 350 to 450 feet. The predominant species in this range are *L. kiyi* and *L. hoyi*. There are also a few of the deep-water, compressed form of *L. artedi*. Later in the autumn the latter tend to disappear and *L. kiyi*, which at this time is becoming ripe, constitutes larger and larger portions of the catch. At Christmas, when they are actually spawning, practically all the catches are made up of this species.

There are only about two months in the year when the harbours are frozen over and the fishermen cannot fish in this area. This period varies with the year, but it usually lies between the middle of December and the middle of February.

It was felt that the fluctuations in the fishery mentioned above, should be summarized and thus be more easily available. This summary is set down in two tables below. Table 6 includes the "ciscoes" and table 7 the "herring". The numbers are for the references appearing on the pages noted, on which the complete statement with the authority is given.

TABLE 6. Summary of the fluctuations in the numbers of deep-water "Ciscoes" from 1860 to 1928 for the three regions in Lake Ontario.

Year	Western Region (off Lincoln, Wentworth, Halton and Peel counties)	Middle Region (off York, Ontario, Durham and Northumberland counties)	Eastern Region (all of the lake east of Brighton)
1860	Numerous (1, p. 13)...	....	No cisco fishing here. Water too shallow.
1876 } 1877 }	....	Scarce (2, p. 14)......	
1885	....	Numerous (4,5, p. 14).	
1891	Marked decline (7, 8, 9, p. 15)	Scarce (3, 6, p. 14)...	
1902 } 1903 }	Increasing (30, p. 17)...	Increasing (29, p. 16)..	
1911	Increasing again (31, p. 17)...............		
1926 to 1928	Plentiful (32, p. 17)....		

Some of the facts recorded in this historical outline suggest that there may be some sort of natural fluctuation in the numbers of these fishes in Lake Ontario, comparable to what has been shown to be the case for some marine fishes (Hjort, 1914) and certain mammals (Elton, 1927). This suggestion is brought forward as a result of the statements of fishermen who had observed conditions over long periods, rather than as a result of the study of statistics, which in the case of fish are affected by many factors such as the type and amount of gear, price, etc.

For the ciscoes, we have the statement of William Montgomery, who said in 1892, that fifteen or sixteen years before, the ciscoes had been plentiful, and then "they fell off just to nothing the same as they have done this while back here and then came on as thick as they could be". His brother, Robert Montgomery, quoted figures to illustrate the nature of the decline. In the spring of 1891, their usual catch was from four thousand to forty-seven hundred ciscoes

TABLE 7. Summary of the fluctuations in the numbers of the shoal-water "Herring" from 1860 to 1927 for the three regions in Lake Ontario.

Year	Western Region (off Lincoln, Wentworth, Halton and Peel counties)	Middle Region (off York, Ontario, Durham and Northumberland counties)	Eastern Region (all of the lake east of Brighton)
Previous to 1860	....	....	Very plentiful (10, p 15)
1867	....	....	Scarce (11, p. 15)
1868	Plentiful (15, p. 15)....		
1872	....	Abundant (13, p. 15)..	
1892	....	Scarce (14, p. 15).....	
1892 to 1897	....	....	Scarce (12, p. 15) Scarce (16, p. 16)
1899 } 1900 }	Increasing (24, p. 16)..	Increasing (22, p. 16)..	
1902	....	Decrease (23, p. 16)...	Plentiful (17, p. 16)
1903 } 1904 }	....	....	Decreasing (18, p. 16)
1907	Decrease (25, p. 16)....		
1909 to 1918	....	....	Plentiful (19, p. 16)
1910	Large increase (26, p.16)		
1915	Plentiful (27, p. 16)....		
1922	....	....	Scarce (20, p. 16)
1927	Scarce (28, p. 16).....	....	Increasing (21, p. 16)

in 2100 yards of net, but when they began fishing in the autumn again, twenty-one hundred fish was the largest number that they were able to catch.

Mr. Larue, of Belleville, volunteered the suggestion that in the Bay of Quinte region the numbers of herring had fluctuated rather markedly over more or less definite intervals of time which he estimated at seven years. The statement of "Salmo" (1903) also suggests that some such phenomenon occurs in this area.

It has usually been considered that the depletion which periodically occurs in the numbers of ciscoes in the Great Lakes has been due to overfishing. If not enough fish are left in the waters to reproduce, depletion is certain to occur, but examination of the statistics for the years immediately preceding the periods of depletion mentioned by Montgomery, for instance, strongly suggests that overfishing was not the cause of depletion in those instances. The quantities of fish caught in those early years were very small as compared with those taken out of the lake in several recent years. In very early times of course, the use of seines at spawning time may have brought about depletion, but there is no indication that seines were responsible in the cases discussed above.

MEASUREMENTS

In the comparison or separation of a number of closely related species of fish, it is usual to make detailed measurements and counts of a number of body parts. As a result of experience, it has been found that the comparison of such data is useful not only in separating the species themselves, but also serves to indicate the degree of affinity existing between such species. The assumption which is the basis for this procedure and in fact the one which is in line with the general procedure underlying all systematic zoology, is that the more similar two species are in structure, the more closely related they may be considered. Measurements and counts such as those noted below, if done in a detailed manner, are thought to show these structural differences.

The great variability of the fishes in this genus necessitated the measuring of a considerable number of individuals of both sexes and of as many sizes as possible of each species.

In this work, it was found impossible to measure the fish when fresh, so that all proportions in the descriptions are given for preserved specimens. The specimens were first placed in a six per cent. formalin solution for about one week. At the end of that time, they were removed, washed, and measured. They were then placed in a sixty-six per cent. alcohol solution, in which preservative they were kept per-

manently. Those taken in 1925 and 1926 consisting of 25 *L. artedi* from Winona, 25 from Bronte, 25 from Port Credit, 25 from the Bay of Quinte, 40 *L. reighardi* from Port Credit, 22 *L. hoyi* from Port Credit and 9 *L. kiyi* from Port Credit, were measured after being in alcohol for some time. All other specimens were measured after removal from the formalin and before being placed in alcohol. Since the measurements of the former have been used chiefly for comparisons among themselves, the difference in treatment of these and other specimens does not affect the general results.

All measuring was done with dividers of various sizes, outside calipers, and a steel tape. Methods followed in making the measurements are described below.

LENGTH IN INCHES. Measured from the tip of the snout (*i.e.*, the junction of the premaxillaries) to the middle of the fork of the tail (*i.e.*, the distal end of the shortest ray of the caudal fin). These points were marked by pins and the distance measured in a straight line along a steel tape, not over the curvature of the body.

LENGTH IN CENTIMETRES. Measured from the tip of the snout (junction of the premaxillaries) to the posterior end of the vertebral column.

HEAD LENGTH. Measured from the junction of the premaxillaries to the farthest posterior part of the bony margin of the operculum, not including the fleshy flap.

HEAD DEPTH. Measured from the base of the occiput (end of supraoccipital bone) to the inner edge of the boundary between interoperculum and suboperculum.

SNOUT TO OCCIPUT. Measured from junction of premaxillaries to the end of the supraoccipital bone.

OCCIPUT TO DORSAL INSERTION. Measured from occiput or supraoccipital bone to base of first dorsal ray.

EYE. The horizontal diameter of the eyeball. It was measured by inserting the calipers inside the orbit, care being exercised not to compress the eyeball.

SNOUT. Measured from the junction of the premaxillaries to the anterior margin of the orbit.

INTERORBITAL. The shortest distance between the orbits measured in a straight line across the top of the head.

MAXILLARY. Measured from the junction of the premaxillaries to the posterior end of the maxilla. This, therefore, is really an expression of the length of both maxilla and premaxilla.

FIN LENGTHS. The length of the longest ray. In the case of the adipose, measured from the insertion to its caudad end.

FIN BASES. Measured from the insertion to posterior edge of base.

PECTORAL TO VENTRAL INSERTION. Measured from insertion of first ray of pectoral to insertion of first ray of ventral.

VENTRAL INSERTION TO VENT. Measured from insertion of first ray of ventral to vent.

DEPTH. The greatest depth of the body measured with outside calipers.

WIDTH. The greatest width of the body.

CAUDAL PEDUNCLE LENGTH. Measured from a point on the lateral line, immediately above the posterior end of the base of the anal fin, to the caudal end of the vertebral column.

CAUDAL PEDUNCLE DEPTH. The least depth of the caudal peduncle.

In order that the measurements of different specimens may be directly comparable, all are expressed in the tables as thousandths of the body length, *i.e.*, the measurement is divided by the body length and multiplied by a thousand.

GILL RAKERS. The number of gill rakers on each angle of the first arch of the left side were counted, every rudiment being considered. Care was taken in removing not to destroy the rakers at the ends. If the left arch were destroyed or deformed, the right was used.

SCALES IN LATERAL LINE. These were counted from the posterior edge of the gill cavity to the posterior end of the vertebral column. In cases where scales had been removed, the number was determined from the number of scale pockets.

LONGITUDINAL ROWS. Scale rows above the lateral line were counted from the insertion of the dorsal fin obliquely back to, but not including, the lateral line. Below the lateral line, the count was made from the insertion of the ventrals up to, but not including the lateral line.

FIN RAYS. Soft rays in front of the fins were not counted unless they were two-thirds the length of the longest ray. The last ray was counted as one, even though it was split right to the base.

The method of taxonomic study by the comparison of proportionate measurements must, of course, be employed with great caution. Some body parts are proportionately larger in younger individuals than in older ones. Young fish for instance, have relatively longer heads, larger eyes, and longer fins than larger fish of the same species. Table 8 has been constructed to illustrate some of these differences as they exist in *L. artedi* in Lake Ontario.

It will be noticed that the tendencies indicated by the measurements of the Port Credit fish are in some cases slightly different from those exhibited by examples from the Bay of Quinte. These and other irregularities in the table are due principally to the fact that too few specimens were measured, the variation between individuals being so great as to make it necessary to mesaure a very large number in order to obtain results which agree in all particulars. Since this point was not one of those with which the study was concerned mainly, it was considered inadvisable to make a longer series of measurements. The table is satisfactory as it is constituted to show that small fish as compared with larger ones of the same species, have relatively larger heads and correlated with this, larger head parts, *e.g.*, eye, snout, maxillary, and the measurement from snout to occiput. The width of the interorbital does not vary to any great extent. The body becomes deeper and wider especially in the larger fish from the Bay of Quinte. The fins decrease in size becoming proportionately much smaller in the larger fish.

It is also necessary to take into account sexual differences when comparing fishes. Differences due to sex in the ciscoes are not so great as those sometimes found among fish, *e.g.*,

TABLE 8. Change in body proportions with increase in length of *Leucichthys artedi* from Port Credit and the Bay of Quinte.

	From Port Credit			From Bay of Quinte			
No. of specimens	27	13	7	20	38	20	4
Size range, mm.	201–250	251–300	301–379	101–150	201–250	251–300	301–396
Average length	229	272	345	132	234	268	350
Scales	75	75	75	70	72	73	76
Gill rakers	28+16	31+18	31+17	30+17	31+17	32+17	31+18
Head length	226	219	206	238	229	225	211
Head depth	148	146	139	141	142	144	144
Body depth	233	230	238	208	226	228	283
Body width	126	124	130	110	123	121	139
Caudal peduncle:							
length	123	125	136	138	129	128	126
depth	78	74	74	80	80	78	82
Eye	55	52	46	61	58	55	50
Snout	58	58	54	58	58	56	52
Interorbital	59	59	58	57	59	57	59
Maxillary	80	78	82	80	80	75	70
Snout-occiput	157	153	144	168	161	152	145
Pectoral-ventral	335	334	341	299	291	321	353
Pectoral length	161	152	144	162	162	153	144
Ventral length	157	148	136	161	160	150	139
Dorsal height	148	141	129	160	155	149	133
Dorsal base	105	102	100	103	108	106	106
Anal height	94	92	88	97	100	96	90
Anal base	103	101	100	106	105	103	100

Pacific salmon (*Oncorhynchus*). The tables of measurements in the appendix of a previous paper (Pritchard, 1928), illustrate a few differences. These proportions which were obtained by measuring spawning fish demonstrate that, in general, the heads of the males are slightly longer than those of females and with them the head measurements, eye, snout and maxillary. The males are more compressed, and not so deep as the females and their fins are slightly longer. In some genera, *e.g.*, *Oncorhynchus* there are also differences in body proportions between fish when they are ripe, as compared with those which are not ripe. In the case of the species under discussion, our data are not sufficient to allow us to state positively that there are definite differences in this

respect. Under these circumstances it seems better to compare individuals of the same stage of sexual development, thus avoiding any error which might occur. Therefore one must be careful to compare fish of the same size, same sex, and of the same stage of sexual development. This is not always easy or possible, since some species reach maturity at a smaller size than others.

Reference has been made above to the fact that there is great variability in body proportions among fishes of this group. It is because of this wide variability that the identification of ciscoes is attended with so much difficulty. In an effort to determine what characters of ciscoes are sufficiently stable to be of use in separating species, Koelz (1929) has investigated the variability of such characters as body contour, depth, width, scales in the lateral line, etc. His conclusion was that the number of gill rakers is the most useful character for the separation of species. Of the others, general body contour, length of lower jaw and length and pigmentation of the maxillary are all of considerable value. He says: "The conclusion is unavoidable that those characters that are of greatest importance in the taxonomy of other groups of fish such as body proportions, number of scales, fin rays, teeth, etc., are not of prime taxonomic value for the Coregonidae". This question of variability is discussed again in this paper.

Considering then these limitations, table 9 has been made from the proportionate measurements of a number of female specimens of approximately equal size of each of the four species of ciscoes in Lake Ontario.

Examination of the figures in table 9 shows that *L. reighardi* differs more from the other three species than any of these do from one another. It has fewer gill rakers, a deeper, wider body, short caudal peduncle, a shorter head, and with it a small eye, short maxillary, short snout, and very short fins. Of the other three, *L. artedi* has the longest, deepest caudal peduncle and shortest head. It also has a small eye, snout and maxillary and short fins, the adipose being especially short. The remaining species, *L. kiyi* and

TABLE 9. Body proportions of females of four species of *Leucichthys* approximately equal in size—*viz.*, 225-250 mms., from Port Credit.

	L. reighardi	*L. artedi*	*L. kiyi*	*L. hoyi*
No. of specimens	14	7	18	14
Average length	237	237	238	234
Scales	75	74	74	71
Gill rakers	22+13	29+16	29+16	28+16
Head length	213	220	238	238
Head depth	143	141	147	145
Body depth	256	244	241	207
Body width	150	126	124	104
Caudal peduncle:				
length	118	135	122	123
depth	72	79	72	67
Eye	50	54	58	56
Snout	56	58	63	62
Interorbital	57	58	58	56
Maxillary	77	80	88	89
Snout-occiput	158	156	164	162
Pectoral-ventral	370	338	353	332
Pectoral length	134	154	174	176
Ventral length	133	151	169	159
Dorsal height	130	144	161	157
Dorsal base	100	104	102	101
Anal height	90	92	107	103
Anal base	103	106	99	102
Adipose length	64	50	63	...

L. hoyi, are characterized by their long fins and long head. They differ in that *L. hoyi* is more slender, and has a slightly smaller eye and shorter fins. *L. kiyi* is deep and spindle-shaped. The relation between the height of the anal fin and the length of its base is striking, that of *L. kiyi* being higher and shorter than that of *L. hoyi*.

DESCRIPTIONS OF SPECIES

As a result of the studies reported herein, the ciscoes of Lake Ontario may be regarded as belonging to four species which are characterized below. Because of the wide variation in some of the proportionate measurements, the average value for all the specimens is given with the usual range in brackets after it. Measurements varying widely from these are given outside the small brackets, but within large brackets.

LEUCICHTHYS ARTEDI (Le Sueur)

LAKE HERRING; SHOAL-WATER HERRING; BLUEBACK; QUINTE HERRING

Body slender, without much rise behind the occiput; greatest depth 20-26 per cent. of body length, occasionally 27 per cent.; width 49-68 per cent. of greatest depth; head short 20-24 per cent. of total length, occasionally 25 per cent., its depth 14-16 per cent. of body length; eye small, 4.2 [3.4(3.8-4.6)] in head; snout 4.0 (3.7-4.4) in head; maxillary short; premaxillaries usually pigmented; cutting edge of maxillary lined with black, pigment running back on to snout; larger fish from the Bay of Quinte have whole maxillary except distal quarter pigmented; lower jaw heavily pigmented at tip, usually included, but in some cases projecting slightly.

Fins short, sum of pectoral, ventral, dorsal and anal being 54 per cent. of the body length on the average, ranging from 50 to 60 per cent., in the case of some of the larger fish descending to 46 per cent., in an occasional one rising to 62 per cent.; ventrals, anals and adipose usually unpigmented, but in some cases, *e.g.* in the Bay of Quinte specimens, slightly pigmented at edges in the case of larger fish; dorsal heavily tipped with black; outer end of pectorals lined with black. Lateral line scales 72 [65(67-79)]; gill rakers 30+17 (27+15-33+19) *i.e.*, 47 (42-52). Length, 240 mm.

The colour is usually dark blue above, and silvery below. In some specimens, such as those taken off the Main Duck Islands, and a few in deep water off Port Credit, the dorsum is a bright green. Cranial patches which are bean-shaped usually appear on the dorsal surface of the head. These are dark green in colour with a brownish reflection. The lateral pair are much larger.

L. artedi may be easily distinguished from *L. reighardi* by the difference in the number of gill rakers. It differs from *L. hoyi* in its short fins and head, non-tuberculated lower jaw, which is usually included. The dorsal fin is more rectangular in shape, *i.e.*, has a longer base. Sometimes in deep water it resembles the chub, *L. kiyi*, but may be distinguished by the length of fins and head, and by the state of gonad development; the former ripens later in the summer. *L. kiyi*, also, has a much narrower and shallower caudal peduncle which gives it its chubby appearance.

This species was at one time, (about 1870), the mainstay of the fisheries of Lake Ontario, being taken in very large numbers in seines in the Bay of Quinte and Burlington beach regions. Its value decreased however on the discovery of the fatter, deep water cisco. In the Bay of Quinte, large numbers are taken in the autumn during the spawning run.

The largest individual procured was 39.6 cms. in length and weighed 3 pounds 6¾ ounces, but fishermen, both in the eastern and western ends of the lake, report them up to five pounds. The size usually taken in the 3 inch gill net in the eastern end is about 11 2/3 inches.

Until lately this species has been regarded as a shoal-water form, but now, the opinion that it is pelagic is fairly well established. In Lake Nipigon, surface settings showed its presence in the upper six feet of water. In Lake Ontario food studies have demonstrated that these fish must have been swimming at or near the surface in order to procure such food as terrestrial flies and mayfly sub-imagos. Many individuals were actually seen within eight inches of the surface of the water at the Main Duck islands. They are most commonly taken in depths of eighty to one hundred and seventy-five feet, but a few of the larger specimens were procured in water as deep as four hundred feet. In the Bay of Quinte during the spawning period, practically all are in water ten to twenty feet in depth.

Spawning occurs in the autumn. The smallest spawning female procured was 8 7/8 inches in length and 4½ ounces in weight.

LEUCICHTHYS REIGHARDI Koelz

REIGHARD'S CISCO

Body least compressed of all the species of *Leucichthys* in the lake, tapering regularly to the head and tail from the deepest point in front of the dorsal fin; greatest depth 22-26 per cent. of body length, occasionally 27 per cent.; width 47-62 per cent. of the greatest depth; head short, 20-23 per cent. of total length, its depth moderate, being about 14-15 per cent. of body length; eye smallest of all the species, 4.2 (3.8-4.5) in head; snout short, truncated in side view due to the almost vertical position of the premaxillaries, contained 3.8 (3.4-4.1) in head; premaxillaries slightly pigmented, pigment running back on to the snout; maxillaries short 2.7 (2.5-2.9) in head, more or less pigmented with cutting edge rimmed with black one-quarter way from its proximal to its distal end; lower jaw shorter than upper and heavily tipped with black.

Fins shorter than those of any of the other species in the lake; sum of pectoral, ventral, dorsal and anal about 49 per cent. of body length, ranging from 46 to 56 per cent.; caudal and dorsal fins pigmented; others immaculate. Lateral line scales 74 (68-78); gill rakers always fewer than 41; 23+13 (20+12-25+13) *i.e.*, 36 (32-38). Length, 239 mm.

The colour is light greenish straw-coloured above, shading into silvery below. Preserved specimens become yellowish straw-coloured all over.

This species, as noted, differs widely from all the others, and therefore cannot be easily confused with them. There are never more than 41 gill rakers on the first branchial arch, while the other species have more than this number. The fins are shortest and broadest of all the species. In addition it is usually least compressed, with a short truncated snout and non-protruding lower jaw. The colour difference may not be so marked in some cases, but none of the other species show the typical yellow-green straw colour of *L. reighardi*.

Reighard's cisco, which grows to at least fourteen inches in length and one pound, three ounces in weight, is one of the most important and valuable of the ciscoes in the lake. The flesh is preferred by some to that of the whitefish. It is found in depths of 75 to 300 feet off all the northern shore, but few are taken at a depth of less than 75 feet. The maximum number occurs at 250 feet. This is in direct contrast to the Lake Nipigon form which is found in maximum abundance from 90 to 100 feet (Dymond 1926).

Spawning takes place mainly during April and the first two weeks in May in about 250 feet of water. A spent female has been taken as early as January 26th. We have been unable to establish definitely when spawning ends, but a few fish have been found ripe in May and the first week in June. In late winter and early spring, these fish are on the bottom presumably in preparation for spawning and at that time they constitute the bulk of the cisco catch. At other seasons of the year, they are taken only incidentally. The time of the large catch varies in the two ends of the lake. Largest numbers are taken off Port Credit and Bronte in April, May and June, while off Cobourg and Bowmanville, they are taken later in July.

LEUCICHTHYS KIYI Koelz

CHUB; KIYI; WATERBELLY

Body fusiform, more compressed than in *L. reighardi* or *L. artedi*, depth greatest in front of the dorsal fin, comprising on the average 24 per cent. of the body length, ranging from 20-27 per cent., occasionally as high as 30 per cent.; width 44-62 per cent. of greatest depth; head long, 23-26 per cent. of total length, its depth moderate, being about 14-16 per cent. of body length; eye largest of any of four species here considered, 3.8-4.5 in head; snout usually longer than eye, ending sharply in the premaxillaries which are directed forward; dorsal part of snout and all premaxillaries heavily pigmented; maxillary long and pigmented for part of its length; lower jaw usually hooked or possessing a tubercle projecting beyond the upper and heavily pigmented at the tip.

This species has the longest fins of any of the species of the genus in the lake; sum of dorsal, pectoral, ventral and anal 57-68 per cent. of body length, averaging 61 per cent.; anal base usually much shorter than anal height; first ray of dorsal black, tips of rays widely margined with pigment; pectorals usually black on dorsal margins; ventrals and anals usually immaculate but occasionally sparingly scattered with pigment; adipose sprinkled with black. Lateral line scales 74 (66-86); gill rakers 28+16 (25+14-30+17) *i.e.*, 44 (39-47).

The colour is very dark on the back, shading into silvery on the belly. The sides in the lateral line region show a blue tinge through the dense black pigment. The top of the head is heavily pigmented, cranial patches showing only faintly.

L. kiyi may be easily distinguished from *L. reighardi*, and in most cases from *L. artedi*. Sometimes, however, it may be much like *L. artedi* in superficial appearance. Close examination will likely show longer fins and head in the same sized fish. *L. kiyi* in some cases resembles the bloat, *L. hoyi*, very closely, but several differences may be seen on closer examination. Usually the latter is more compressed and shallow. At most seasons of the year, they may be separated by the state of development of the gonads; *L. hoyi* spawns later in the fall than *L. kiyi* and the eggs of the former are therefore smaller during the summer. Usually, also the anal height and anal base of *L. hoyi* are about equal, while in *L. kiyi*, the height is greater than the base.

This cisco is at present of considerable commercial importance in the western end of Lake Ontario. Fishermen set nets in water over 400 feet for their capture; very few come into water less than 250 feet in depth. The point of maximum abundance is at about 410 feet. Nets were set in 475 feet off the Main Duck islands at the eastern end of the lake, and none were taken although a few were taken in shallower water in the same area. The Canadians do not fish for this species in this area because there is too much shallow water; but it has been fished on the United States shore.

Spawning takes place in the late fall and early winter. Some were still spawning as late as January 8th, 1927. The run began that year in late October. In the summer, these fish are found on the bottom, apparently in preparation for spawning. The result is that they constitute the bulk of the cisco catch during the summer and winter until their spawning is over.

LEUCICHTHYS HOYI (Gill)

BLOAT; HOY'S CISCO

Body long and slender, quite compressed, usually badly bloated when removed from nets; depth 17-23 per cent. of body length, occasionally as high as 24 per cent.; width 40-60 per cent. of greatest depth; head long, 23-27 per cent. of total length; its depth 14-16 per cent. of body length; eye 4.1 (3.8-4.4); snout longer than eye, rather sharp at the end, 3.9 (3.6-4.3) in head; maxillaries 2.7 (2.4-2.9); premaxillaries directed forward and pigmented; some pigment on tip of snout; interorbitals quite narrow; lower jaw with tubercle at end, usually projecting beyond upper, pigmented at top.

Fins long, sum of dorsal, pectoral ventral and anal 56-67 per cent. of body length, averaging 60.5 per cent.; dorsal fin tipped with black; pectoral with dorsal edge rimmed with pigment; caudal broadly margined with black, especially median rays; anal, ventral and adipose immaculate. Lateral line scales 69 (60-76); gill rakers 27+16 [25+13 (27+15-28+17)] *i.e.*, 43 [38(42-45)].

This species is silvery in colour, with a slightly greenish tinge above the lateral line. The top of the head is fairly heavily pigmented so that cranial spots show only faintly.

The bloat, the smallest and least valuable of all the ciscoes, ranges at all depths from 125 to 400 feet. The range of maximum abundance is from 250 to 300 feet. They are found in all the Canadian waters of the lake and are little esteemed anywhere. The flesh is soft and of poor quality, and there is a tendency to develop thin, worthless individuals called "racers" or "razor backs".

Spawning occurs in the late autumn,—November to January.

The bloat sometimes resembles *L. kiyi*, but can be differentiated on the basis of its colour, its narrow and shallow body, and the development of the gonads, as noted in the description of *L. kiyi*. The anal height is almost equal to the anal base. Sometimes it is very like *L. artedi* but close examination usually shows longer head and fins and shorter, shallower caudal peduncle. There is usually also a very definite colour difference.

ORIGIN OF LAKE ONTARIO CISCOES

Since it is evident that the four species here discussed differ from one another, not only in morphological characters, but also in habits and habitat preferences, the question naturally arises as to what extent the differences which distinguish the species are of adaptive significance.

One of the most constant differences between the species of ciscoes in the Great Lakes is the difference in number of gill rakers on the first branchial arch. These gill rakers serve to prevent food materials from being carried out between the gill arches by the current of water which serves respiratory purposes. Among fishes in general the number and size of the interspaces between the gill rakers is related to the size of the food taken. In the case of the four species under consideration no such correlation has been found to exist. There is little if any difference in the food eaten by *L. reighardi* as compared with the other species, certainly no such difference as exists in the number of gill rakers. In fact the species which has the most numerous gill rakers (*L. artedi*) is the only one which takes any considerable quantity of insects which are much larger than the organisms forming the food of the other species. Since the fish compared are all of the same size, the gill arches are of equal length and hence the width of the interspaces

between the rakers vary with the number. This is in direct contrast to the condition in the Cichlid fishes of Lake Tanganyika where Regan (1925) reports: "There are ninety species that appear to have evolved in a lake from two ancestral forms; the difference between these species in the form and size of the mouth and the dentition are an indication that their diversity is related to specialization for different kinds of food."

It is also fairly generally accepted that in the case of some species of fish the size of the eye may be correlated within limits, with depth, the larger eye being found in deeper water, as reported by Regan (1925) for Loch Rannoch char. In the ciscoes, however, no such correlation exists. *L. reighardi* which inhabits water of a depth of two hundred and fifty feet has the smallest eye, and *L. artedi* which is in general a shoal-water or pelagic form has a larger one. The size of the eye cannot therefore, be correlated with the depth at which these fish live.

In some instances too, adaptation has been demonstrable in the size and shape of fins in different habitats. If the length of fins were correlated with the depth of water in which the fish ranged, we would expect a gradient from the shortest finned fish at the surface to the longest at the bottom, or *vice versa*. No index of activity has ever been constructed, but from continued observation it would appear that *L. artedi*, which is pelagic, is the most active. It is, however, intermediate as far as this character is concerned.

It has been impossible to conclude that the differences which separate these species of ciscoes are in any way adapted to observed differences in habit and habitat. That such is perhaps the usual situation among closely related species is the conclusion of Richards and Robson (1926) as a result of a recent consideration of the species problem. They say: "It thus seems that the direct utility of specific characters has rarely been proved, and is at any rate unlikely to be common. Furthermore,—since the correlation of structure, etc., with other characters shown to be useful, does not at present rest on many well proved examples, it cannot yet be assumed that most specific characters are indirectly useful." They point out that this does not involve a wholesale denial of the power of natural selection. Structural differences of a size likely to be of survival value are of wide occurrence among animals. For instance, it seems likely that the differences which distinguish whitefish from ciscoes are of adaptive significance. Thus the whitefish's inferior mouth is related to its bottom-feeding habits, and its fewer and shorter gill rakers to the larger organisms which it eats as compared with those which make up the food of ciscoes. Such differences are more common between genera than between species. What is in doubt is the capacity of selection to use on a large scale, the small differences between closely allied species.

If one is led to doubt that the difference observed between the species of ciscoes in Lake Ontario are related to utility, one naturally is led to speculate as to the circumstances and the conditions under which the differences have arisen. Koelz (1929) has pointed out that the species now found in the Great Lakes had already been differentiated before they came into the precursor of the Great Lakes at the close of the glacial epoch. This is evident when one remembers that there are the same species in different lakes which have been long separated. Apparently eight species of *Leucichthys* came into the waters towards the end of glacial times. As the waters subsided some fish dropped out of each basin as habitat conditions such as depth became unfavourable. Each species chose the habitat which was most to its liking.

So much is fairly evident, but the question as to where these species were evolved is still unsettled. Were they evolved under conditions similar to those they now occupy, or were they evolved under conditions more widely different?

It seems reasonable to suggest that perhaps before the ice age there may have been only one or a few species of ciscoes, probably fewer than at the present time. With the advance and retreat of the ice, opportunities were afforded for the almost complete destruction of a species.

Small samples of the population may have survived, perhaps in widely different areas under widely different conditions, and have diverged in different directions. In view of the lack of correlation between morphological differences and differences in habitats and habits of the various species at the present time, it seems more reasonable to suppose that the ciscoes evolved under some such conditions of isolation as here suggested rather than as a result of physiological, ecological or habitudinal isolation in a single body of water.

With the retreat of the ice, these forms found themselves in the Great Lakes and in a great many smaller lakes. In the range of conditions in these new water areas, several species were able to survive by taking up conditions which they could tolerate even though they may not have been ideal for them. In the smaller lakes, due to their limited size and range, only one or two species survived. Such an idea is confirmed by the number of species existing at present in these lakes which are given in order of area, as follows: Huron and Michigan (really one body of water), 8; Superior, 6; Erie, 1; and Ontario, 4. The only one of the Great Lakes which is at variance with this theory is Lake Erie. The difference here is explicable by the fact that although Lake Erie is larger than Lake Ontario, it is shallow and presents a limited range of habitats. Lake Nipigon, which has 6 species, seems also to fall in line, if we consider that on account of the number of its bays and islands, and deep and shallow water areas, it presents a large number of different habitats.

Once these various species become inhabitants of the same lake, is it not possible that the relatively uniform conditions which have thereafter existed in the deep waters for some of them, *e.g.*, *L. hoyi* and *L. kiyi*, have led to a convergence of characters, which would account for the difficulties in separating them?

The discovery of Dymond and Hart (1927) is perhaps of interest in this connection. These authors have shown that *Coregonus clupeaformis* (Mitchill) and *Leucichthys nipigon* Koelz in Lake Abitibi showed parallel variations from the Lake Nipigon forms of the same species, inasmuch as both have deeper and more compressed bodies, with shorter and stouter caudal peduncles, larger fins and fewer scales.

FOOD STUDIES

The data resulting from a study of the food of ciscoes and lake herring in Lake Ontario have been summarized in tables 10 to 18. In making the analysis, the stomach contents were placed in a flat dish and estimates were then made of the percentage which each organism constituted of the whole volume. If the material was microscopic, several samples were taken on a glass slide and the proportions calculated therefrom.

In the tabulations, there is given the number of stomachs in which each organism appeared, the average percentage which it comprised when present and the maximum percentage in any one stomach. + indicates the presence of organisms in quantities too small to valuate. In cases where the stomach contents were made up chiefly of insects, the actual numbers of each species are recorded.

Tables 10 to 14 contain the results of the food analysis of 187 adult specimens of the four species taken in the open lake. Two summaries are given for *L. artedi*, the first, table 10, to show the food organisms found in fish taken at different depths in the western end of the lake, and the second, table 11, to show the food of those taken in the eastern end. In tables 15 and 16 are tabulated the results of the examination of specimens of adult *L. artedi* which were captured in protected bays in the eastern end of the lake, viz., the Bay of Quinte, and in a small bay on the east shore of the Main Duck islands. Table 17 presents data on the food of yearling *L. artedi* from the Bay of Quinte, while table 18 gives similar data for fish of the same species and age from Lake Nipigon.

A study of these tables reveals the fact that there is no essential difference in the open lake in the food of the four species. The major constituents in all cases are *Mysis relicta*

TABLE 10. *Analysis of the contents of stomachs of Leucichthys artedi from specimens taken at various depths in the open water of Lake Ontario off Port Credit.*

Depth range . . .	*0–100 feet*			*101–200 feet*			*201–300 feet*			*301–411 feet*		
No. of stomachs	10			10			17			4		
Organism	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach
PLATYHELMINTHES	1	+	+				3	6	2			
CRUSTACEA	10	92	100	10	91	100	16	89	100	3	93	100
Cladocera												
Leptodora kindtii . . .							1	+	+			
Copepoda												
Limnocalanus macrurus . . .				1	50	50						
Ostracoda . . .				1	+	+				1	+	+
Amphipoda												
Pontoporeia hoyi	3	25	35				7	49	90	1	85	85
Mysidacea												
Mysis relicta	10	84	100	10	75	100	16	65	100	3	65	100
INSECTA							2	+	+	2	2.5	5
Diptera												
Chironomid larvae . . .							1	+	+	1	5	5
MOLLUSCA	2	5	10	3	8	10	11	14	60	1	5	5
Sphaeriidae . .	2	5	10	3	8	10	11	14	60	1	5	5
MISCELLANEOUS												
Fish scale	1	+	+	1	+	+	2	+	+			
Fish fin							1	+	+			
Plant							1	+	+			
Inorganic material												
Sand	1	50	50									

and *Pontoporeia hoyi*, although molluscs and insect materials are found in appreciable quantities. Still smaller quantities of cladocera, copepods, ostracods and other organisms appear.

Table 10 has been constructed to determine if there is any variation in food which can be correlated with the depth at which the specimens were taken. Its contents fail to reveal any difference worthy of note. Molluscs, however, appear more frequently in specimens from depths of two to three hundred feet, although even in this range, they constitute less than fifteen per cent. of the food taken. In

TABLE 11. Analysis of the contents of six stomachs of *Leucichthys artedi* from specimens taken at a depth of 250 feet, five miles southwest of Main Duck Islands

Organism	No. of stomachs containing organism	Average % per stomach	Greatest % in any one stomach
CRUSTACEA	6	96	100
Copepoda	1	+	+
Cyclops	1	+	+
Ostracoda	1	+	+
Amphipoda	6	96	100
Pontoporeia hoyi	6	96	100
INSECTA	1	+	+
Coleoptera			
larvae	1	+	+
MOLLUSCA	5	5	10
Sphaeriidae	5	5	10

addition, fish from the deepest water (*L. kiyi* from 411 feet) contained practically nothing but *Mysis*.

The presence of such organisms as molluscs and chironomid larvae indicates that ciscoes feed to a certain extent off the bottom. Indeed it is likely that the larger part of the food is obtained within a few feet of the bottom.

In shallow water, especially in protected bays such as the Bay of Quinte, *L. artedi* has very different food habits from those which it and other species of the genus have in the open lake. Table 15 summarizes what may be con-

sidered the normal food of this species in situations of the former type, as compared with what is found in the open lake; *Mysis* forms a much smaller percentage of the total,

TABLE 12. Analysis of the contents of 27 stomachs from *Leucichthys reighardi* taken in the open water of Lake Ontario, 18 from a depth of 250-300 feet off Port Credit, and nine at a depth of 250 feet, five miles southwest of the Main Duck Islands.

Organism	18 from Port Credit			9 from Main Duck Islands		
	No. of stomachs containing organism	Average % per stomach	Greatest % in any one stomach	No. of stomachs containing organism	Average % per stomach	Greatest % in any one stomach
PLANT REMAINS	2	+	+			
PLATYHELMINTHES	1	+	+			
CRUSTACEA	18	74	100	9	91	100
Copepoda	2	50	100			
Diaptomus	1	30	30			
Cyclops	2	35	70			
Ostracoda	1	2	2	1	2	2
Amphipoda	12	55	100	9	91	100
Pontoporeia hoyi	12	55	100	9	91	100
Mysidacea	14	40	100			
Mysis relicta	14	40	100			
INSECTA	1	20	20	3	2	5
Diptera	1	20	20	2	2.5	5
Culicid larvae				1	+	+
Chironomid larvae	1	20	20	1	5	5
Coleoptera larvae				1	+	+
MOLLUSCA	2	2	2	3	12	15
Sphaeriidae	2	2	2	3	12	15
FISH EGGS						
Eyed*	2	+	+			
Infertile*	2	40	70	1	20	20

*These eggs are cisco eggs, probably of *L. kiyi*, with the exception of those taken off the Main Duck Islands.

while cladocera and copepods have increased considerably. Such a condition is not unexpected since *Mysis* usually occurs in a deep water habitat. The outstanding difference however, lies in the increased proportion of insect material.

At a certain season, this shallow water species comes up to the surface to feed on the swarms of emerging mayflies. At this time only, they may be taken with the artificial fly. For many years, anglers in considerable numbers have resorted to Lake Simcoe to take advantage of the cisco rise.

TABLE 13. Analysis of the contents of 55 stomachs of *Leucichthys kiyi* from specimens taken in Lake Ontario, 53 off Port Credit and 2 off Main Duck Islands.

Organism	53 from Port Credit			2 from Main Duck Islands		
	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach
PLANT REMAINS	2	+	+			
PLATYHELMINTHES	4	2	10			
TROCHELMINTHES	1	+	+			
Keratella cochlearis	1	+	+			
CRUSTACEA	51	78	100	2	40	80
Copepoda	2	+	+			
Epischura lacustris	1	+	+			
Senecella	1	+	+			
Amphipoda	3	43	80	1	80	80
Pontoporeia hoyi	3	43	80	1	80	80
Mysidacea	47	85	100	1	+	+
Mysis relicta	47	85	100	1	+	+
INSECTA	2	+	+	1	5	5
Diptera	1	+	+			
Chironomid larvae	1	+	+			
Coleoptera remains				1	5	5
MOLLUSCA	3	4	10	1	15	15
Sphaeriidae	3	4	10	1	15	15
EGGS(?)	1	5	5			

In the Bay of Quinte region the fish behave similarly. Analyses of the stomach contents of six specimens captured during such a period, *i.e.*, July 7th, 1928, are given in table 16. The food of these specimens consisted wholly of insects. They had not confined themselves to mayflies, however, but had taken representatives of four other orders, including at least eight families. A large number of forms were adults of terrestrial species, *e.g.*, Muscidae and Dolichopodidae which must have been taken by the fish from the surface of the water. In addition, the mayflies and dragonflies were adults which must also have been procured in the same way.

TABLE 14. Anlaysis of the contents of 58 stomachs of *Leucichthys hoyi* from specimens taken in Lake Ontario, 50 off Port Credit and 8 in the Bay of Quinte region.

Organism	50 from Port Credit			8 from Bay of Quinte		
	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach
PLATYHELMINTHES	4	1	5	1	5	5
CRUSTACEA	49	91	100	8	94	100
Cladocera	1	+	+			
Polyphemus	1	+	+			
Copepoda	4	18	60	3	60	100
Diaptomus				2	5	10
Cyclops	1	10	10	1	5	5
Limnocalanus macrurus	3	20	60	2	82	95
Ostracoda	2	+	+	1	+	+
Amphipoda	13	17	100	2	55	80
Pontoporeia hoyi	13	17	100	2	55	80
Mysidacea	45	93	100	6	77	100
Mysis relicta	45	93	100	6	77	100
INSECTA	1	+	+			
Diptera	1	+	+			
Chironomidae	1	+	+			
MOLLUSCA	5	4	15	2	10	20

The presence of such large numbers of dipterous larvae may be accounted for by the propinquity of a mass of decaying fish offal in which these larvae had no doubt hatched. It is more than likely that the mollusc shell found in one of the stomachs had been obtained some time previously, but owing to its indigestibility had not yet passed out of the alimentary tract.

Previous to our investigations yearlings of *L. artedi* had rarely been taken. Clemens (1924) reports the analysis of the stomachs of forty specimens, 2¾ to 5¾ inches in length from Lake Nipigon. In July 1928, we took by seining some thirty-two specimens, ranging in length from 5¼ to 6¼

TABLE 15. Analysis of the contents of 37 stomachs of *Leucichthys artedi* from specimens taken in the Bay of Quinte, near Pleasant point.

Organism	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach
PLANT REMAINS	1	+	+
ACANTHOCEPHALA	1	1	1
CRUSTACEA	36	80	100
Cladocera	3	+	+
Leptodora kindtii	3	+	+
Copepoda	11	17	100
Diaptomus	3	1	2
Cyclops	9	6	25
Limnocalanus macrurus	1	80	80
Ostracoda	13	8	20
Amphipoda	25	69	100
Pontoporeia hoyi	25	69	100
Mysidacea	14	63	100
Mysis relicta	14	63	100
INSECTA	6	20	100
Diptera	6	20	100
Bibionid adults	1	100	100
Chironomidae	5	4	15
larvae	4	5	15
pupae	1	+	+
MOLLUSCA	22	18	45
Sphaeriidae	22	18	45
FISH EGGS*	1	100	100

*Ling eggs probably.

inches. The results of the examination of 36 of these is given in table 17. These analyses show that insect material constituted ninety-nine per cent. of the food of the yearlings. In order of abundance this consisted of Diptera, Ephemeroptera, Trichoptera, Hymenoptera, Hemiptera, Homoptera, Coleoptera, and Megaloptera. As in the case of the larger

TABLE 16. Analysis of the contents of 6 stomachs of *Leucichthys artedi* from adult specimens taken from a shallow bay on the east shore of the Main Duck Islands.

Organism	No. of stomachs containing organism	Average number per stomach	Greatest number in any one stomach
INSECTA*	6	114	232
Diptera	6	40	117
Muscidae			
Phorma regina	4	6	15
Dolichopodidae	3	2	5
Tipulidae	3	18	28
Chironomidae			
adults	4	35	84
larvae	1	4	4
Dipterous larvae	3	36	75
Misc. Diptera	2	2	3
Trichoptera	6	30	88
Calamoceratidae			
adults	1	8	8
Misc. Trichoptera			
adults	5	34	88
pupae	1	5	5
Megaloptera	3	2	4
Sialididae	3	2	4
Odonata	2	1	1
Sympetrum	1	1	1
Misc. Odonata	1	1	1
Ephemeroptera	5	27	69
Baetidae			
Blasturus cupidus			
imagos	3	10	13
Baetis			
imagos	2	25	42
Heptageniidae			
Ecdyonurus tripunctata			
adults	2	16	16
sub-imagos	1	1	1
Ecdyonurus canadensis group			
adults	2	1	1
Ecdyonurus sp.			
adults	2	9	4
MOLLUSCA			
Sphaeriidae	1	1	1

*Where not otherwise stated, all insects are in the adult stage.

TABLE 17 Analysis of the contents of 36 stomachs of *Leucichthys artedi* from specimens in the summer of their second year taken in the Bay of Quinte.

Organism	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach	No. in which organisms were counted	Average no. per stomach	Greatest no. in any one stomach
NEMATHELMINTHES..	1	35	35	1	1	1
CRUSTACEA.........	3	1	2	1	1	1
Amphipoda						
Pontoporeia hoyi.	2	1	1	1	2	2
Mysidacea						
Mysis relicta....	1	+	+			
ARACHNIDA.........	1	1	1	1	1	1
Hydracarina......	1	1	1	1	1	1
INSECTA*...........	36	99	100	26	67	180
Hemiptera........	2	4.5	5	2	1	1
Corixidae.......	1	4	4	1	1	1
Misc. Hemiptera	1	5	5	1	1	1
Homoptera.......	4	5	15	4	1	3
Jassidae........	2	4.5	5	2	1	1
Aphididae......	3	3	10	3	1	2
Diptera..........	34	69	100	23	53	180
Dolichopodidae..	1	+	+	1	1	1
Stratiomyidae ..	9	3	7	8	2	4
Bibionidae......	3	1	2	3	1	1
Tipulidae.......	23	4	15	20	3	9
Chironomidae						
adults........	31	68	100	18	55	175
pupae........	14	6	20	11	3	7
Cecidomyiidae..	1	5	5	1	1	1
Mycetophylidae.	1	+	+	1	1	1
Misc. Diptera...	8	4	20	5	2	3
Trichoptera.......	8	58	90	8	23	56
adults........	5	81	90	5	34	56
pupae........	4	14	25	4	3	4
Megaloptera......	3	22	65	2	2	2
Sialididae.......	3	22	65	2	2	2
Ephemeroptera....	22	26	88	19	14	76
Baetidae						
*Blasturus***						
adults.......	3	9	18	3	6	9
sub-imagos...	9	35	70	9	15	62
nymphs.....	2	27	50	1	25	25

TABLE 17—*Continued*

Organism	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach	No. in which organisms were counted	Average no. per stomach	Greatest no. in any one stomach
*Ephemerella****						
adults.......	4	3	10	4	1	2
sub-imagos...	6	10	18	5	6	8
Baetis						
adults.......	7	9	30	7	4	11
sub-imagos....	1	2	2			
Heptageniidae						
*Ecdyonurus*****						
adults.......	4	2	5	4	1	3
sub-imagos...	1	25	25	1	2	2
Misc. Ephemeroptera						
adults.......	4	5	2	4	1	1
sub-imagos ..	1	7	7	1	1	1
Coleoptera........	4	3	5	4	1	1
Staphylinidae...	2	2.5	5	2	1	1
Misc. Coleoptera	2	3.5	5	1	1	1
Hymenoptera.....	15	2.5	6	11	2	4
Formicidae.....	6	2	5	6	2	4
Chalcidoidea....	9	2	6	7	2	4
Ichneumonidae..	3	3	4	3	1	2

*Where not otherwise stated, insects are in the adult stage.
**_Blasturus cupidus_.
***_bicolor_ group.
****One of these identified as being of *fusca* group, other *canadensis* group.

individuals from the Main Duck islands, July 7th, 1928, these yearlings had taken chiefly adult insects which they must have secured at or near the surface. Prominent among these insects were subimagos of mayflies emerging from the nymphal stage, and adult chironomids which had just emerged. These forms have a definite time of emergence and it may be that the presence of the yearlings in that place at that time is bound up in some way with this. That the taking of this type of food by these fish was not an unusual occurrence is shown by the data given in table 18 for fish of the same species and age from Lake Nipigon.

As far as the individuals taken in the open lake are concerned, there is no definite change in food habits attendant

TABLE 18. Analysis of the contents of 10 stomachs of *Leucichthys artedi* from specimens in the summer of their second year, taken from Sand Point bay, Lake Nipigon.

Organism	No. of stomachs containing organism	Average per cent. per stomach	Greatest per cent. in any one stomach	No. in which organisms were counted	Average no. per stomach	Greatest no. in any one stomach
PLANT REMAINS.....	1	10	10	1	1	1
ARACHNIDA.........	1	8	8	1	1	1
INSECTA*...........	10	98	100	10	11.5	21
Hemiptera........	1	3	3	1	1	1
Homoptera........	6	13	30	6	2	3
Psyllidae........	1	16	16	1	2	2
Jassidae.........	3	14	30	3	1	2
Diptera...........	10	96	100	10	11	21
Simulidae.......	2	35	60	2	5	8
Chironomidae...						
adults........	1	26	26	1	2	2
pupae.........	10	73	100	10	8	21
larvae........	1	+	+	1	1	1
Misc. Diptera...	2	5	10	2	1	1
Ephemeroptera....	1	20	20	1	2	2
Baetidae						
Baetis imagos.	1	20	20	1	2	2
Hymenoptera.....	3	13	24	3	1	2
Chalcidoidea....	3	4	12	3	1	1
Misc. Hymenoptera..........	1	12	12	1	1	1

*Where not otherwise stated, the insects are in the adult stage.

upon a change in season, except that very little food is taken while the spawning run is on. Of 32 Reighard's ciscoes examined on February 12, 1926, 25 fish or 76 per cent. of the number examined were empty, and on March 29, 1926, 12 fish or 75 per cent. were empty. During the fall run of *L. artedi* in the Bay of Quinte in 1927, 62 were examined of

which 54 fish or 87 per cent. were empty. In the summer of 1928, 64 were examined and 35 or 55 per cent. were found to contain food.

Sometimes ciscoes eat their own eggs. In table 12 a record is made of Reighard's cisco containing two eyed eggs which from the location and date are believed to have been those of *L. kiyi*. In addition, in the fall of 1927, out of 62 stomachs which were taken from *L. artedi* in the Bay of Quinte, six contained lake herring eggs. Several other eggs which were probably those of ling (*Lota maculosa*) were found in the stomachs of specimens from this area. The probability that this is not a serious drain on the ciscoes is discussed later.

It has been found that ciscoes also eat whitefish fry. Mr. Hart has found 3300 whitefish fry in the stomachs of twelve ciscoes, an average of 275 per stomach. The maximum number in one stomach was six hundred. These fish were taken at the dock at the hatchery at Belleville where they were evidently lying in wait for the fry escaping from the overflow. If this were not the case, this might represent a considerable destruction of whitefish fry per cisco but the total drain on the whitefish due to this cause would not be great because few ciscoes are present in the bay when the whitefish are in this stage.

DETERMINATION OF AGE

The ages of 567 individuals have been determined in order that a comparison may be made of the rates of growth of the different species in the lake, and in the case of *L. artedi* of the same species in different habitats. Such determinations also make it possible to say at what age spawning begins in the different species. This information is essential in framing regulations for the conservation of these forms.

Scales were removed from fish of different lengths secured at different seasons in various parts of the lake. These were cleaned and mounted in glycerin jelly on glass slides. The ages were estimated by determining the number of winter rings. This method is now in such general use that no further explanation is deemed necessary (Van Oosten, 1929).

In recording ages, we have used the method commonly employed in designating human age. If a scale has one winter ring, it has completed its first year, because all species, with the possible exception of *L. reighardi* hatch in the spring. In the tables, the figure 1+ denotes that the fish possesses scales with one winter ring (*i.e.*, they are one year old or in their second year).

In the use of these figures, we obtain what may be designated as the "average rate of growth" for the species in the locality under discussion. Van Oosten (1929) states "in order to obtain the norm of growth of a long lived species which is not influenced by seasonal cycles of growth or annual fluctuations in it, we must combine the rates of growth for corresponding ages of all year classes". To procure this average rate of growth, the actual measurement of each fish is taken and the age group to which it belongs is determined. The average for each of these age groups is calculated and used in the discussion.

In table 19 is given a summary of the results of the age studies. This contains the average length in millimetres and inches, and the average weight in ounces of all the specimens for each of the four species in the various year classes. In the case of *L. artedi* the measurements of all the individuals taken in the lake have been averaged.

From table 19 and figures 2 and 3, it is evident that there is considerable difference in growth rate between the various species. At first *L. reighardi* and *L. artedi* grow much more quickly in length than *L. kiyi*, but the latter overtakes them at six years of age.[2] From this time on *L. kiyi* increases most quickly in length. *L. hoyi* is the smallest of the four at all ages.

The rate of increase in weight is similar to that in length

[2]The figures for *L. reighardi* at six years of age are unsatisfactory owing to the fact that only two specimens were available for study, but it seems probable that *L. artedi* and *L. kiyi* are larger at that age.

TABLE 19. The average length in millimetres and inches, and the average weight in ounces of specimens of each of the four species of the genus *Leucichthys* in the various year groups.

Age in years	Length in millimetres to end vertebral column				Length in inches to fork of tail				Weight in ounces			
	L. reighardi	*L. artedi*	*L. kiyi*	*L. hoyi*	*L. reighardi*	*L. artedi*	*L. kiyi*	*L. hoyi*	*L. reighardi*	*L. artedi*	*L. kiyi*	*L. hoyi*
1+	175**	129			7 1/4**	5 3/5			1 3/4**	1 1/10		
2+		196		144		8 3/10		6 1/10		3 7/10		1 1/10
3+	227	226	178	161	9 2/3	9 7/10	7 1/2	6 9/10	6 4/5	5 3/5	2 9/10	1 8/10
4+	233	233	203	188	9 9/10	10 1/10	8 1/2	8 1/5	7 4/5	6 2/5	4 2/5	3 1/10
5+	250	253	222	214	10 3/5	10 3/4	9 2/3	9 1/10	9 1/10	7 5/8	5 9/10	4 1/10
6+	241*	270	241	222	10*	11 1/2	10 3/5	9 7/10	7 1/8*	10 7/10	7 3/10	4 9/10
7+	270	297	274	255	11 2/5	12 9/10	11 7/10	11 1/10	12 3/5	17 1/5	10 2/3	7 7/10
8+	272	303			11 1/16	13 3/5			14 3/4	16		
9+		358***				16 3/10				26 1/2		
10+		345**				14 1/2**				23 1/2**		

*These figures based on the examination of only two specimens are obviously too low.
**These figures based on one specimen.
***This is low since only Port Credit fish were used.

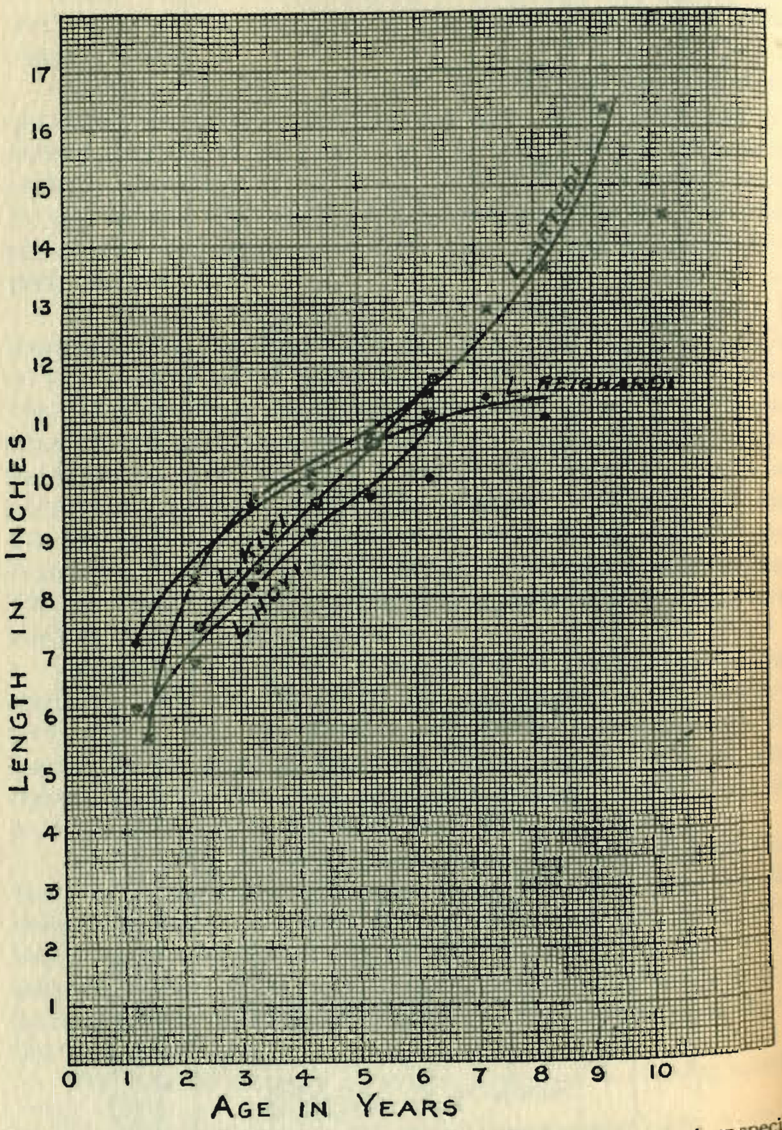

Fig. 2. The relation between length in inches and age in years in the four species of the genus *Leucichthys* in Lake Ontario.

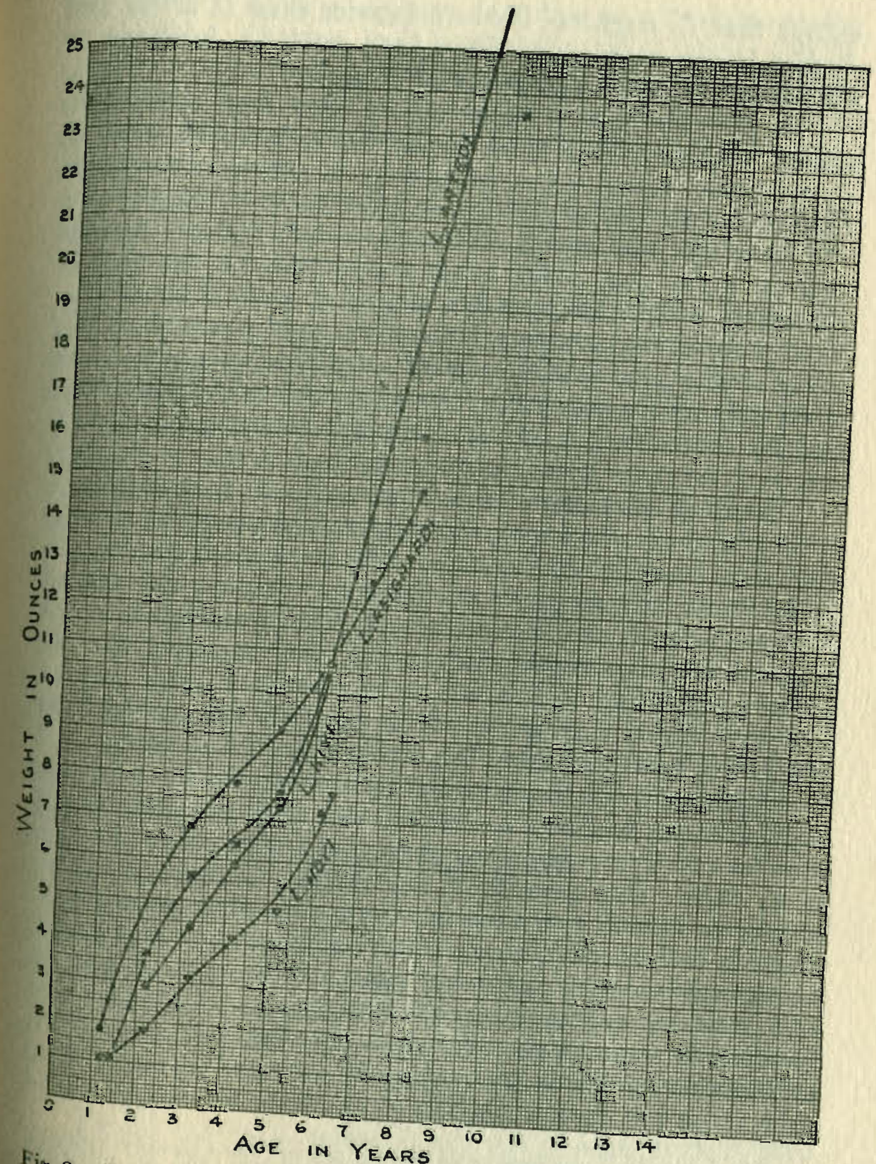

Fig. 3. The relation between weight in ounces and age in years in the four species of the genus *Leucichthys* in Lake Ontario.

except that *L. reighardi* is much heavier than *L. artedi* and *L. kiyi* in the early ages. They both catch up, however, at six years.[2] *L. hoyi* is smallest at all ages.

L. artedi attains a much greater size than any of the others, specimens over three pounds being sometimes taken. *L. reighardi*, which when full grown is considerably larger than either *L. kiyi* or *L. hoyi*, reaches the next largest size.

It will be observed from a study of table 19 and figure 3 that in every case there is an acceleration in the rate of growth in weight as the fishes approach their limit of size. This tendency may account for the fact that while *L. kiyi* has a slower growth rate than *L. reighardi* throughout most of its life, in its seventh year (6+years old) it overtakes that species. Acceleration in rate probably sets in at a smaller size in *L. kiyi* due to the fact that its limit of size is smaller.

An understanding of this acceleration in rate of growth in weight as the fishes near their greatest size may be of considerable practical importance. Other things being equal, it would be advantageous economically to have the fishery regulations such that the fishes would be permitted to make some of this rapid growth before they were caught. On the other hand, there seems to be, according to our data, a heavy mortality among the fish in the older age groups. On this point, however, there is no conclusive information.

Reference has been made to the possibility that the rapid increase in size of *L. artedi* in the older years (table 19) may be due to a cause other than that suggested in the case of *L. kiyi*. The growth of the former corresponds quite closely to that of the other species for the first seven years. There is then a very large increase both in weight and length between the eighth and tenth years. This type of growth rate may be characteristic of this species. On the other hand, it is more likely that there are two forms involved, differing materially in rate of growth and size attained. Two such races are found in Lake Erie where the larger called

[2]The figures for *L. reighardi* at six years of age are unsatisfactory owing to the fact that only two specimens were available for study, but it seems probable that *L. artedi* and *L. kiyi* are larger at that stage.

the "Jumbo" herring has been described as a distinct species *L. eriensis*. (Jordon and Evermann, 1911) Koelz (1929) however regards the latter merely as a subspecies, *Leucichthys artedi albus*, which he also found in Lake Ontario. This question has been discussed at greater length in the consideration of races.

Table 20 and figures 4 and 5 below have been prepared to show the difference between the rates of growth of groups of *L. artedi* in various parts of the lake.

The difference in length and weight between specimens of the same age from Winona and those from the Bay of Quinte is very striking. Similar differences, although less marked, exist between specimens from any other two areas. The fish in each place have their own characteristic growth rate.

The data for the Port Credit fish indicate that they have a much greater acceleration in growth in weight than the others as they approach their maximum size. These figures are believed to include more of the larger-sized, faster-growing individuals mentioned above, than any of the remaining groups although there appear to be a few among those from the Bay of Quinte. The large size of *L. artedi* in the older age groups of table 19 which was used for comparison for the four species, has no doubt been caused to some extent by the inclusion in the average of these large fish from this locality.

AGE AT SPAWNING

Although the material at hand was not in any way exhaustive, it was sufficient in most cases for the purpose of deciding the earliest age at which the various species spawned and the age at which spawning was general. The specimens examined were especially satisfactory for deciding these points since most of them were taken from spawning runs.

In the case of *L. artedi*, it was not possible to determine the age of the youngest spawning fish in all the areas inspected because the material from Winona and Bronte was very limited. None of the yearlings taken in the Bay of

TABLE 20. The average length in millimetres and inches, and the average weight in ounces of specimens of *Leucichthys artedi* of various ages from different localities in Lake Ontario.

Age in years	Length in millimetres to end vertebral column				Length in inches to fork of tail				Weight in ounces			
	Winona	Bronte	Port Credit	Bay of Quinte	Winona	Bronte	Port Credit	Bay of Quinte	Winona	Bronte	Port Credit	Bay of Quinte
1+				129				5 3/5				1 1/10
2+			181	216*			8	8 7/8*			3 1/2	4 1/2*
3+		229	214	232		9 3/4	9 1/5	10		6 1/8	4 2/5	6 1/5
4+	219	237	226	243	9 2/5	10 1/4	10	10 2/5	5 1/5	7 3/5	6 1/2	6 4/5
5+	230	247	260	256	9 3/5	10 1/2	11 1/16	10 9/10	5 1/2	8 1/3	8 5/8	7 3/5
6+		258	276	265		11 1/5	11 3/4	11 3/10		10 1/2	11 1/5	10 1/5
7+		275	351	278		11 7/8	14 1/5	12 3/5		13	22 2/5	15 4/5
8+				303				13 3/5				16
9+			358				15 3/10	17 1/10			23 3/4	29 1/4
10+				345*				14 1/2*				23 1/4*

*One specimen only.

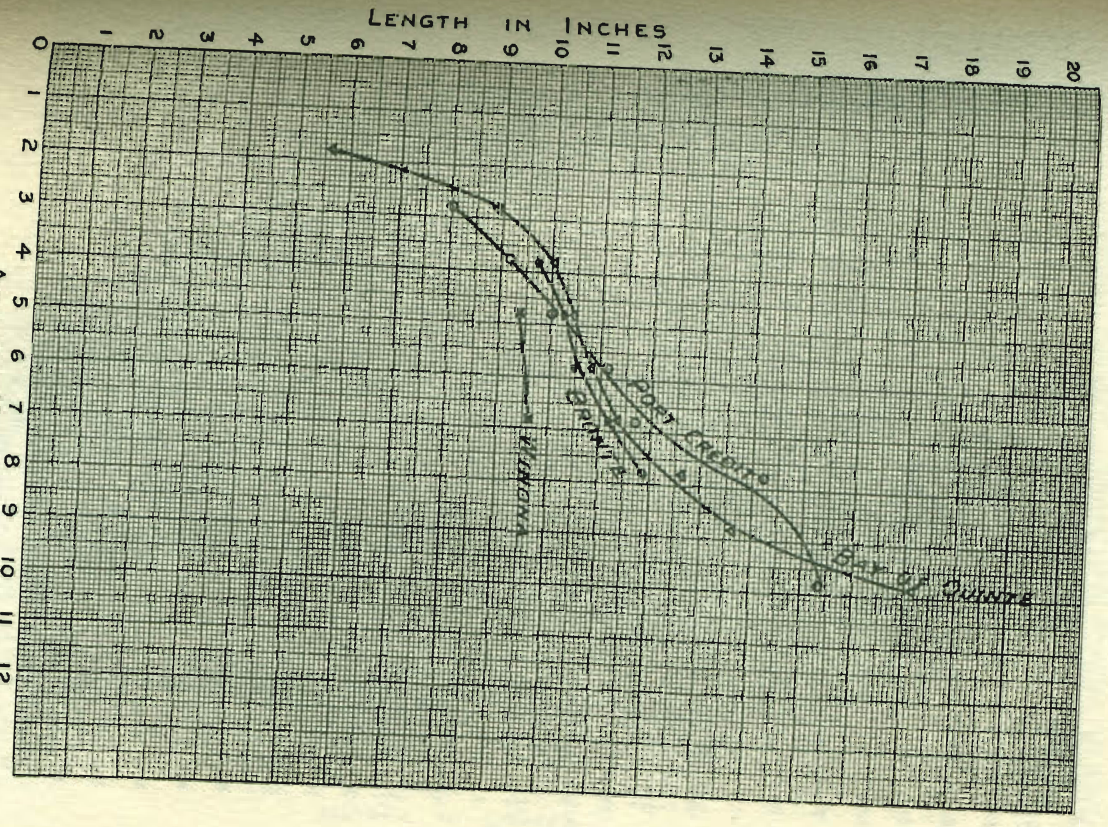

Fig. 4. The relation between length in inches and age in years in *Leucichthys artedi* taken from Lake Ontario off Winona, Bronte, Port Credit and in the Bay of Quinte.

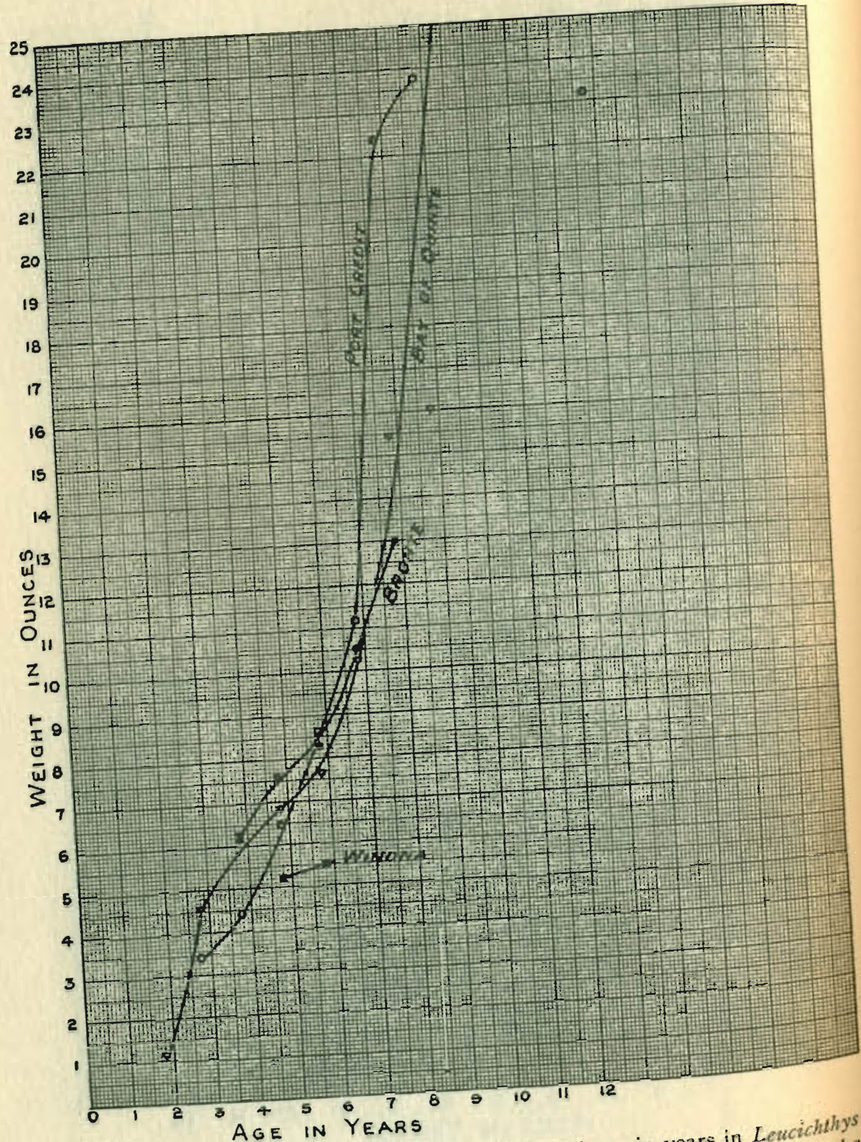

Fig. 5. The relation between weight in ounces and age in years in *Leucichthys artedi* taken from Lake Ontario off Winona, Bronte, Port Credit and in the Bay of Quinte.

Quinte were sexually mature. Three ripe females in their third year (*i.e.*, 2+years old) were captured, two at Port Credit and one in the Bay of Quinte. No ripe males as young as these were caught. Several sexually mature individuals of both sexes were found among the three-year-old fish, while at four years of age, spawning was general. The spawning runs were made up principally of fish which were four and five years old, but at Port Credit and in the Bay of Quinte, they contained a few from the older groups. The individuals of the three ages, eight, nine and ten years old were chiefly females. The oldest specimen of this species captured was ten years.

Some difficulty has been encountered in obtaining young specimens of Reighard's cisco, probably due to the fact that it was almost impossible to locate these fish except at and near the time of spawning. One female sexually mature in the fall of its second year was taken. Considerable numbers were caught in their fourth (*i.e.*, 3+years old). The large majority of the spawners were four or five years old. Very few older than the latter were captured.

The remaining species, *L. kiyi* and *L. hoyi* were similar, in that they matured earlier than *L. artedi* and *L. reighardi*, and did not live as long. *L. hoyi* becomes ripe in many cases in the fall of its second year, a year earlier than *L. kiyi*. Large numbers of both were sexually mature when two years old (*i.e.*, in their third year). The spawning runs were chiefly fish three or four years of age, although a few five or six years old did appear. The two oldest age groups contained in the main, female fish. The oldest individual procured in each case was six years.

VARIATION IN *LEUCICHTHYS ARTEDI*

In a previous paper the present writer (Pritchard, 1928) has pointed out that there are differences between *L. artedi* in different parts of the lake of the same kind as have been considered racial variations in other fish. It was found that "the specimens from Winona, Bronte, and Port Credit resemble each other more closely than any one of them resembles the Bay of Quinte fish. The main differences between the Bay of Quinte herring and those from 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 spawning time."

To what extent such variations are due directly to the effect of the different environments acting directly on the fishes of each generation, and to what extent it represents fixed hereditary differences, is not known in any fish in which racial variations have been investigated.

There appears to be in the case of the same species (*L. artedi*) in Lake Ontario another type of difference to which one hesitates to apply the term racial. Perhaps it is best to describe it as of subspecific rank, as has been done by Koelz (1929). As pointed out in the discussion of the rate of growth of *L. artedi* taken off Port Credit, there appeared to be a marked difference in the case of some of the specimens. The larger, faster growing fish belong to the form to which Koelz (1929) has applied the name *L. artedi albus*. These fish are not confined to this one part of the lake but have been taken in the eastern end as well, although it is probable that they are more common in the western end. They have usually been recognized by the fishermen as something different from the ordinary lake herring. In the diary of C. W. Nash, late Provincial Biologist, which is now in the Royal Ontario Museum of Zoology, there is an entry under the date of July 4th, 1909. "W. Bateman of the Sandbar, Toronto, sent me a herring which I take to be of this species (Jumbo herring, *Leucichthys eriensis*). It was caught in Lake Ontario. Length to the centre of fork of caudal fin 15½ inches; girth at front of dorsal fin 10¾ inches; weight 7 pounds 2 ounces; dorsal fin dusky."

We recognize these different forms but hesitate without a thorough investigation of the genus throughout its range to give them a subspecific rank.

ENEMIES

Throughout the present research, commercial catches of all kinds were examined in order to determine if possible the position of all the species of ciscoes and lake herring in the ecology of the lake. The results of these investigations are set down below.

Petromyzon marinus Linn. Lake lamprey. During the summer of 1927, ciscoes were found in deep water with small lampreys attached. In the summer of 1928, a few lake herring were taken showing lamprey teeth marks. The menace is not serious however.

Coregonus clupeaformis (Mitchill) Whitefish. Mr. J. L. Hart has found whitefish stomachs from the Bay of Quinte to contain eggs among which were a few of *L. artedi*. The numbers were small since most of the whitefish leave the spawning grounds before the ciscoes start to spawn. No serious drain on the eggs would result from this source. Rawson (1930) reports that cisco eggs were found in five out of twelve stomachs of whitefish taken in Lake Simcoe, Ontario, on March 1, 1928. The average number of eggs found in each stomach was 16.

Leucichthys artedi (Le Sueur), Lake herring. That these fish eat their own eggs has been proven beyond a doubt. The records are as follows:

November 15, 1927. Big island, Bay of Quinte—25 stomachs examined, 4 contained one cisco egg each.

November 22, 1927. Belleville, Bay of Quinte—21 stomachs examined, 2 contained cisco eggs (fewer than ten).

Whether they are actually cannibalistic is a question. Mr. Hart has found 3,300 whitefish fry in the stomachs of twelve ciscoes taken in the Bay of Quinte, an average of 270 per stomach. The maximum number found in one stomach was 600. No authentic record is at hand of any fry of *L. artedi* being found, although it seems unlikely when the young of the two species school together that the adults could differentiate when procuring food. In any case our evidence does not indicate that the lake herring destroys many of its own eggs or young.

Leucicthys reighardi Koelz, Reighard's cisco. Two records are given in table 12 of two of these fish taken in 250 feet of water off Port Credit on February 12, 1926, which contained one and two eggs respectively. From the condition of the eggs and the location in which the fish were taken, they were believed to have been those of *L. kiyi.* In no other cases was a similar behaviour noted, although eggs which were evidently not cisco eggs were taken from the stomachs of individuals of this species which were captured south of the Main Duck islands.

Cristivomer namaycush (Walbaum) Lake trout. This fish ranks second in importance in the commercial fisheries of the lake, and thus merits attention. During our work in 1927, at Port Credit, it was found that the ciscoes constituted the bulk of the food of this species at certain periods. Our conclusions are admirably expressed by Dymond (1928) in connection with factors affecting the production of lake trout here: "the results before and after July 1, are given separately because it was noticed that after that date the percentage of stomachs containing alewives was much less than before—36.7 per cent. as compared with 75.5 per cent. On the contrary the percentage of stomachs containing ciscoes materially increased after July 1, being 53.3 per cent. as compared with 24.5 per cent. before that date. In case of ciscoes, the average number found in a stomach was 2.8 and the largest number 8. The decreased percentage of alewives eaten by lake trout after July 1, is due to the fact that about that date, the alewives begin to move inshore to spawn. The trout, remaining in deep water, were of necessity forced to turn to the ciscoes as food."

Thus the cisco becomes an alternative in the absence of the alewife.

At the Main Duck islands in the eastern end of the lake in July, 1928, out of 79 lake trout stomachs which contained food, four contained ciscoes of the species, *L. hoyi* and *L. artedi.* All these data demonstrate that the ciscoes are of great significance as a food for lake trout.

Although it is difficult to estimate indirect values it is probable that, next to its value as a food for humans, this constitutes the greatest benefit of the cisco. In any attempt to introduce food for the lake trout into barren lakes, attention should be given to such findings.

Ameiurus nebulosus (Le Sueur), Brown bullhead. Several bullhead stomachs examined in 1926 contained what were identified as whitefish eggs and cisco eggs. This drain is negligible since none of those examined contained any considerable number of cisco eggs.

Perca flavescens Mitchill, Perch. This species is by far the worst destroyer of eggs among the fish that live over the cisco spawning grounds. The following table presents the data secured in this connection.

TABLE 21. The number of cisco and whitefish eggs found in stomachs of perch from the Bay of Quinte.

Date	Number examined	Number containing eggs	Average number of eggs per stomach	
			Cisco	Whitefish
November 3, 1926....	20	0		
" 14, 1927....	20	4	15	
" 16, 1927....	1	1	20	50
" 21, 1927*...	79	79	275	

*The greatest number in any one stomach was 1,112. The average percentage of the total stomach contents constituted by the cisco eggs was 82.3.

The fish from which these stomachs were taken were caught at Belleville in the Bay of Quinte on the date noted, shipped to Toronto and examined at the University of Toronto by Messrs. W. J. K. Harkness, G. VanLoon, W. R. Buchner, and G. Falconer.

The last item in the above table is indicative of a wholesale destruction of eggs. Since there are large quantities of perch in the Bay of Quinte, they constitute a very serious menace to the eggs and thus are a serious danger to the fishery there. In the other portions of the lake where the water is not so shallow, they are less detrimental.

It might be well in the face of such a situation to amend the legislation so that it would be permissible to gill net for these fish in the winter. To make a profitable fishery, a 2½ inch stretched mesh net should be permitted. This would not affect any of the commercial fishes of that area to any great extent because the whitefish and ciscoes which are most important are not present in large numbers at that season. It is felt that the damage done to the commercial species would be more than compensated by the benefits accruing from such a procedure.

The perch do not appear to prey on the fry of *L. artedi*. One hundred and thirty-six taken in Prinyer's cove on May 9 and May 10, 1928, were examined and not one contained fry although they were foraging near them. Their food at this time, in this locality consisted of isopods, amphipods, crayfish, chironomids, caddis, sialids, mayflies, damsel flies, molluscs and an occasional small fish, the tessellated darter, *Boleosoma nigrum*.

Lota maculosa (Le Sueur), Ling. It has been been definitely established that the ling prey on ciscoes. Our records however show that they do not consume as many as do the lake trout. Dymond (1928) reports that in 64 ling stomachs examined, ciscoes appeared in three only or 4.7 per cent. He says that "this is partly due to the fact that most of the stomachs examined were taken from specimens caught earlier in the season". The same condition held at other times for on April 13, 1927, in 50 stomachs examined not one cisco was found. This is in direct contrast to conditions in Lake Nipigon where the main item of food of the ling was ciscoes (Clemens 1924).

In addition to the fish mentioned above a few of the following were examined during the spawning run of the lake herring in the Bay of Quinte in November 1926: *Lepisosteus osseus* (Linn.), long-nosed gar pike; *Catostomus commersonii* (Lacépède), common sucker; *Moxostoma aureolum* (Le Sueur), short-headed red-horse; *Moxostoma anisurum* (Rafinesque), white-nosed red-horse; *Esox lucius* Linn., pike; and *Aplodinotus grunniens* Rafinesque, sheepshead. No eggs were found in any of them.

PARASITES

During our examination of the individuals of these species, it was noticed that in many cases the fish were heavily parasitized by copepods, tapeworms, round worms and hook-headed worms. Hubbs (1927) has shown that parasites may have some effect on the growth of a fish. Although in most cases there did not seem to be a large enough number of parasites on the ciscoes and lake herring to inhibit or change growth, there were cases where it was felt that the long, thin "racers", especially in the species *L. artedi* and *L. hoyi*, were retarded because they were so heavily parasitized. The numbers were noted and the specimens have been identified as set forth below.

COPEPODA

These were sent to Dr. Charles B. Wilson, of the State Normal School, Westfield, Mass., who identified all of them as the species listed below.

Salmincola inermis. These were probably the scarcest of all the parasites. They were found embedded in the flesh at the edge of the gill cavity, and on the operculum. During 1928 in the Bay of Quinte region, fish examined at random showed these forms present in the following numbers:

L. artedi—9 out of 66 *or* 15 per cent.
L. reighardi—1 out of 20 *or* 5 per cent.
L. hoyi—2 out of 10 *or* 20 per cent.
L. kiyi—0 out of 4 *or* 0 per cent.

That they were present in *L. kiyi* as well was demonstrated in the fish taken off Port Credit in the western end of the lake.

Since there is usually only one of these copepods in the gills of any fish, it does not seem that they would be any serious detriment to it, nor does it seem likely when they are present in such small numbers that they will do much damage to the genus as a whole. As Dr. Wilson comments, in a letter to the author: "the only danger from them would be the starting of a sort of epidemic during which their number would increase sufficiently to weaken the fish, and so become instrumental in killing them. But such a thing is practically impossible in a body of water the size of Lake Ontario."

The worms which are recorded below were worked over by the zoologists at the Bureau of Animal Industry, United States Department of Agriculture, who have identified them as follows.

PLATYHELMINTHES

Bothriocephalid larvae. These occurred as cysts connected to the wall of the stomach. In the case of *L. artedi*, they were found in 14 fish out of 66 or 21 per cent. of those examined in the Bay of Quinte region in 1928. Specimens of the same parasite had been procured at Port Credit in the autumn of the previous year. One was taken in *L. hoyi* and one in *L. kiyi*. They do not seem to be very plentiful.

Rhyncobothrid cestode. The only specimen of this form found was taken from the outside of the intestine of an individual of the species *L. artedi* in the Bay of Quinte region, on July 4, 1928.

NEMATODA

Cystidicola sp. This is by far the most prevalent parasite in the ciscoes. Large numbers were taken from the swim bladders of a large percentage of the individuals of all four species. In *L. artedi* in the Bay of Quinte 41 per cent. were affected, in *L. hoyi* 40 per cent.; *L. reighardi* 45 per cent. and *L. kiyi* 20 per cent. One or two worms were found in the intestines of some of the species. Whether these are harmful could not be proven definitely, but it was felt that some of the *L. artedi*, which were long and thin as opposed to normal individuals, had been seriously affected by the large

number of these parasites which existed in their swim bladders.

The species is evidently a new one for this genus of worm and is now being described by one of the zoologists at the Bureau of Animal Industry, United States Department of Agriculture, Washington, D.C.

ACANTHOCEPHALA

Echinorhynchus sp. These specimens were taken out of the intestines of nine individuals of the species *L. reighardi* which were part of the 20 procured in a lift out of 250 feet of water, ten miles southwest of the Main Duck islands, in the eastern end of Lake Ontario. They were very common in this form, but were not taken in any of the other species.

Neoechinorhynchus sp. Among those individuals of *L. artedi* which were examined from the Bay of Quinte, this parasite occurred inside the stomachs of 22 per cent. None were taken by us from any of the other ciscoes examined.

From these data it seems that these species of hook-headed worms are found in a special host, *Echinorhynchus* being taken in *L. reighardi* and *Neoechinorhynchus* in *L. artedi*.

MEASURES OF CONSERVATION

In a previous paper (Pritchard, 1928) attention was drawn to the relatively great difference in the numbers of fish taken in nets of slightly different size. "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 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." The figures quoted in support of this statement were procured from Koelz (1926) and from fish taken by us in the autumn of 1926. Since that time more conclusive data have been obtained which are presented below.

In framing measures for the conservation of any species of fish one of the essential pieces of information which one should have is the relative numbers of individuals of each age group. The securing of this and similar information is dependent on being able to secure accurate and representative samples of the population. That we are quite unable to be at all certain as to the accuracy of our present sampling methods is shown by the following considerations.

It is well known as noted above what a great difference in the size of fish taken may result from a small change in the mesh of net used. In table 19, the average length of a three year old individual of the species *L. artedi* is given as 9 7/10 inches. Our net records show that in a two and one quarter inch net, the average length of fish of this species taken is 8 5/8 inches; and in the two and one half inch, 10½ inches. It is evident then that even though a few three year old lake herring may be taken in these two nets, the majority may not be captured. One must not then decide that a failure to catch fish of a particular year group in a gill net of a given mesh necessarily indicates that the fish of that year group are not present in the area.

Another source of error arises from what seems to be a different choice of habitat by fish of different ages. Our studies have suggested that the larger individuals of *L. artedi* may frequent the deeper water. If this is the case and settings are confined to the area in which the great majority of the fish of commercial sizes are taken, the conclusion might easily be reached that there is an extreme paucity of older individuals even though the facts are far different.

The time of sampling may seriously affect our ideas of abundance. It has been demonstrated that *L. reighardi*, is only taken in large numbers from February to June, when it is on the bottom presumably in preparation for and in the act of spawning. If then, nets were set at any other time of the year, one might very incorrectly decide that this species was very scarce or entirely absent.

In the same way the proportion of the sexes may vary widely in the same area from time to time. Pritchard (1929) has shown that for the alewife (*Pomolobus pseudoharengus*) "toward the beginning of the run, the sexes are present in approximately equal numbers, but towards the close the percentage of males rises to 80 or 90 per cent." There is also evidence that the males appear first in the spawning run of *L. artedi* in the Bay of Quinte.

In drawing conclusions from the data which are submitted in tables 22 and 23 care was exercised to take account of these factors.

TABLE 22. The numbers of ciscoes of all species caught in equal lengths of various size mesh at different depths off Port Credit in the summer of 1927.

Depth in feet	Date	Size of mesh (stretched mesh as manufactured) 1¼	1½	2	2¼	2½	2¾	3	3½	4	4½	4¾	5
175	June 29	17	24	18	3	4	8	3	2	1			
175	Aug. 5	36	23	38	13	11	19		6	1	1	1	3
284	June 14	15	35	76	72	44						3	1
300	June 29	39	60*		53	29		13		6	2	2	1
328	June 20		8	25	21	8	6	3	1			1	
340	Aug. 28	9	12	90	88	24							
411	July 18	9	18	86	18	40	34	12	17	3	3	5	4
Totals		126	120	333	268	160	67	31	26	11	6	12	9=1169
Percentage		10.8	10.3	28.5	23	13.7	5.7	2.7	2.2	0.9	0.5	1.0	.8

*Omitted in calculation.

From this table, it is evident that the two and two and one quarter inch nets are most efficient in catching ciscoes. Reference to the detailed summary of the net records shows however, that most of the individuals caught in these nets are too small to sell. Few fish were taken in a net larger than the two and a half inch (stretched mesh) but those taken in this net were large enough to be sold profitably. It is therefore, not wise from the economic point of view to use a net smaller than the two and one half inch stretched mesh, but the use of a larger one than this is also unprofitable.

The usual minimum weight limit set on ciscoes is eight ounces for the larger lakes and six ounces for the smaller. Our investigation shows that in the western end of Lake Ontario, where cisco fishing is prosecuted most heavily, the fishery would cease to be profitable if the eight ounce limit were enforced. Some data pertinent to this are given in table 23, where there are listed the numbers of each species taken in nets of various mesh at all depths and times during the summer of 1927 off Port Credit and the percentage of those fish which are under eight and six ounces in weight respectively. These are the results of settings made in 175 (2 settings), 284, 300, 328, 340 and 411 feet of water.

TABLE 23. The numbers of each species taken in a given mesh of net at all depths and times off Port Credit in the summer of 1927, and the percentage of those fish under eight and six ounces in weight, respectively.

Size of mesh	*L. reighardi*			*L. artedi*			*L. kiyi*			*L. hoyi*		
	No.	% under 6 oz.	% under 8 oz.	No.	% under 6 oz.	% under 8 oz.	No.	% under 6 oz.	% under 8 oz.	No.	% under 6 oz.	% under 8 oz.
1¼	1	100	100	7	100	100	16	100	100	100	100	100
1½				5*	100	100	25*	100	100	88*	97	100
2	2	50	100	55*	88	97	186*	93	100	90*	96	100
2¼	8	50	88	58	86	100	140	83	97	62	87	100
2½	6	33	66	37	45	65	85	58	99	32	84	95
2¾	3	0	0	18	17	43	36	42	94	10	87	100
3	1	0	0	9	0	17	13	28	59	8	64	90
3½				3	0	0	12	78	100	10	100	100
4				2	50	50	1	100	100	8	83	100
4½				1	0	100	2	100	100	3	100	100
4¾				1	0	100	5	88	100	2	100	100
5				1	100	100	3	100	100	5	100	100

*The numbers for the setting at 300 feet are omitted from this total because in the net record the catches of 1½ and 2-inch mesh were recorded together and could not be separated.

From these tables it is immediately evident that of all the specimens examined, there were only a few of the species *L. reighardi* and *L. artedi* over eight ounces. All the individuals in the other two species (*L. kiyi* and *L. hoyi*) were

under eight ounces. If the minimum weight permitted were six ounces, many of the fishes taken in meshes of two and one half inches and over would be legal.

No matter what the size limit may be however, we cannot by regulating the mesh of the gill nets preclude the capture of fish which are too small, especially in the case of the deep water forms, *L. kiyi* and *L. hoyi*. These species, which have long heads and projecting jaws, have a tendency to become "bridled" or entangled in the meshes of the larger nets, even up to five inches. It is useless to return undersized fish taken in this way to the water because they are not usually in a fit condition to survive.

From these discussions, we can see that in making regulations for the conservation of ciscoes in Lake Ontario, the setting of a minimum weight which would be applicable in all cases, is almost impossible. It would probably be better to set the size of the net which seems most satisfactory when all phases of the situation are considered and allow the fishermen to keep all the fish taken therein.

Since we have as yet no idea of how often a fish must be allowed to spawn before it should be taken and still ensure the perpetuation of the species, we should make our regulations in accordance with the best knowledge available at the time and try the results over a period of years. This long period of observation is necessary so that one may be sure that the decrease or increase is not merely due to the natural fluctuations in numbers which occur in many species. If the fish do really become scarcer, more rigid protection should be afforded, even to closing the fishery for some time. The regulations mentioned below for the four species seem to be the most logical at the present time.

In fixing a limit in mesh, it is well to consider the forms in three groups, (1) the deep water forms, *L. kiyi* and *L. hoyi* (2) *L. reighardi* and (3) *L. artedi*. The first two as noted do not grow to a large size and could not be fished with profit unless in a net as small as two and one half inches. The fish obtained in that net are in large numbers and of good size for marketing. The average weight of specimens of *L. kiyi* taken thus would be about five and nine-tenths ounces. This would allow the fish to spawn at least once, if not twice in most cases, before they could be taken legally. In addition, *L. kiyi* frequents a habitat in deep water so far from shore that fishermen who have boats which are large enough to go such a distance are often prevented from fishing it heavily due to the inclement weather.

L. hoyi being of little value commercially need not be considered very seriously, but it may be pointed out that it begins to spawn earlier than any of the other species and would have spawned in most cases twice if not three times before it could be taken legally.

Since *L. reighardi* is a deep water form, it would be impracticable to prescribe a net other than that used for *L. kiyi* and *L. hoyi* (*i.e.*, two and one half inch stretched mesh) because it would be difficult to enforce two different regulations. The average weight of specimens taken in that mesh is about six ounces. This would allow only one year's spawning in most cases, according to our statistics. Our data, however, are not sufficiently complete for us to state that some do not spawn at a younger age than this. In addition as pointed out before, fishermen seem able to procure this fish only for about four months in the spring, when it is on the bottom presumably in preparation for spawning. At that time the weather is bad and fishing is difficult. It seems reasonable, then, considering these conditions to believe that this size mesh will give enough protection. The species, however, should be watched closely and at the first sign of depletion, the season should be closed because this is by far the most valuable of the ciscoes.

More stringent regulations as to the size of net might be enforced in the case of *L. artedi*, the shoal-water species. This species is very scarce in the western end of Lake Ontario, where it was once abundant. For this reason it should be rigidly protected, with the hope of establishing something approaching its former abundance. In the eastern end of the lake, where it is still common, nothing less than a three inch mesh net may be used in its capture, according to the

present regulations of the Ontario Department of Game and Fisheries. This net takes specimens of an average weight of over eight ounces. A fish of this size will have spawned at least once and usually twice before it is taken. If this three inch mesh were made compulsory in the western end of the lake in water of 175 feet or less, where the shoal-water herring is now scarce, the numbers might be given a chance to increase. If, however, it shows no signs of increase in a few years under such regulations, it would be wise to prohibit fishing altogether in shallow water, especially at spawning time to provide further opportunity for it to become re-established again in numbers.

SUMMARY AND CONCLUSIONS

(1) The ciscoes (*Leucichthys*) are an important group of freshwater fishes, closely related to the whitefishes (*Coregonus* and *Prosopium*) and more distantly to the salmon and trout.

((2) The Canadian waters of the Great Lakes produced on the average 55.5 per cent. of the ciscoes taken in Canada between 1923 and 1927. Lake Ontario produced on the average 6.2 per cent. of the total average yearly production for that period in the Great Lakes.

(3) Production of fish by a lake is influenced by other factors than area, depth being probably one of the most important.

(4) The history of the cisco fishery in Lake Ontario is sketched from the earliest times to the present and shows that the abundance of these fish has fluctuated rather markedly from time to time. It is suggested that perhaps the action of some unknown factor or factors and not fishing alone may be responsible for the periodic scarcity.

(5) In differentiating species of ciscoes on the basis of morphological differences by the use of proportionate measurements, caution must be exercised because such proportions vary with the location from which the fish are taken, the size of the fish and their sex.

(6) The ciscoes of Lake Ontario are recognized as belonging to four species: *Leucichthys artedi*, *Leucichthys reighardi*, *Leucichthys kiyi* and *Leucichthys hoyi*. *L. artedi* is a shoal-water or pelagic form found most abundantly in the eastern end of the lake at the present time. It is characterized by short head and fins, a rather compressed body, a blue or green colour on the back, and dry flesh. It spawns in late November and December. *L. reighardi* occurs in water of medium depth (250-350 feet) throughout the lake. It has the shortest head and fins of the four species, a thick, terete body, a yellowish-green colour, and a quite oily flesh. This form usually spawns in May and June. *L. kiyi*, taken in the deep water (300-450 feet) throughout the lake, has the longest head and fins, a spindle-shaped body, a black back and head, and a moderately oily flesh. It spawns in December and early January. *L. hoyi* ranges in all depths from 175-450 feet, occurring in maximum abundance at about 200 feet. It is silvery in colour. These fish are easily identified because they are usually very thin and compressed with a long head and a projecting lower jaw.

(7) From a study of these forms it is evident that the characters which serve to differentiate species, such as the number of gill rakers, size of eye, and size of fins, are not of adaptive significance. Generic characters such as those separating the whitefish and ciscoes may be adaptive.

(8) Apparently eight species of the genus *Leucichthys* came into the precursor of the Great Lakes at the end of the ice age, and these have become distributed mainly as a result of habitat preferences. Thus more species occur in the larger lakes where presumably there is a greater range of habitats.

(9) These eight original species may have been evolved in interglacial times under some conditions of geographical isolation rather than as a result of ecological or habitudinal segregation in the same body of water.

(10) It is suggested that a convergence in body form may have taken place since these species came into the lake.

(11) Ciscoes in the open lake feed mostly on *Mysis relicta* and *Pontoporeia hoyi*. There is practically no difference in food in this habitat in the case of any of the four species at any time of the year.

(12) *L. artedi* in shallow water consumes large numbers of insects. At certain seasons insects constitute ninety per cent. of the food of this species.

(13) One year old *L. artedi* have been taken on a few occasions in shallow water and in every case their stomachs have been found to contain large quantities of insects.

(14) In some cases, ciscoes eat their own eggs and whitefish fry.

(15) There are considerable differences in rates of growth, both in weight and in length between the four species in the lake.

(16) All species show an acceleration in rate of increase in weight as they approach their maximum size.

(17) In the case of *L. artedi* the form of the curve for increase in weight suggests that this species is constituted by two forms (subspecies), one of which shows a more rapid increase in weight and reaches a larger size than the other. This larger, more rapidly growing form occurs in relatively small numbers.

(18) The commoner, slower growing subspecies of *L. artedi* from different localities in the lake, *e.g.*, those from Winona, Bronte, Port Credit, and the Bay of Quinte, show differences in body form and in rate of growth.

(19) The youngest spawning fish captured in each species were as follows: *L. artedi*, *L. reighardi*, and *L. kiyi*, 2+years; *L. hoyi*, 1+years. Spawning was general in *L. artedi*, and *L. reighardi* at 4+years, and in *L. kiyi* and *L. hoyi* at 3+years.

(20) The greatest enemies of the lake herring are the perch and lake trout. Ling, catfish and even ciscoes themselves prey on the fry and eggs at times.

(21) The ciscoes in Lake Ontario are usually not badly infected with parasites. Those most commonly found are parasitic copepods, tapeworms, round worms, and hook-headed worms.

(22) Estimates as to the proportions of fish of different

sizes in the lake based on present methods of sampling by means of gill net catches, are unreliable because of the great difference in size of fish taken in nets differing by a slight amount in the size of the mesh, and because of the possibility of differences in habit and habitat preferences of fish of different age and sex.

(23) It is recommended that regulations for the conservation of these fish should prescribe the size of net to be used in taking them, rather than the size of fish which may be taken. At the present time the two and one half inch stretched mesh seems the most reasonable for the deep water forms, *L. reighardi*, *L. kiyi* and *L. hoyi*. This should probably not be permitted in depths less than 175 feet. In waters shallower than this the use of a three inch mesh is recommended, in the hope that it will permit an increase in the numbers of *L. artedi*, in areas where it has become scarce.

LITERATURE CITED

*Agassiz, Louis. 1850. Lake Superior, its physical character, vegetation, and animals, compared with those of other and similar regions, with a narrative of the tour, by J. Elliot Cabot, and contributions by other scientific gentlemen. Boston.

Clemens, W. A. 1922. A study of the ciscoes of Lake Erie. Univ. Toronto Stud. Biol. 20. Pub. Ont. Fish. Res. Lab. 2.

Clemens, W. A. *et al.* 1924. Food studies of Lake Nipigon fishes. Univ. Toronto Stud. Biol. 25. Pub. Ont. Fish. Res. Lab. 25.

Cope, E. D. 1872. Observations on the systematic relations of the fishes. Proc. Amer. Ass. Adv. Sci. **20**: 333.

*Dybowski, B. 1874. Die Fische des Baical-Wassersystemes. Verh. Zool.-bot. Ges. Wien. **24**: 383-394.

Dymond, J. R. 1926. The Fishes of Lake Nipigon. Univ. Toronto Stud. Biol. 27. Pub. Ont. Fish. Res. Lab. 27.

*Not consulted.

Dymond, J. R. 1928. Some factors affecting the production of lake trout (*Cristivomer namaycush*) in Lake Ontario. Univ. Toronto Stud. Biol. 31. Pub. Ont. Fish. Res. Lab. 33.

Dymond, J. R. and J. L. Hart. 1927. The fishes of Lake Abitibi (Ontario) and adjacent waters. Univ. Toronto Stud. Biol. 29. Pub. Ont. Fish. Res. Lab. 28.

Elton, Chas. 1927. Animal ecology. Macmillan Co.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe viewed in the light of biological research. Rapp. Cons. Explor. Mer. **20**: 1-228.

Hubbs, C. L. 1927. The related effects of a parasite on a fish. Jour. Parasit. **14**: 75-84.

Jordan, D. S. and B. W. Evermann. 1911. A review of the Salmonoid fishes of the Great Lakes, with notes on the Whitefishes of other regions. Bull. U.S. Bur. Fish. **39**: 32-34.

Jordan, D. S. 1923. A classification of fishes, including families and genera as far as known. Stanford Univ. Pub., Univ. Series, Biol. Sci. vol. 3, no. 2.

King, W. Ross. 1866. The sportsman and naturalist in Canada. London.

Koelz, W. 1926. Fishing industry of the Great Lakes. App. 11, Rep. U.S. Comm. Fish. for 1925.

Koelz, W. 1929. Coregonid fishes of the Great Lakes. Bull. U.S. Bur. Fish. **43**: 297-643.

Pritchard, A. L. 1928. A preliminary study of the genus Leucichthys in the Canadian waters of Lake Ontario. Univ. Toronto Stud. Biol. 31. Pub. Ont. Fish. Res. Lab. 32.

Pritchard, A. L. 1929. The alewife (*Pomolobus pseudoharengus*) in Lake Ontario. Univ. Toronto Stud. Biol. 33. Pub. Ont. Fish. Res. Lab. 38.

Rawson, D. S. 1930. The bottom fauna of Lake Simcoe and its rôle in the ecology of the lake. Univ. Toronto Stud. Biol. 34. Pub. Ont. Fish. Res. Lab. 40.

Regan, C. Tate. 1914. The systematic arrangement of the fishes of the family Salmonidae. Ann. Mag. Nat. Hist. **13**: 405-408.

Regan, C. Tate. 1925. Organic evolution. Rep. Brit. Ass. Adv. Sci. for 1925, pp. 75-87.

Richards, O. W. and G. C. Robson, 1926. The species problem and evolution. Nature **117**: 345-382.

"Salmo." 1903. Forest and Stream **60**: 65.

Smyth, David William. 1799. A short topographical description of His Majesty's province of Upper Canada, North America. London, p. 30.

Van Oosten, John. 1929. Life history of the lake herring (*Leucichthys artedi*, LeSueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. U.S. Bur. Fish. **44**: 265-428.

Department of Game and Fisheries, Ontario, Annual Reports. Toronto.

Department of Marine and Fisheries, Canada, Annual Reports. Ottawa.

Reports and recommendations of the Dominion Fishery Commission on the fisheries of the province of Ontario, 1893. Ottawa, 1894.

Canada Year Book, Department of Trade and Commerce. Ottawa, 1928.