COREGONID FISHES OF THE GREAT LAKES

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GENERAL REMARKS

THE COREGONID FISHES

The family Salmonidæ, as formerly constituted, contains less than 100 species, which are distributed in the temperate and arctic regions. In the systematic arrangement formerly followed by ichthyologists it was divided into two subfamilies—the Coregoninæ and the Salmoninæ. Cope (1872) thought that the differences between the two types of fishes concerned were sufficiently marked to place them in separate families. Accordingly, he proposed the family Coregonidæ for those fish of the group with united parietals and retained Salmonidæ for those with parietals separated by the supraoccipital. Gill (1895) believed that Cope was wrong in his observation that the parietals were united in Coregonus, reduced Coregonidæ to subfamily rank, and combined it with Salmoninæ under the Salmonidæ. Regan (1914) retained these subfamilies but not the characters on which Gill based them. Regan's Coregoninæ are Salmonidæ with "parietals meeting in the middle line;

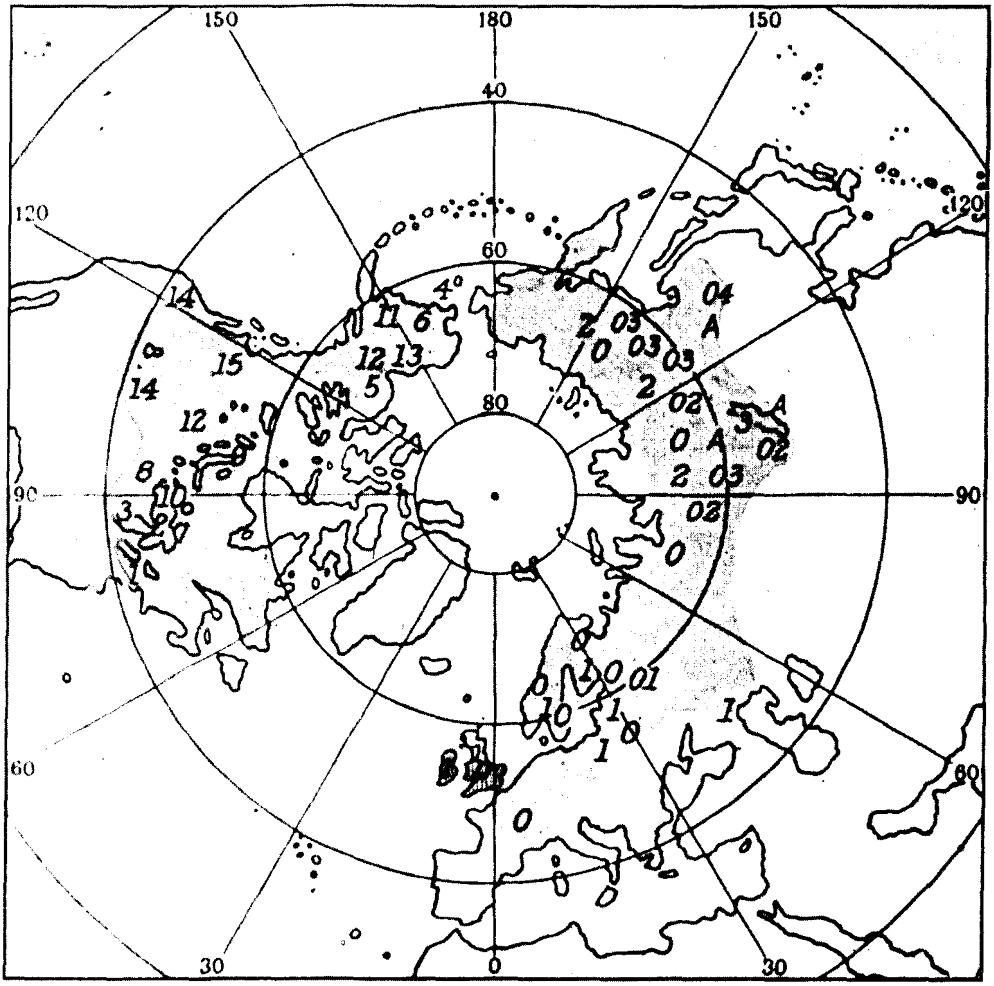

Fig. 1.—Map of the boreal regions, showing approximately the known distribution of the coregonids. Modified after Meek

teeth on vomer and tongue, when present, in several series; scales larger, 13 or less in a transverse series from the origin of the dorsal fin to the lateral line." Regan recognized four genera—Stenodus, Coregonus, Phylogephyra, and Thymallus. Coregonus is distinguished from the others chiefly by having no teeth or vestigial ones. In agreement with Cope recent American writers have accepted the family Coregonidæ, and I follow current American practice in this paper.

The genus Coregonus, as recognized by Regan and most other European ichthyologists, includes all the known species of whitefish and lake herring, but certain American ichthyologists have recognized several minor groups of species and have given them generic or subgeneric names. Thus, the lake herrings are placed by Jordan and Evermann (1911) in the genus Leucichthys under three subgenera, Thrissomimus, Cisco, and Allosomus, while the whitefishes are placed in the genus Coregonus under the subgenera Coregonus and Prosopium. For reasons to be given later, I do not find their arrangement satisfactory. I hold the three groups Leucichthys, Coregonus, and Prosopium as distinct genera and disregard the subgenera of Leucichthys.

The genus Coregonus of the Europeans, which is approximately the family Coregonidæ of Americans, has an almost completely circumpolar distribution. (See fig. 1.) The various species occur in rivers, lakes, or in the ocean. Certain Siberian species spend most of their life in the Arctic Ocean but ascend rivers periodically; while others, notably the Scandinavian species *albula* and *lavaretus* and the American *quadrilaterale*, are supposed to occur in lakes, rivers, and in the sea. Most of the recognized species, however, are confined to inland lakes.

STATEMENT OF THE PROBLEM

Wherever they occur, the coregonids, like the salmonids, are important food fishes; but probably nowhere else do they attain so much importance in the fisheries as in the region of the Great Lakes. In view of the great importance of these fisheries it is desirable, from a purely economic point of view, to determine what forms are found in the various lakes of the region and to obtain full knowledge of the natural history of these forms and of the conditions under which they live. Without such knowledge any legislative or fish-cultural steps designed to conserve the fisheries concerned must be unintelligent in character and their success must be a matter of chance. The present investigation had as its object the determination of the forms of coregonid fishes that occur in these lakes and the collection of data on their natural history. In addition to its economic significance, the problem is one of scientific interest. It concerns not merely the ecology of the Great Lakes species but it involves also the ultimate consideration of their origin and evolution and of their relationships with one another and with the coregonids of Asia and Europe, as well as with those of other parts of America.

SOURCE OF MATERIAL AND DATA

THE GREAT LAKES

This investigation of the systematic relationships and the natural history of the coregonids was begun on Lake Huron for several reasons. Inasmuch as this lake, together with the North Channel and Georgian Bay, presents a maximum differentia-

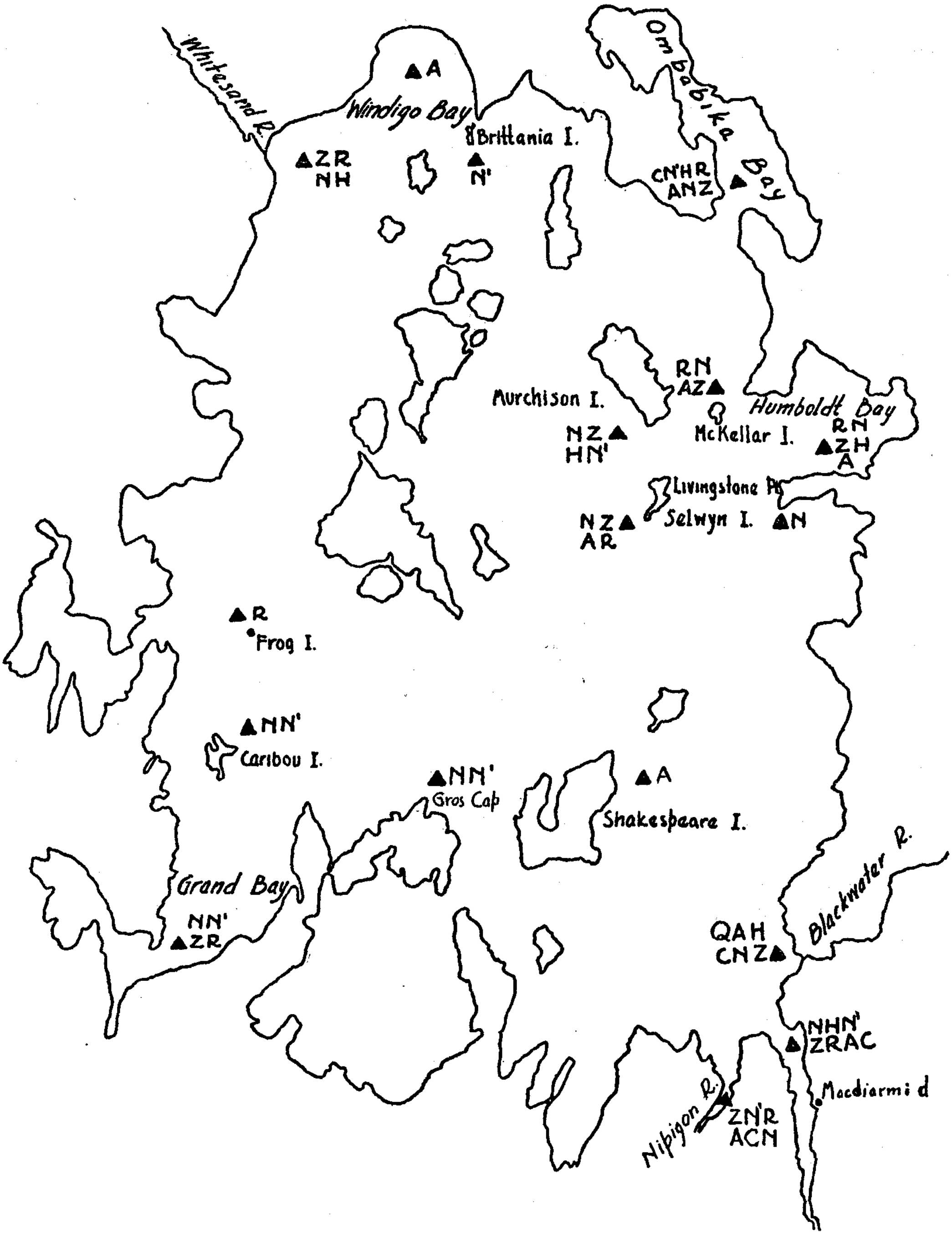

FIG. 2.—Lake Nipigon, showing the location of the distribution records of the various coregonids from Tables 26, 34, 46, 62, 75, 79, and 90. The letters beside the triangles are the first letters of the various specific names, except that for *Leucichthys nipigon* the letter N′ has been used and for *Leucichthys alpenæ* the letter A′. The letters N and A appearing elsewhere in the figure represent *L. nigripinnis* and *L. artedi*.

tion of aquatic habitats, and as these are, for the most part, of considerable extent, it was to be expected that the maximum number of Great Lakes forms would be found here. In addition to this, there are many fishing ports on the lake, and out of most of these various kinds of apparatus are in use, in shallow water as well as in the deeper waters, so that a considerable variety of species is taken at such ports.

The investigations were extended subsequently to the other lakes. In Lakes Michigan and Erie the commercial fishing operations are at least as extensive and varied as in Lake Huron, but in Lakes Superior, Nipigon, and Ontario the smaller species of fishes, including Leucichthys, are sought for but little by commercial fishermen, so that on the latter lakes I was compelled to make use of special apparatus. The lakes themselves differ considerably in their physical characteristics and consequently are not equal in productivity.

Lake Nipigon

Lake Nipigon, in Canadian territory, is the smallest and most northerly, as well as one of the shallowest, of the series of lakes considered in this paper. It is about 65 miles long by 40 miles wide, but its area is much interrupted by numerous islands and shallow bays, so that the total water surface is only about 1,530 square miles. Throughout most of its area the depth is less than 30 fathoms, though small areas are known with a depth of about 60 fathoms. It is connected with Lake Superior through the Nipigon River, but a fall at the river's source probably prevents the interchange of members of the fish fauna. The Canadian authorities opened the lake to commercial fishing in 1916 and have attempted to regulate the number of fishing boats and the maximum output. The annual production, which so far has been principally whitefish and trout, has averaged around 1,500,000 pounds, of which the true whitefish has constituted more than two-thirds.

Lake Superior

Lake Superior lies at the head of the Great Lakes and is the largest, deepest, and coldest of the chain. Its northern and eastern waters are controlled by the Province of Ontario, those on the south by the States of Michigan and Wisconsin, and those on the west by Minnesota. It receives the waters of Lake Nipigon to the northward and drains through St. Marys River into the North Channel. The lake is broadly crescentic in shape, with a length of about 355 miles and a width on the western half of about 70 miles and on the eastern half of 90 to 110 miles. Its area is about 32,000 square miles. The main body of the lake is more than 100 fathoms in depth, and a sounding of 196 fathoms has been recorded. The shore on the outer curve of the crescent is precipitous, and at many points a 100-fathom depth can be reached within 2 miles of land. The bottom slopes more gradually from the southern shore, and the 50-fathom contour is on the average about 5 or 6 miles out. There are several bays and a number of large islands in the lake, in and around which conditions are more tempered than in the lake itself. These areas, however, are relatively insignificant, and the only important stretches of shallow water lie in the Apostle Islands region, Whitefish Bay, and in the bay region on the north shore. The shores are rocky for the most part, except on the south, where there are broad stretches of sand, gravel, and clay. Most of the bottom in the deeper parts is clay.

The principal species of commercial fish are the whitefish, trout, and herring. The annual production has averaged about 15,000,000 pounds, of which the coregonids have comprised the bulk.

Lake Michigan

Lake Michigan is the only one of the Great Lakes that lies wholly within American jurisdiction. On the north and east its waters are controlled by the State of Michigan, on the west by Wisconsin and Illinois, and at the extreme south by Indiana. The lake is about 325 miles long, with an average width of 65 miles and an area of about 22,000 square miles. In the lake bottom are two basins—one at each end—separated in the center by an uneven stretch about 60 miles in length, which bears several well-defined though yet uncharted reefs. From the south the bottom slopes very gradually (at the rate of 1 or 2 fathoms to a mile) into a basin with a maximum recorded depth of 97 fathoms. In this depression a somewhat circular area, about 40 miles in diameter, is inclosed by the 60-fathom contour. The rise to the elevation in the center is rather abrupt and begins about 100 miles from the southern shore. The most extensive depression extends for about 100 miles in the northern half of the lake and is overlaid by 90 to 144 fathoms of water. The 90-fathom contour roughly outlines a triangle with the apex pointing north. For about 50 miles the figure has an average width of 30 miles and then tapers rapidly. So far as is known this area is not productive. The rest of the northern sector is dotted with islands and reefs with conspicuous depressions between. Green Bay, with an approximate area of 1,700 square miles and a maximum depth of about 20 fathoms, and Grand Traverse Bay, with an area of about 300 square miles and a maximum depth of more than 100 fathoms, are the only extensive bays, and both lie near the north end. The bottom along the shore is largely sand, but there are stretches of clay and, in the north, of rock. The deeper waters overlie clay for the most part.

The principal species are whitefish, chubs, herring, trout, perch, and suckers. The annual production has been about 25,000,000 pounds, of which usually half or more were coregonids.

Lake Huron

Lake Huron is situated in the center of the Great Lakes chain, and its waters lie about equally within the jurisdiction of the Province of Ontario on the east and the State of Michigan on the west. It receives the waters of Lake Superior through St. Marys River and those of Lake Michigan through the Straits of Mackinac. It drains southward through the St. Clair River, Lake St. Clair, and the Detroit River into Lake Erie. Its greatest length, from the head of the St. Clair River to the Straits of Mackinac, is about 250 miles and the greatest width (near the middle) about 100 miles. Excluding Georgian Bay and the North Channel, the lake has an area of approximately 17,500 square miles.

Lake Huron is divided into two approximately equal areas by the Big Reef, which extends continuously from Point Clark, Ontario, to North Point, Mich. North of the reef lie the deepest waters of the lake. Here the 30-fathom contour is rarely more than 10 miles from shore, and a considerable portion of the area lies within the 60-fathom curve. The maximum depth of 125 fathoms known in the lake is found here. The southern portion is shallower. Here depths of 30 fathoms

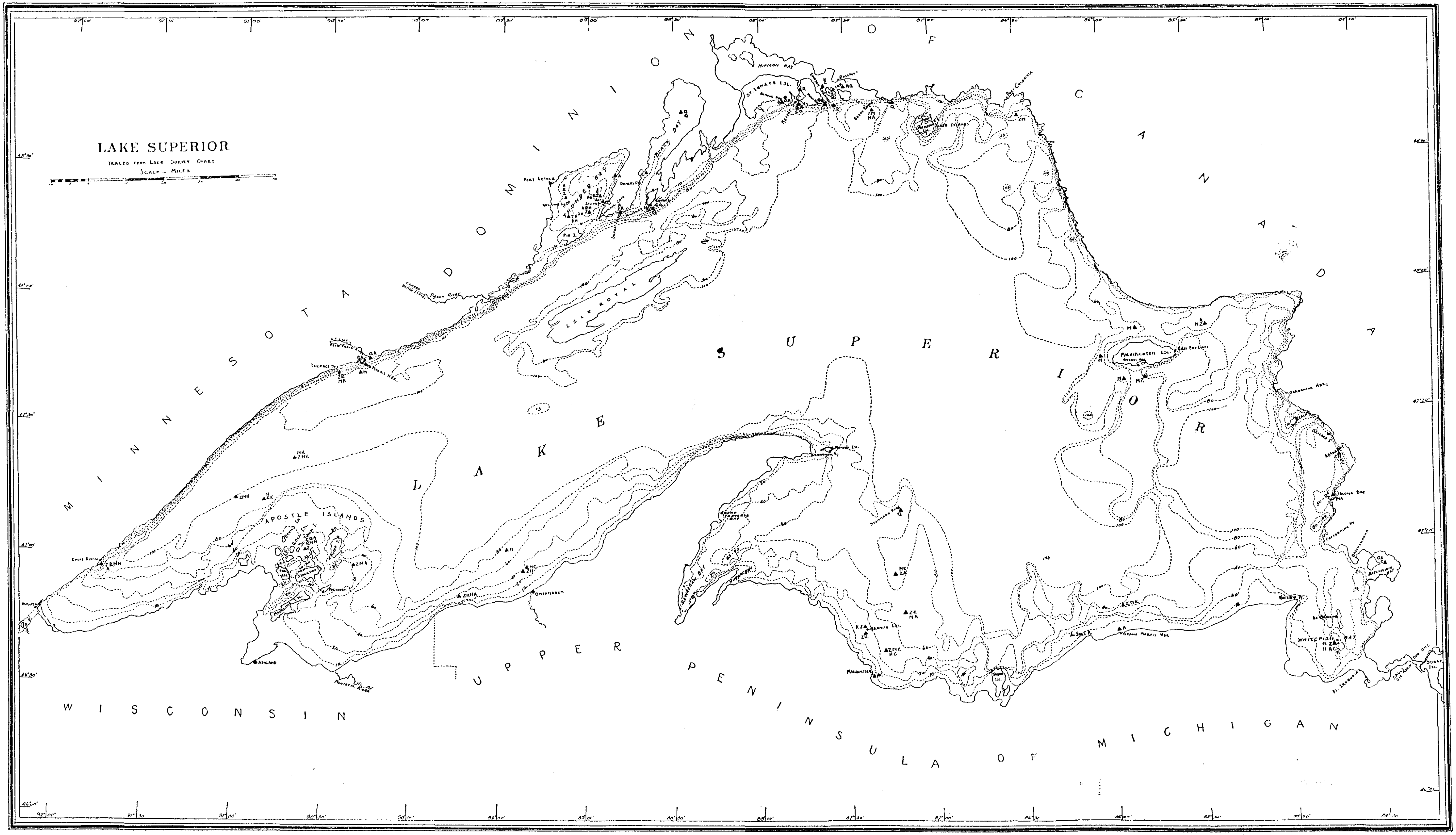

FIG. 3.—Lake Superior, showing the location of the records of occurrence of the coregonids from Tables 24, 36, 44, 52, 60, 73, 87, and 100. (See legend to fig. 2.)

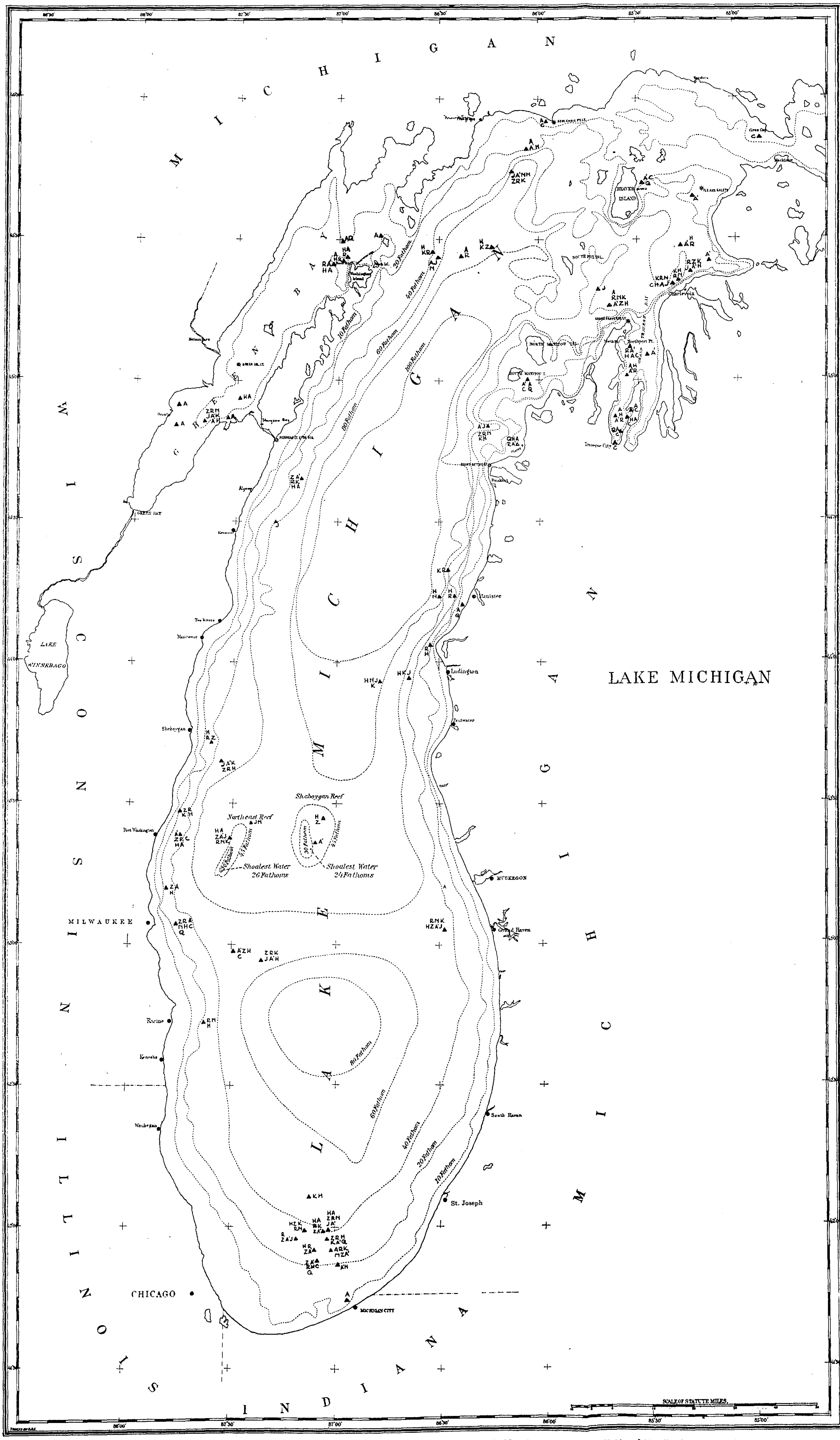

FIG. 4.—Lake Michigan showing the location of the records of the occurrence of the coregonids from Tables 16, 20, 28, 32, 40, 48, 56, 68, 81, and 96. (See legend to fig. 3.)

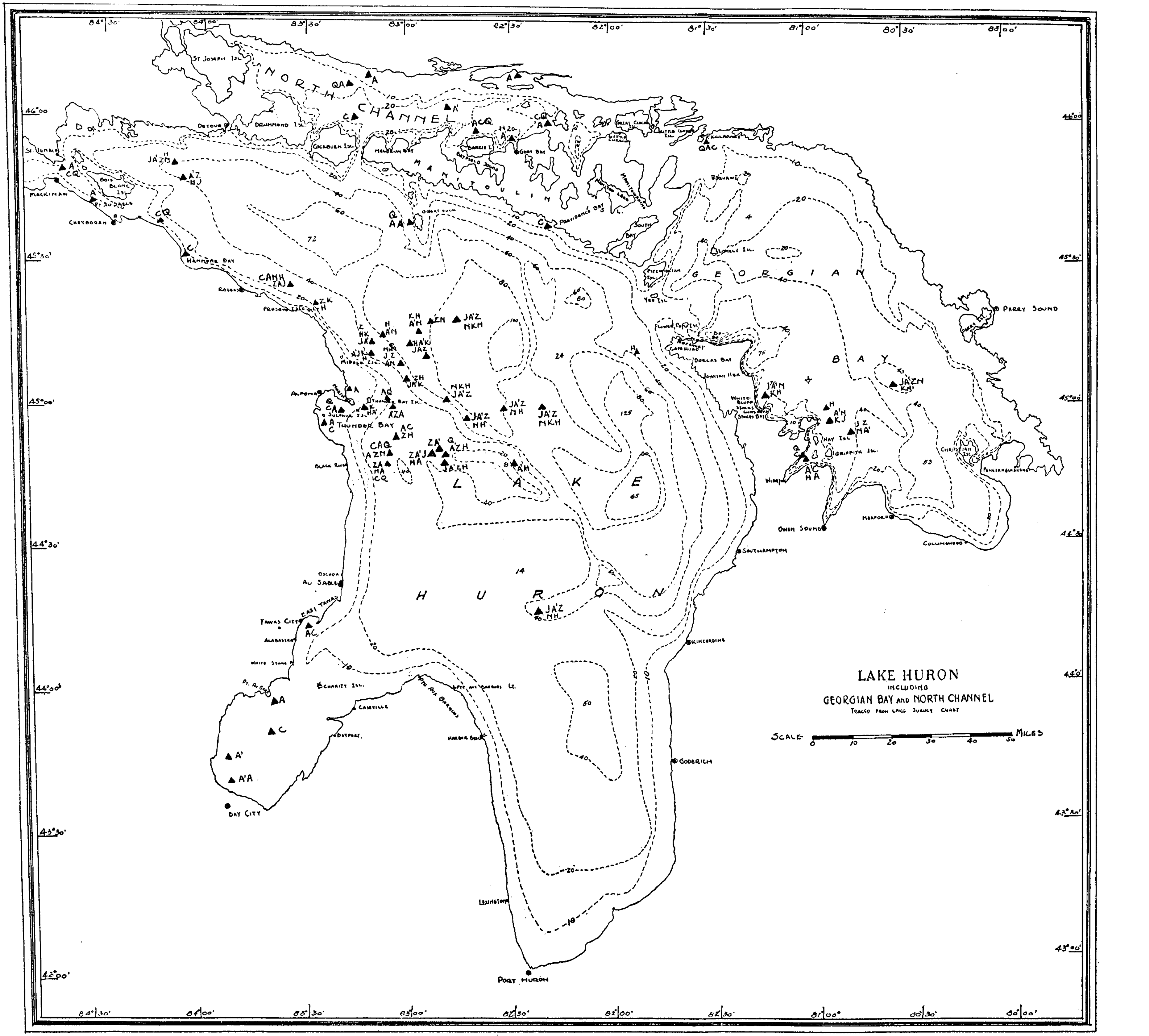

FIG. 5.—Lake Huron, showing the location of the records of occurrence of the coregonids from Tables 18, 22, 30, 42, 50, 58, 70, 84, and 98. (See legend to fig. 2.)

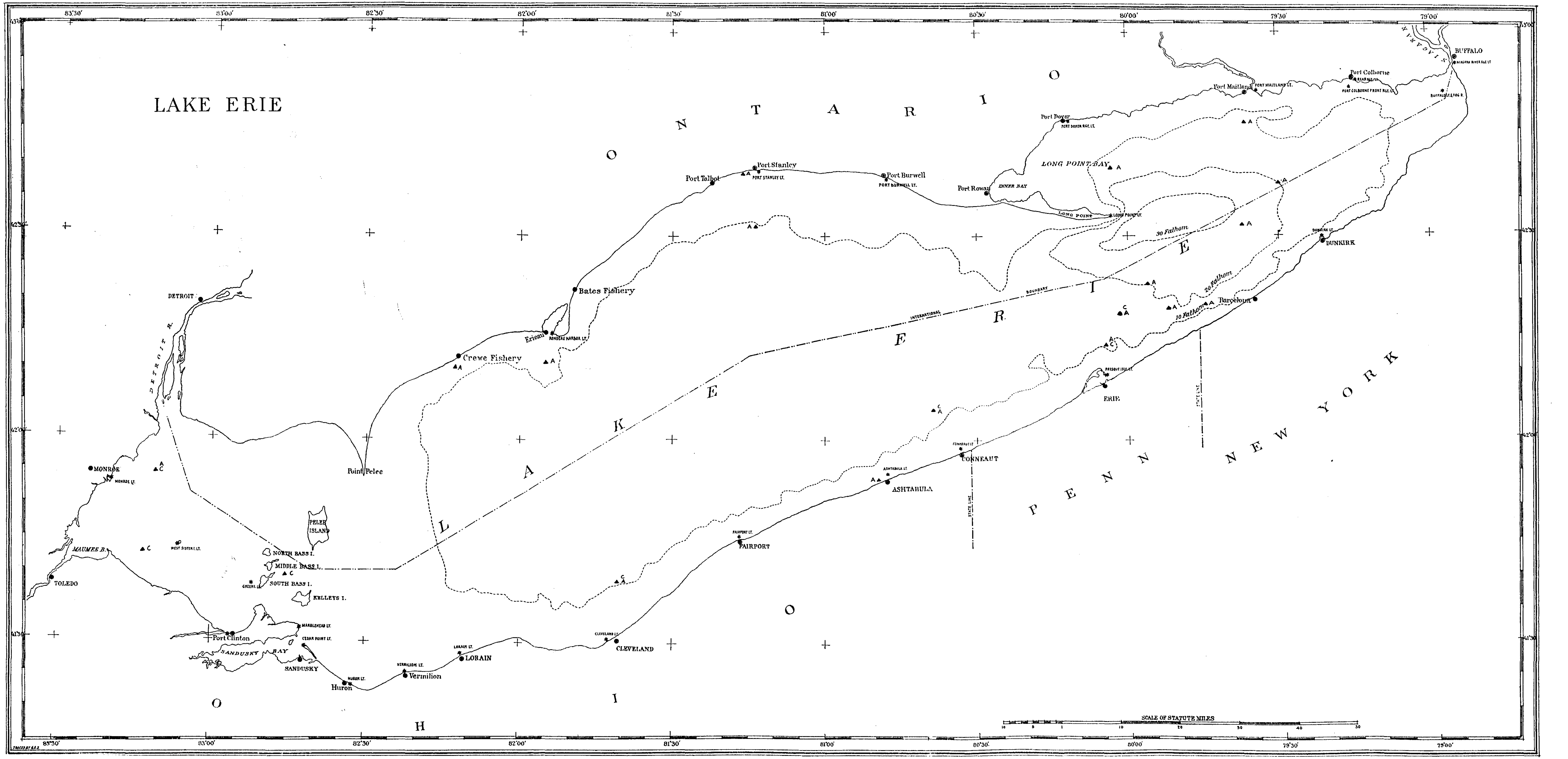

FIG. 6.—Lake Erie, showing the location of the records of occurrence of the coregonids from Tables 66 and 92. (See legend to fig. 2.)

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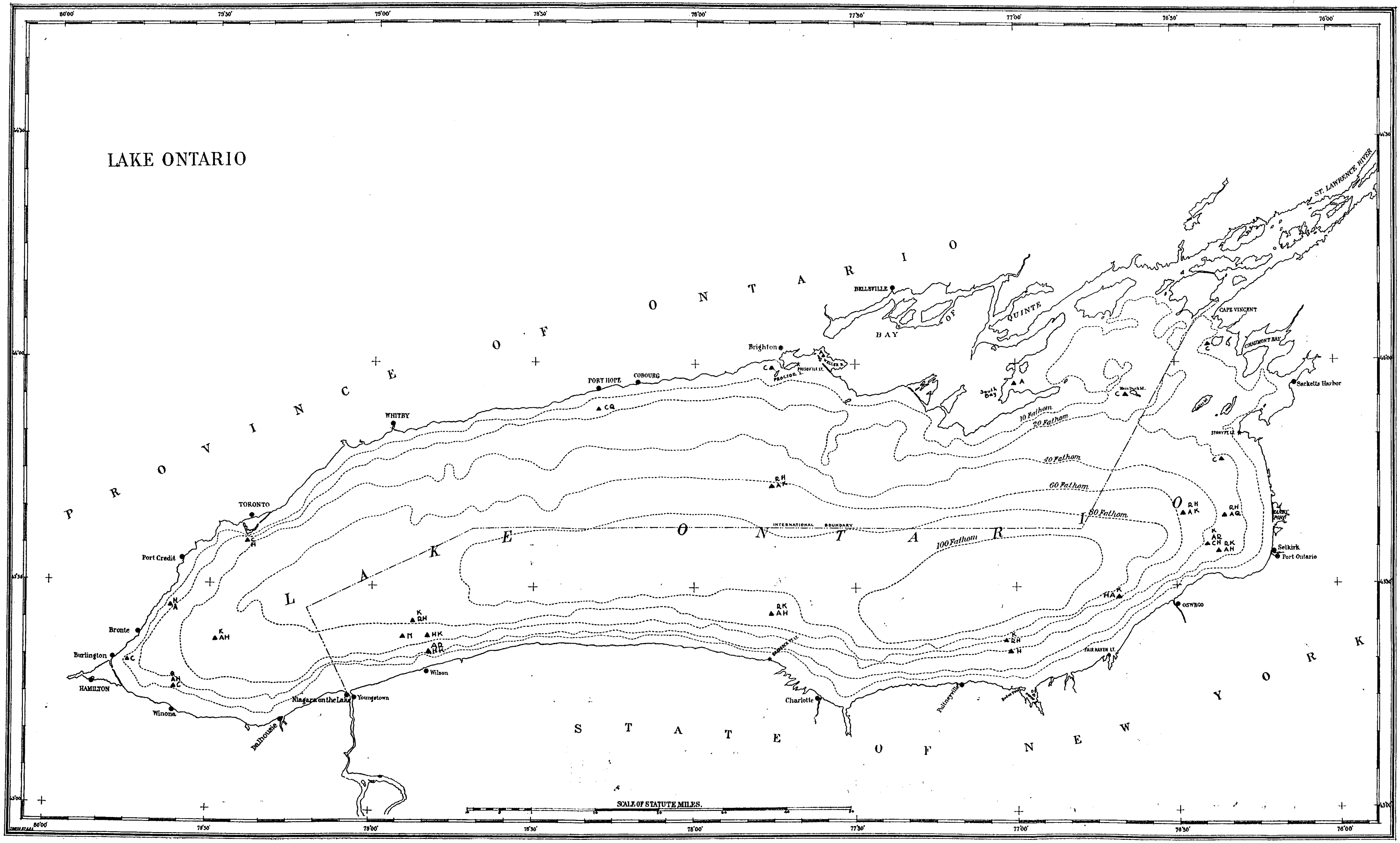

FIG. 7.—Lake Ontario, showing the location of the records of occurrence of the coregonids from Tables 38, 54, 64, 77, and 94. (See legend to fig. 2.)

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and less are more extensive, and the maximum depth known is only 54 fathoms. The bottom along shore is variable in character, consisting of rocks, bowlders, gravel, sand, clay, and mud, irregularly distributed. The deeper waters overlie chiefly clay and mud.

Separated from the main body of the lake and wholly within Canadian territory are the divisions known as the North Channel and Georgian Bay. Their water surfaces are approximately 1,500 and 5,000 square miles. From the junction of the North Channel with the St. Marys River to the foot of Georgian Bay at Collingwood is a distance of about 240 miles, while the greatest width of the district, from the mouth of the French River to the junction of Georgian Bay with Lake Huron, is about 60 miles. The North Channel and the northern and eastern shores of the bay are dotted with numerous islands and reefs, and the best fishing grounds are in these sections. The water in the North Channel deepens from north to south, with the maximum depth of 29 fathoms off Manitoulin Island, which forms its southern shore. The average depth is about 20 fathoms. The floor of Georgian Bay is tilted also, but from east to west, so that the deepest waters lie hard off Bruce Peninsula. From the east the slope is gradual, and the 40-fathom contour approximately bisects the bay from north to south. The descent into depths of 60 to 90 fathoms is rapid. The shores for the most part are rocky, but stretches of sand, gravel, and clay are not uncommon. In the deep water the bottom is clay.

Whitefish, herring, chubs, trout, wall-eyed pike, and suckers are the principal species. The annual production has been in Lake Huron, about 15,000,000 pounds, of which coregonids have averaged nearly half. In the North Channel and Georgian Bay the annual production has been around 5,000,000 pounds, of which coregonids constituted about one-third.

Lake Erie

Lake Erie has an area of approximately 10,000 square miles, exceeding in size only Lakes Ontario and Nipigon. Its length is about 250 miles, and the average width is about 45 miles. It is bounded on the north by the Province of Ontario, on the west by the State of Michigan, on the south by Ohio and Pennsylvania, and on the east by New York. Lake Erie receives the waters of the upper Great Lakes through the Detroit River and drains through the Niagara River. The deepest water occurs in the eastern sector, in that part bordered by Pennsylvania, New York, and the portion of the Canadian shore lying eastward of Long Point. The maximum depth recorded is 35 fathoms off Long Point. The stretch for 100 miles between Long Point and Point Pelee is a nearly flat plain covered by no more than 14 fathoms of water. East of Point Pelee is a shelf with numerous islands and reefs, having a maximum depth of 7 fathoms.

Lake Erie offers most favorable conditions for the growth of fish, and in virtually every census, in spite of its small size, it has led all the lakes in quantity of production. On account of its shallowness, warmth, and diversified conditions, many species of fish occur in its waters, and no less than 15 species have been important at one time or another in the commercial catches. In late years the most important species have been herring, whitefish, wall-eyed pike, perch, and saugers. The annual production has ranged probably between 40,000,000 and 75,000,000 pounds, of which the coregonids supplied about half.

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Lake Ontario

Lake Ontario is the easternmost and, excepting Lake Nipigon, the smallest of the Great Lakes and is bounded on the north and west by the Province of Ontario and on the south and east by the State of New York. It has a length of 185 miles, an average width of 40 miles, and, with its bays, a total area of about 7,300 square miles. There are no islands or shoals except near the outlet, where it discharges into the St. Lawrence River. The shores everywhere slope rapidly into deep water, but most rapidly on the south, and the deep trough runs nearer this shore. The 30-fathom contour on an average runs less than 3 miles from land on the southern shore, while on the north it is about 5 to 10 miles distant. The trough broadens toward the east and is overlaid by depths of 70 to 90 fathoms in the western half and by 90 to 123 fathoms in the eastern half. The bottom over most of the lake is clay with narrow stretches of sand and rock along the shores, particularly among the islands at the eastern end.

The lake's output is less than that of any of the others except Lake Nipigon, but in the early days fish seem to have been rather common in it. The annual yield has been about 5,000,000 pounds, most of it from the Canadian side. The principal species are whitefish, trout, and herring, with the coregonids predominating.

FISHING METHODS

The gill net is the type of apparatus most widely used on the Great Lakes. Gill nets of three sorts are in general use: (1) Nets of mesh of about 4 to 4¾ inches, stretched, though the mesh may be larger at certain seasons (these are used principally for whitefish and trout); (2) nets of 2 to 3 inch stretched mesh (these are employed chiefly for the lake herrings and chubs); (3) nets of about 1½-inch stretched mesh (used to take bait for the trout hooks).

Pound nets, with the related trap, crib, and fyke nets, are employed in the shore fisheries and take all the species that occur along the shores. All of them, of necessity, are restricted to use in shallow water and are therefore most numerous in those lakes where there are broad shoals. The use of certain varieties is proscribed within the jurisdiction of certain of the Governments that control the lakes.

Seines are now employed only in special fisheries and take few coregonids.

Hooks are used commonly in some of the lakes, principally for trout. Coregonids are never taken in commercial quantities by them.

For a more complete account of the fishing industry of the Great Lakes, consult Koelz, 1926.

COLLECTION OF DATA

Localities and Dates

In Tables 1 to 4 are given the localities visited in making collections and in gathering data for this paper, together with the periods of time during which the work was carried on and the number of lifts examined and specimens of each kind of fish preserved. While approximately 16 months were spent in the field, during only a fraction of this time was it possible to make observations. Much time was consumed in traveling from one port to another, and bad weather, especially in the fall, often prevented fishing operations for days at a time. During the entire period many thousand pounds of fish were seen and examined, and a total of about 15,000 specimens was collected. These are mostly catalogued and preserved in the Museum of Zoology of the University of Michigan at Ann Arbor.

Field Methods

In the field it was my practice to be present when the nets were being lifted. In the case of the whitefish usually it was possible then to examine nearly every fish taken in the lift; but in the case of Leucichthys the individuals of a catch were far more numerous, so that it was possible to examine only samples of the catch. In any case these samples seldom comprised less than one-tenth of the catch and often (in the case of lifts under 1,000 pounds in weight) constituted half or more. The results of these examinations are given as applicable to the whole catch.

In addition to actual specimens, stomachs were collected also, chiefly on Lake Huron. These have been examined by Dr. Carl L. Hubbs, of the Museum of Zoology, University of Michigan, and his report is given under the heading "Food" for Lake Huron species.

At first fish were measured in the field, but as these measurements, of necessity, were made under such adverse conditions that it was not possible to check them, the practice was discontinued. Records of fish companies and log books of fishermen showing the weight and the locations of catches were copied wherever they could be obtained conveniently, and from every port the accounts of the habits of the various species of coregonids were recorded as given by the fishermen. Information of this kind has been secured through correspondence, also.

As a result of all the field work adequate material was made available on which to base conclusions regarding the systematic status of the various forms that occur in the Great Lakes. These conclusions from the study of specimens are supported by the accumulated field data dealing with the geographical and bathymetric distribution of these forms in the lakes, with their breeding grounds, breeding seasons, and their food.

EXPLANATION OF TERMS AND NOMENCLATURE

GLOSSARY

Measurements

All specimens collected were examined or reexamined in the laboratory. All measurements were made with fine dividers, calipers, a steel tape, and a wooden rule gauged in millimeters. The percentages and proportions used in the text or in the tables were arrived at by arithmetical calculation. The form of expressing the range of values is an arbitrary one. The usual values of a series given between the figures in parentheses (which are the extremes) represent, roughly, two-thirds of the individuals in that series. No series was subjected to statistical treatment because the number of individuals in none is adequate for refined analysis. All parts were measured and counted on the left side wherever possible. The method of making the measurements, the actual points from which measurements were made, and the symbols by which the measurements are designated in the tables and in Figure 8 are given below:

Length (L).—Measured from the junction of the premaxillaries to the end of the last vertebra. If the specimen was distorted, it was returned as nearly as possible to its original shape. All measurements were made with dividers and then read on the rule, or the points marked by pins and measured with the tape.

Snout to dorsal (SD).—Measured from the junction of the premaxillaries to the base of the first dorsal ray.

Snout to anal (SA).—Measured from the junction of the premaxillaries to the base of the first anal ray.

Dorsal to adipose (DA).—Measured from the anterior end of the base of the dorsal fin to the anterior end of the base of the adipose.

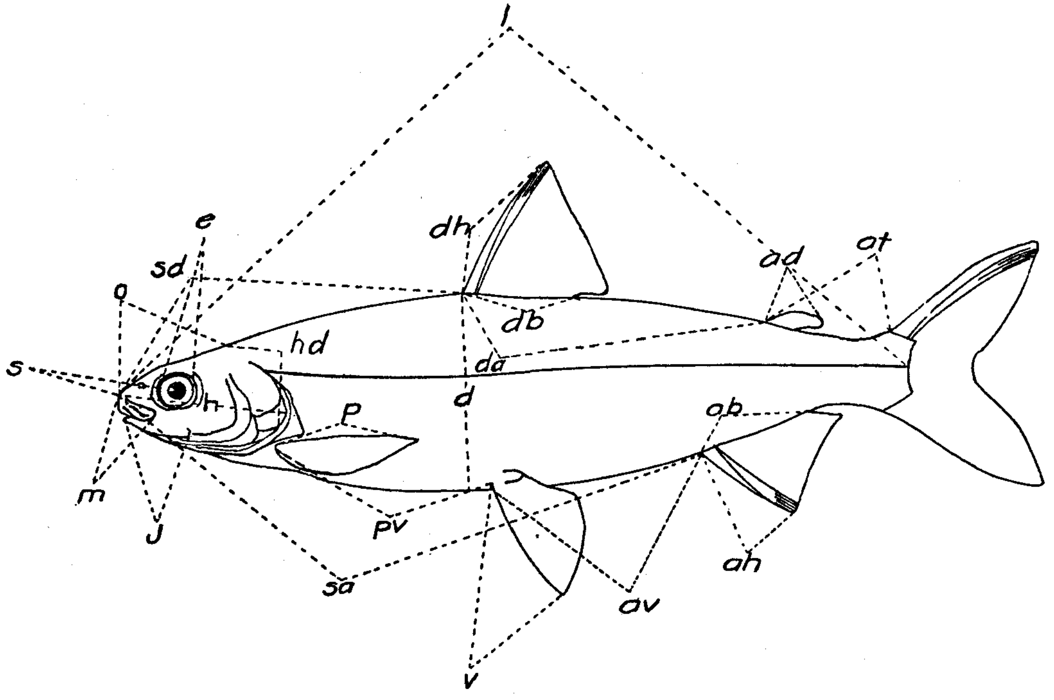


FIG. 8.—Outline of the whitefish, showing how the measurements referred to in the text and tables were taken

l—length
sd—snout to dorsal
sa—snout to anal
da—dorsal to adipose
at—adipose to caudal
h—head
o—occiput
s—snout
p—pectoral length
v—ventral length
ad—adipose length
db—dorsal base
ab—anal base
dh—dorsal height
ah—anal height
pv—pectoral-ventral distance
m—maxillary
j—mandible
e—eye
av—anal-ventral distance
d—depth
hd—head depth

Adipose to caudal (AT).—Measured from the anterior end of the adipose base to the first of the upper procurrent caudal rays.

Head (H).—Measured with dividers from the junction of the premaxillaries to the extreme bony margin of the operculum, not including the opercular membrane. This measurement, therefore, as given has not always been made parallel to the longitudinal axis of the body.

Head depth (HD).—Measured with dividers from the outer edge of the boundary between the suboperculum and interoperculum to the base of the occiput.

Occiput (O).—Measured from the junction of the premaxillaries to the end of the supraoccipital bone, not to the beginning of the scales. The exact point was determined by feeling with a sharp instrument.

Snout (S).—Measured from the junction of the premaxillaries to the anterior bony margin of the orbit. The dividers were inserted into the eye socket.

Maxillary (M).—This is in reality a measurement of the upper jaw and is taken from the symphysis of the premaxillaries to the caudal end of the maxillary bone.

Mandible (J).—Measured from the articulation of the articular with the cranium to the symphysis of the dentaries.

Eye (E).—The measurement given is the horizontal diameter of the eyeball, not the distance across the cornea. Dividers were inserted into the eye sockets and their points brought against the eyeball at the ends of its longitudinal axis. Care must be taken not to compress the ball in fitting the divider points.

Fin length (P, V, Ad).—Measured from the origin of the fin to the tip of its longest ray, or, in the case of the adipose, to its distal end.

Fin bases (DB, AB).—The length of the base of the dorsal and anal fins.

Dorsal coefficient (DC).—The height of the dorsal divided by its base.

Anal coefficient (AC).—The height of the anal divided by its base.

Pectoral-ventral distance (PV).—The distance between the anterior ends of the insertions of the pectoral and ventral fins.

Ventral-anal distance (AV).—Measured from the anterior end of the insertion of the ventral fin to the corresponding point of the anal.

Depth (D).—The greatest vertical depth of the body measured with calipers.

Width (W).—The greatest width of the body measured with calipers. In bloated specimens the width was taken in the region of the lateral line. This character is very unsatisfactory, inasmuch as the width of the body very frequently has been reduced by artificial compression in the preserved material.

Counts

Gill rakers (R).—The left arch, after being carefully removed with a sharp scalpel, was held completely spread out, and the counts were then made. (Care must be taken, in removing the arch, that no rakers are lost at the ends.) By this method the number of gill rakers on each part of the arch can be determined readily. Every visible raker has been included in the counts.

Scales in lateral line (SC).—In specimens with all their scales only those scales with pores were counted. In some specimens a few scales at the caudal end of the line lack pores. These have not been included in the counts. When scales had been lost accidentally from the lateral line, however, the scale pockets were counted throughout the entire length of the lateral line.

Longitudinal scale rows.—These were counted around the body at three locations—(1) just in front of the dorsal and ventral, (2) just in front of the adipose and the anus, and (3) around the caudal peduncle just behind the adipose and anal. The rows run lengthwise of the fish and can be counted easily except in the proximity of the fins. In front of the dorsal and adipose fins and behind the adipose and anal fins there frequently are developed very short rows, comprising sometimes only one or two scales. All these were considered rows and were included in the counts.

Fin rays (DR, PR, VR, AR).—In the dorsal and anal fins the first one or two unbranched rays are poorly developed. Only when their length approached three-fourths that of the longest ray of the fin were they included in the count. Every ray in the pectoral and ventral fins was counted.

Vertebræ.—The flesh was removed from one entire side of the fish until the vertebral column was plainly exposed. Every vertebra was counted, including the last of the upturned ones at the base of the caudal fin.

Pyloric cæca.—The gut was removed and each cæcum picked off with the forceps. The count includes the cæca on the small intestine.

Branchiostegal rays (Br).—Every ray in the membrane was counted.

Miscellaneous Terms

Body.—Where the term "body" is used in the text it is meant to designate the body of the fish exclusive of the head.

Pearl organs.—These excrescences of the epidermis are developed only during the breeding season, often only in males. They attain their greatest development in the coregonids on the scales of the sides but also are evident on those of the other surfaces and usually on the head and fins.

SYSTEMATIC TREATMENT

In many groups of animals most of the species have been described already, and systematists, in turning their attention to the analysis of these species, have found that a species group is by no means so homogeneous as was supposed originally. It appears that most animals and their offspring, either from incapacity to do otherwise or from choice, breed in an area that, in comparison with the range of their species, is very restricted. Regional differences in structure or habit, associated with conditions of the environment, may be developed, therefore, and the animals of a species in certain localities may be distinguished by peculiar features. In the case of land animals it has been current practice to call these geographic races or varieties subspecies. Some species appear to be more plastic than others, and the number of subspecies that has been recognized in some species groups has reached a confusing total. Though it has been apparent that in certain widely separated regions the same sort of changes often were exhibited by the species of an animal group (for example, the coastal areas of British Columbia and Labrador are inhabited by several races of widely distributed birds that are darker than their relatives of the same species elsewhere), the changes are not identical throughout; and in general it is not known to happen commonly that two intraspecific groups of animals alike in their external features occur in geographically separated areas. In other words, the range of a terrestrial subspecies is considered continuous, and a subspecific name has a geographic connotation.

As a matter of fact, probably no species has a strictly continuous range. Its distribution depends on the distribution of suitable areas within the broad limits of its range. Thus, animals that inhabit swamps are found only where in their range swamps occur, and one such swamp may be separated by a vast distance from another.

To be sure, in mountainous areas, where altitude alters the natural effects of latitude, and in insular areas like habitats may be markedly disconnected and the ranges of a morphologically distinct race likewise may be interrupted. Where these areas of similarity are not widely separated geographically or, geologically speaking, in time, the distinctive races may be considered subspecies, as usually their relationships with other members of the species group is clear even though they are so separated from them that there is no possibility of finding intermediate forms, which ideally is the criterion of a subspecies. But where like areas are widely separated in space and time, even though the forms in each may be nearly identical in structure and habit, taxonomists generally have preferred to consider them species rather than subspecies.

In aquatic habitats such zoogeographical islands also may occur; in fact, lakes are particularly good examples of isolated habitats. Though the types of lakes vary within certain limits, it is also true that aquatic habitats are simpler, in general, than terrestrial ones; they are influenced by fewer variables. Land habitats vary more because of differences in humidity, temperature, light, soil, elevation, etc. In aquatic environments humidity is not a variable, and temperature is limited in temperate regions between 0° and 25° or 30° C. At depths temperature differences are even eliminated, as are those of illumination. There remain differences in the chemistry of the water, depending on the soil of the basin, in depths, and exposure to wind. Where variables like temperature are not involved, the ordinary effect of latitude, which is so important in the distribution of land animals, is minimized; and, of course, where factors are few, the chances of finding them frequently in like combinations are greatest. It is thus possible to find in a lake in Indiana, as far as certain species are concerned, the same sort of habitat as in a lake in Canada 500 miles farther north; and it is likewise possible that two lakes in the same township may be so totally different in their physical conditions that their fish populations are very dissimilar. Now, in a given species the same mutation has a tendency to recur with a somewhat definite frequency. If it marks a higher degree of habitat adaptation than its parent in one place, and therefore tends to supersede its parent, it is only natural to expect the same outcome in another location where the environment is the same. It should not be surprising, then, to find varieties of a species of fish distributed according to the type of habitat rather than according to geographic zones.

The forms of the Great Lakes whitefishes thus appear to be distributed. The deep-bodied type of herring (*Leucichthys artedi*) is distributed here and there in lakes between New York and Manitoba, while in other lakes in this area the other extreme in development possible to this species may occur. Where two morphologically distinct forms of a species occur in the same lake, both extremes may be found in the area of intergradation, whether as a result of migration or of Mendelian segregation of interbred characters.

Botanists are confronted regularly with the irregular distribution of morphologically distinct individuals in the case of certain species of plants and find it convenient to introduce the terms "variety" and "form" in their nomenclature as units ranking less than a subspecies. In the case of the whitefishes it might be desirable, for certain reasons, to follow botanical practice; but, on the other hand, it is also desirable to keep the question of zoological nomenclature as simple as possible, and it is already sufficiently complicated by the use of trinomials. There seems to be on possibility of standardizing these new terms when systematists are not even agreed as to the definition of a "species" or even of a "genus." An understanding of relationships between the various morphological forms depends on experimental breeding, which is often impracticable; and even where it is not, the results of such breeding may not leave the experimenter much the wiser. After all, a scientific name is regarded best only as a name. When its originator attempts to describe either the characteristics of the group of animals it stands for or to reflect in it his opinion of the origin or relationships of that group he meets with difficulties in expressing himself within the codes of nomenclatural standards.

I use here a subspecific name to designate individuals or a group of individuals that are distinct, morphologically, from a similar group of other individuals of the same species, regardless of what the relative distribution in space of those individuals or groups may be. Thus, two subspecies may be represented in the same school or a subspecies may be scattered throughout the range of its species group.

I believe that the whitefishes offer no unique problem in the field of zoological nomenclature. Certainly many other species of widely distributed fishes will be found to exhibit the same phenomenon of irregularly distributed morphological forms when they are studied in the same way, and workers in other fields of classification already are finding, with every addition to knowledge of the variations of animals, the insufficiency of a subspecific concept that is restricted to one geographical unit.

SYSTEMATIC HISTORY OF THE AMERICAN COREGONIDS

The genus Coregonus was established by Linnæus. For a century afterwards its species were a stumblingblock to the taxonomists of Europe. Apparently on account of faulty analyses, as well as of inadequate descriptions, these early systematists failed to distinguish clearly between the various forms. So confused and vague is much of this work that often it is not even mentioned in later revisions. Through accumulated knowledge of the morphology and natural history of the various coregonids and through a better comprehension of the relationships of other groups of fishes taxonomists of more recent times have been able to make progress in the classification of these fishes. To understand to what extent the representatives of the group have been confused it is only necessary to examine the synonomy of the species given by Regan (1908) for the forms of the British Isles, by Smitt (1895) for the Scandinavian forms, by Fatio (1890) for those of Switzerland, and by Berg (1916) for those of the old Russian Empire.

The present situation in North America is much the same as in Europe. The work done has been pioneer in character and the specific descriptions, for the most part, have been based on but few specimens, often from a single locality. No really extensive studies have been made hitherto of the variations that the various forms exhibit, and the systematic work has not been checked adequately by biological data; consequently species have been multiplied and confounded. All the works on North American coregonids in which new species have been described or in which existing descriptions have been revised are abstracted briefly in the succeeding paragraphs.

Under the synonomy of each species treated in the main body of this report are given only the first description of the species or redescriptions under another name and references to it in only the two reviews of the coregonid fauna of North America—those by Evermann and Smith (1896) and Jordan and Evermann (1911) and in that of Dymond (1926) for Lake Nipigon. Few of the other works on these fishes have been critical, and often it is impossible to determine to what species the accounts refer. A more or less complete list of works containing other references to Great Lakes coregonids is appended in the bibliography.

References to the whitefishes are to be found in the earliest literature dealing with the Great Lakes region, namely, in the "Relations," of the Jesuit fathers. As early as 1634 Paul le Jeune mentioned the whitefish in the Canadian waters; and in the "Relation" of 1669 and 1670 Father d'Ablon described the method of capturing the whitefish (*clupeaformis*) at the Sault of Sainte Marie. He added that, on account of the custom of the natives to linger along the rapids for the purpose of fishing the whitefish, a mission was established at this place. He said further that a great many herring (*artedi*), which were much like those of the sea in shape and size but were not quite as good for food, were taken in Superior, particularly in November. Explorers of the eighteenth century (Charlevoix, Hennepin, Lahontan, and others), also spoke of the whitefish and attested to its fine qualities as a food fish.

Pennant (1792) was the first zoologist to record an American species of Coregonus. He stated (on p. 298) that "*Salmo laveretus* or *gwiniad* is found in Hudson Bay in vast abundance." He added that "there is a lesser kind called the Sea Gwiniad," which he describes briefly. Richardson (1823), said these fish undoubtedly were *C. clupeaformis* and *P. quadrilaterale*, for the reason that no other fish of similar appearance or habit were known from the area that Pennant visited. A later mention of the whitefish, which antedated the first description by about three years, was made by DeWitt Clinton in a letter to S. L. Mitchill, dated February 1, 1815. He said in this letter that the whitefish is the most delicious of the fishes in the western waters and that it must be a nondescript Salmo, judging from the account he received of its form and habitudes.

Dr. S. L. Mitchill (1818) described the whitefish, which he called *Salmo clupeaformis*,[1] whitefish of the lakes. The description is based on a specimen obtained from the falls of St. Mary at the northern extremity of Lake Huron, and is the first scientific description of an American Coregonus. While the description is not adequate, and was supposed, for many years afterward, to refer to *artedi*, it seems safe to assume that Mitchill actually had the whitefish. The review of the remaining literature on American forms follows in chronological order.

LeSueur, C. A., 1818.—Inadequate descriptions of two coregonids are given—*Coregonus artedi* and *C. albus*. The latter is figured. The two fish thus described are lake herring. As they were taken from Lake Erie (though the former was said to occur in the Niagara River also), LeSueur must have had in hand the two types of herring that are known to occur there—the blueback, which is found in the other lakes, and the cisco, a fatter and broader variety, which is abundant in Lake Erie. It has been supposed by many ichthyologists, erroneously, that LeSueur had the true whitefish (the Erie form of *clupeaformis*) in mind when describing *albus*, and consequently the name *albus* has been associated with this form. A study of the original account indicates that this is not likely, even though LeSueur did say that *albus* was called the whitefish. He says, for example, "This species differs from the preceding one (*artedi*) in its body having more depth, its back a greater

[1] This name has been altered frequently to the classically correct form *clupeiformis*.

elevation, and its proportions much stronger in body, fins, and scales." He records no difference in the shape of the snout, which for *artedi* is "pointed." The figure of *albus* made by LeSueur himself is distinctly not a Coregonus.

Richardson, John, 1823.—*Coregonus quadrilateralis* from "the small rivers about Fort Enterprise and in the Arctic Sea" is described. The description is recognizable and is accompanied by a crude cut. A fish is described as *C. albus*, which is undoubtedly the whitefish, and the tullibee is mentioned under the name *C. artedi* ?.

Richardson, John, 1836.—On page 201 of this publication (Fauna Boreali-Americana, Vol. III) is given a description of *Salmo* (*Coregonus*) *tullibee* from Cumberland House, Pine Island Lake, latitude 54° N., and on page 204 *quadrilateralis* from Great Bear Lake, latitude 64½° N. is more fully described and better figured than in the preceding publication. In the same volume are described (on p. 206) *labradoricus* from Musquaw River, Gulf of St. Lawrence, (on p. 207) *lucidus* from Great Bear Lake, and (on p. 210) *harengus* from Penetanguishene in Georgian Bay, Lake Huron. All but *tullibee* and *labradoricus* are figured.

Storer, D. H., 1846.—Storer gives a list of the North American coregonids that had been described up to 1846, together with the synonomy of each.

Agassiz, Louis, 1850.—In this work the name Argyrosomus was first proposed to designate the whitefishes having the lower jaw longer than the upper, in contrast with the true Coregonus, with a truncated snout and included lower jaw. The name Argyrosomus was already occupied and has been replaced provisionally by Jordan and Evermann with Dybowski's Leucichthys. Two new species from Lake Superior, *Coregonus sapidissimus* and *latior*, are described, but neither is valid.

Prescott, W., 1851.—Two new species of Coregonus are described from Lake Winnepesaukee, N. H.—*neo-hantoniensis* and *nov-angliæ*. These have been considered subsequently as synonyms of *clupeaformis* and *quadrilaterale.*

Girard, Charles, 1856.—A species of Coregonus from Des Chutes River, Oreg., is described inadequately as *williamsoni.*

Günther, Albert, 1866.—All American forms are described with synonomy and a description of *C. richardsonii*, from "Arctic North America," is given for the first time.

Hoy, P. R., 1872.—Hoy makes mention of two species of Argyrosomus, of which he had sent specimens to Gill and which Gill named *hoyi* and *nigripinnis* but did not describe. While Hoy gives no technical description of either fish, and only two mutilated specimens, both of which are labelled *hoyi*, are preserved in the United States National Museum, it is certain that the fish Hoy referred to as *nigripinnis* is the blackfin. He says of it that it has black fins and lives off Racine in water over 60 fathoms in depth. The two specimens, 5½ and 7¼ inches long without the caudal (catalogue No. 8902, U. S. National Museum), are called "mooneyes" in his account. Of the "mooneye" he says that it is the smallest of the whitefishes, being only about 8 inches long, and is found in water over 40 fathoms deep. Hoy's specimens are too small to have been gilled in the commercial nets and were, according to the statement of Charles Hyttel, sr., who furnished them to Doctor Hoy, brought in with the bloaters and a few immature chubs that had entangled their jaws in the nets. As the bloater is the only species commonly caught in this way, it is likely that Hoy had this fish in mind as the "mooneye." One of the specimens (No. 8902) is a bloater and has been selected by me as the type; the other is a chub, either *alpenæ*, *reighardi*, or *zenithicus*. The only description of *hoyi* based on Hoy's specimens was made by Hugh M. Smith (1894). Smith, however, did not recognize the fact that the two fish were not of the same species and apparently based his description on both.

Milner, J. W., 1874a.[2]—On page 86 Milner describes *Argyrosomus hoyi*, *A. nigripinnis*, and *Coregonus couesii*. *Hoyi* and *nigripinnis* had been named by Doctor Gill and mentioned by Hoy in 1872. Milner's *nigripinnis* is from Lake Michigan and is the same fish referred to by Hoy. *Hoyi* is described from Lake Superior, but the description is wholly insufficient. Under the United States National Museum catalogue No. 10576 (not 10756, as given in Milner's text) are entered the three specimens of Milner's account—two specimens of *zenithicus* and one of *hoyi*. The description

[2] H. M. Smith, Bulletin, U. S. Fish Commission for 1894, Vol. XIV, on p. 7, says: "The report was certainly not issued in 1874 * * * and the indications are that the report was not printed before May or June, 1875."

given by Milner apparently involves both species. *C. couesii* is a whitefish taken in Chief Mountain Lake at the head of the Saskatchewan River.

Jordan, D. S., 1875.—A description, accompanied by a crude figure, is given of *Argyrosomus sisco* from Lake Tippecanoe, Kosciusko County, Ind. This species is compared with a fish that the author calls *A. hoyi*, a name based not on the specimens of Gill and Hoy but on another fish sent by Hoy to Jordan. This fish probably was the Lake Michigan representative of *zenithicus*, which Jordan, in his subsequent writings, seems to have had in mind as *hoyi*. This paper was abstracted in the same year in the American Naturalist.

Jordan, D. S., 1878.—Seven species and four possible varieties of whitefishes are mentioned on pages 274 to 276. The interest of this work lies in the subgeneric divisions, which are outlined on pages 360 to 362. Prosopium is published from Milner's manuscript as a generic designation for whitefishes of the *quadrilateralis* type.

Bean, T. H., 1881a.—Coregonus laurettæ is described as a new species on the basis of four specimens taken at Point Barrow and one at Port Clarence, Alaska.

Jordan, D. S., and C. H. Gilbert, 1882.—This account condenses the species that previously had been described for North America to the following: *Coregonus couesi* (Milner), *C. williamsoni* (Girard), *C. quadrilateralis* (Richardson), *C. clupeiformis* (Mitchill), *C. labradoricus* (Richardson), *C. hoyi* (Jordan), *C. artedi* (LeSueur), *C. nigripinnis* (Gill), *C. tullibee* (Richardson). In addition to these, *C. kennicotti*, from Fort Good Hope, British America, and Yukon River, Alaska, is included from Milner's manuscript; and *C. merki* (Günther), from the Bering Sea to the north shore of Siberia, is added to the North American fauna.

Bean, T. H., 1884a.—Coregonus nelsonii is described as a new species. It is said to occur only in Alaska from the Bristol Bay region northward. The type is from Nulato.

Bean, T. H., 1888.—Coregonus pusillus was referred to by the author in Proceedings, United States National Museum, volume 4, 1881, page 256, as an unnamed variety of *C. merki* and is described from a specimen collected in Putnam or Kuwuk River, Alaska.

Bollman, Charles H., 1889.—Bisselli, from Rawson and Howard Lakes, Mich., is described as a new subspecies of *Coregonus tullibee.*

Jordan, D. S., 1891.—Cismontanus, from the Madison River, Mont., is described as a new subspecies of *Coregonus williamsoni*. Two figures accompany the text.

Eigenmann, C. H., and R. S. Eigenmann, 1892.—A description is given of *Coregonus coulterii* based on over 100 specimens from Kicking Horse River, Field, British Columbia.

Smith, H. M., 1894.—Coregonus osmeriformis is described and figured from Seneca and Skaneateles Lakes, N. Y., and *Coregonus prognathus* from Lake Ontario off Wilson, N. Y. The synonomy of *hoyi* is discussed, and a figure and description obviously based on the two fish sent by Hoy are added.

Evermann, B. W., and H. M. Smith, 1896.—No new species are described but the accounts given in this publication are more detailed than in any previous or subsequent publication. The previously described forms for North America are reduced to 20 species and subspecies: *Coregonus coulterii, C. williamsoni, C. williamsoni cismontanus, C. kennicotti, C. richardsonii, C. quadrilateralis, C. clupeiformis, C. nelsonii, C. labradoricus, Argyrosomus osmeriformis, A. artedi, A. artedi sisco, A. hoyi, A. pusillus, A. lucidus, A. laurettæ, A. prognathus, A. nigripinnis, A. tullibee,* and *A. tullibee bisselli.* All but *C. richardsonii, A. artedi sisco,* and *A. tullibee bisselli* are illustrated by pen drawings.

Jordan, D. S., and B. W. Evermann, 1896.—All the known species of the lake herrings and whitefishes, together with their synonomy, are listed under two genera—Coregonus subgenera Coregonus and Prosopium, and Argyrosomus subgenera Argyrosomus and Allosomus. The species of Prosopium are *coulterii, williamsoni, w. cismontanus, kennicotti, richardsonii,* and *quadrilateralis;* the species of Coregonus are *clupeiformis, nelsonii,* and *labradoricus;* the species of Argyrosomus are *osmeriformis, artedi, a. sisco, hoyi, pusillus, lucidus, laurettæ, prognathus,* and *nigripinnis;* and of Allosomus the species are *tullibee* and *t. bisselli.*

Scofield, N. B., 1899.—Argyrosomus alascanus (Scofield) from Point Hope and Grantley Harbor, Alaska, is published as a new species from Scofield's manuscript, which appeared subsequently in D. S. Jordan, "The fur seals and fur-seal islands of the North Pacific Ocean," part 3, 1899.

Kendall, W. C., 1903.—Coregonus stanleyi from the thoroughfare between Mud and Cross Lakes, Me., is described and figured as a new species.

Jordan, D. S., and B. W. Evermann, 1909.—Argyrosomus eriensis and *huronius* from Port Stanley, Lake Erie, and *A. zenithicus* from Duluth, Lake Superior, are described and figured. The synonomy of *clupeaformis* and *albus* is appended.

Jordan, D. S., and J. O. Snyder, 1909.—Coregonus oregonius is described from the McKenzie River, Oreg. The species was included in part in the description of *C. williamsoni* by N. B. Scofield, 1899, page 463.

Wagner, George, 1910.—Argyrosomus johannæ is described from specimens secured in Lake Michigan some 18 miles out from Racine, Wis., at a depth of 25 fathoms.

Jordan, D. S., and B. W. Evermann, 1911.—Most of the literature on the coregonids is reviewed and the species in the Great Lakes redescribed. Five new forms of Leucichthys are added to the fauna—*supernas* and *harengus arcturus* from Lake Superior near Duluth, *cyanopterus* from Lake Superior off Marquette, *manitoulinus* from the North Channel off Blind River, and *ontariensis* from Lake Ontario off Deseronto. All the Great Lakes species except *prognathus* are figured. Six of the illustrations are from paintings.

Wagner, George, 1911.—Leucichthys birgei is described from Green Lake, Wis.

Bean, T. H., 1916.—Leucichthys macropterus is described from a specimen obtained in Lake Erie.

Harper, F., and J. T. Nichols, 1919.—Of the six species described, four are whitefishes—*Coregonus preblei* from Tazin River, about 1 mile above its confluence with the Taltson River, Mackenzie, Canada (with photograph); *Leucichthys entomophagus* from Tazin River, Mackenzie, Canada; *L. athabascæ* from Lake Athabasca, at the mouth of Charlot River, northern Saskatchewan, Canada; and *L. macrognathus* from the shore waters of Great Slave Lake, near Fort Resolution, Mackenzie, Canada.

Jordan, D. S., 1918.—The genus Irillion is proposed with *Coregonus oregonius* as the type.

Snyder, J. O., 1919.—Leucichthys gemmifer, Coregonus spilonotus, and *Coregonus abyssicola* are described from specimens secured in Bear Lake near Fish Haven, Idaho. Each species is figured.

Koelz, W., 1921.—Leucichthys kiyi is described as a new species from Lake Michigan off Sturgeon Bay, Wis.

Koelz, W., 1924.—Leucichthys alpenæ is described from Lake Michigan off Charlevoix, Mich., and *Leucichthys reighardi* from off Michigan City, Ind.

Koelz, W., 1925.—Leucichthys nipigon is described from Lake Nipigon.

Dymond, J. R., 1926.—A very good systematic account is given of the species of Coregonidæ that inhabit Lake Nipigon.

Hubbs, C. L., 1926.—In this check list a preliminary outline is given of the systematic arrangement of coregonids followed in this paper.

VARIABILITY AND DETERMINATION OF SPECIES IN THE GREAT LAKES COREGONIDS

GENERAL STATEMENT

Smitt (1895, p. 827) says of the Salmonidæ (which in his arrangement include the coregonids), "there is hardly any other part of the system where the scientist is confronted with such difficulties in defining the limits of the species." Any systematist who knows the Salmonidæ, or only the Coregonidæ, will agree with Smitt. The descriptions of the coregonids in the early days of taxonomy were very vague and were simply general remarks about shape, size, and color; or, if they were more specific, they emphasized insignificant details. The best workers of the nineteenth century, up to 1882, confined themselves in their diagnoses to purely external characters. Nüsslin (1882) calls attention to this fact and cites as an example the work of Nilsson, Cuvier and Valenciennes, Siebold, and Günther. He shows that two forms that had been considered identical have different numbers of gill rakers. He points out the specific importance of the shape of the snout, the number of gill rakers, and of biological data. Later workers on the coregonids have paid heed to Nüsslin but still have given too much weight in their diagnoses to differences in proportions and other similar characters which may be influenced by the environment. In fact, little effort has been made to determine, by a study of the variability of the external characters, what relation, if any, existed between them and the environment.

VARIABILITY OF INDIVIDUAL CHARACTERS

My own work on the forms in the Great Lakes, based on measurements of some 10,000 specimens from many localities and cursory inspection of some hundreds of thousands, has involved, then, of necessity, an attempt at analysis of the variability of these forms. The effort has been made to study all possible characters in order to learn which ones so vary that they are of little or no use in classification and which ones are sufficiently stable to be of use. At the same time the available data on spawning seasons, bathymetric and geographic distribution, seasonal movements, and other biological factors have been studied in order to learn whether they are correlated with the structural characters found usable in classification.

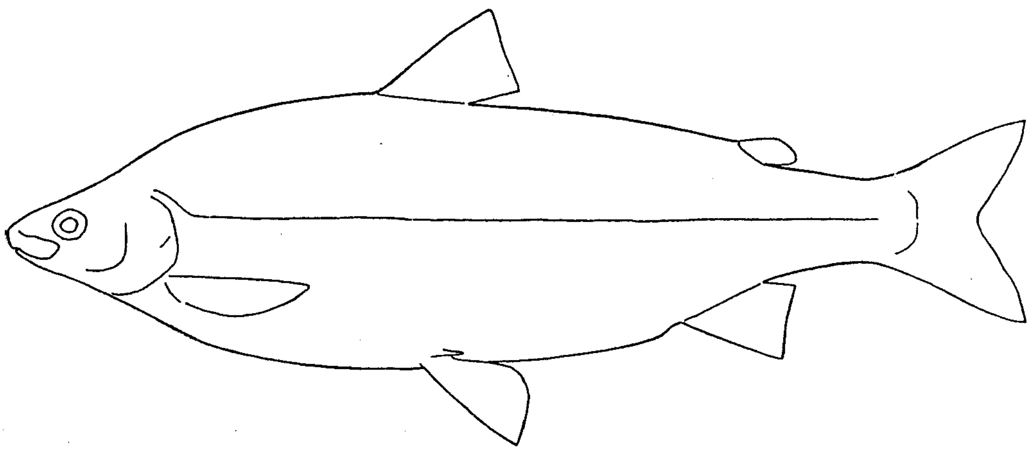


FIG. 9.—Body outline of the typical Lake Erie whitefish

Body Contour

Leucichthys.—Two groups may be separated according to contour or form of body as seen from the side. In the first of these the body is more or less perfectly elliptical. The species included are *alpenæ*, *zenithicus*, *reighardi*, *hoyi*, *artedi*, and *nipigon*. Of these, *hoyi*, *reighardi*, *nipigon*, and the *albus* and *manitoulinus* subspecies of *artedi* are least elongated and the typical *artedi* is most elongated. In the second group, comprising *johannæ*, *nigripinnis*, and *kiyi*, the anterior dorsal profile rises rapidly for two-thirds its extent and continues thence to the dorsal fin as a nearly horizontal line. In *nigripinnis* the anterior ventral profile extends in a direction similar to the dorsal, so that the anterior half of the body in this species is distinctly the deeper. In *johannæ* the tendency of the contour line between the dorsal and the adipose to become straight further interrupts the symmetry of the lateral profile.

All the above are compressed laterally, but the degree of compression is least in typical *artedi* and typical *reighardi*.

Coregonus.—The body of *clupeaformis* is most like that of *johannæ* in outline.

Prosopium.—The body of *quadrilaterale* is an elongated ellipse in outline, as in the first group of *Leucichthys*, but the body is nearly terete.

Length

The coregonid forms in the Great Lakes have about the same average and maximum lengths. The range in size of specimens seen by me is shown by the dimensions below. From this it appears that the maximum lengths of *Coregonus clupeaformis* and of the smallest species of Leucichthys (*hoyi* and *kiyi*) only are very different from those of the rest and would be of value in discriminating certain specimens of these species. It appears, further, that the maximum lengths known for each species from the various lakes also are very similar.

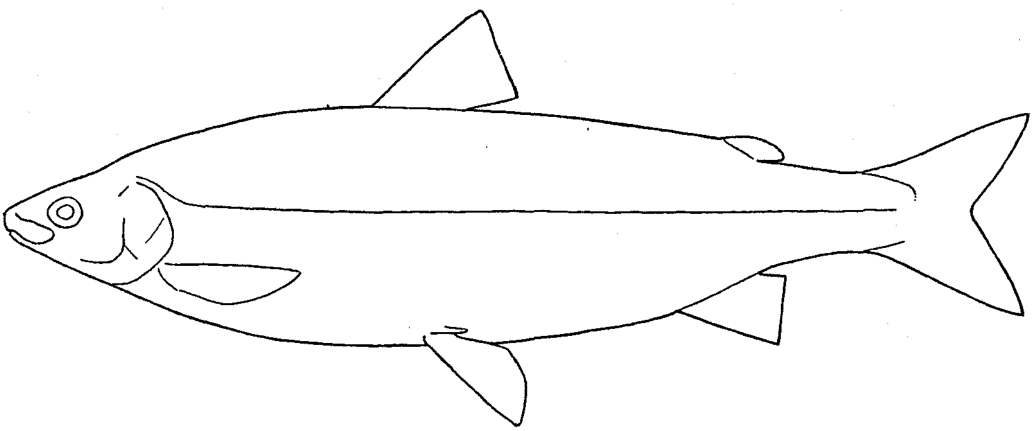


FIG. 10.—Body outline of the type of whitefish common in the upper lakes

Species	Lake	Range in length, in millimeters	Species	Lake	Range in length, in millimeters
Leucichthys johannæ	Michigan	181–288	L. hoyi	Michigan	82–265
Do	Huron	132–332	Do	Huron	79–221
L. alpenæ	Michigan	130–386	Do	Superior	107–251
Do	Huron	131–368	Do	Nipigon	106–231
L. zenithicus	Superior	134–332	Do	Ontario	128–277
Do	Nipigon	153–308	L. artedi	Erie	128–402
Do	Michigan	152–312	Do	Michigan	127–367
Do	Huron	139–318	Do	Huron	125–371
L. reighardi	Michigan	144–278	Do	Superior	135–435
Do	Superior	203–320	Do	Nipigon	138–253
Do	Nipigon	145–304	Do	Ontario	155–366
Do	Ontario	203–295	L. nipigon	Nipigon	220–447
L. nigripinnis	Michigan	220–360	Coregonus clupeaformis	Michigan	179 mm. to 6 lbs.
Do	Huron	208–371	Do	Huron	192 mm. to 15 lbs.
Do	Superior	198–375	Do	Superior	180 mm. to 6 lbs.
Do	Nipigon	141–355	Do	Nipigon	203 mm. to 4 lbs.
Do	Ontario	297	Do	Erie	291 mm. to 5 lbs.
L. kiyi	Michigan	122–245	Do	Ontario	253 mm. to 6 lbs.
Do	Huron	105–249	Prosopium quadrilaterale	Michigan	156–419
Do	Superior	132–204	Do	Huron	176–393
Do	Ontario	148–263	Do	Superior	65–380
			Do	Nipigon	191–318
			Do	Ontario	213–361

Depth and Width

Depth and width measurements of the body can not be recorded satisfactorily for specimens of coregonids, because those coming from the deeper waters are always bloated, sometimes even burst, and because the softness of the flesh of the individuals of the species renders it very difficult to preserve the shape properly during the period of collection. These characters also change proportionally during the growth of the individual, all young fish of the group having frailer bodies than the adults. The relative width and depth of the body, therefore, is variable for each species, and for none of the species is it a distinguishing character. In certain species the body depth varies relatively much more than in others. In the case of the lake herring (*L. artedi*) the several varieties are differentiated sharply by the relative depth of the body. In the typical *artedi* L/D is higher, on the whole, than for any other coregonid in the basin, while for the *albus* type occurring in the same lake it may be as low as or lower than that of any other coregonid. The races of *reighardi*, *nigripinnis*, and *clupeaformis* also are differentiated in part by variation in this character.

Scales in the Lateral Line

The number of scales in the lateral line is variable within a species and even within a race. It may be seen from Table 7 that the extremes are much the same for the various species in each lake. In most of the lakes *quadrilaterale*, with the maximum number of scales, is more or less distinctly separated only from *hoyi*, which has the smallest number; though in Lake Nipigon, where most of the species of Leucichthys have relatively few scales, it is probable that the scale count usually would be a generic distinction between Leucichthys and Prosopium. However, the usual number of scales is rather different for the various coregonids in each lake.

The usual number of scales also is more or less different for most of the geographically separated forms of each species. As has been pointed out above, all the races of Leucichthys occurring in Lake Nipigon have fewer scales on the average than those from other lakes, except the race of the species *hoyi*, which tends to have more than its relatives. The Huron forms of *johannæ*, *nigripinnis*, *kiyi* and *quadrilaterale*, the Superior form of *kiyi*, and the Erie form of *clupeaformis* also seem to have somewhat fewer scales than the Michigan forms of these species. The subspecies of *artedi* may differ conspicuously in the character, as is illustrated by the *manitoulinus* form of Huron and the *albus* subspecies of Superior and Erie.

Scale Rows

The number of longitudinal scale rows around the body also is variable within a species and within a race. Below are given the comparative values for the forms of Lake Michigan. A similar table for the other lakes would show about the same relation between the counts.

Species	Number in front of dorsal and ventrals	Number in front of adipose and anal	Number around caudal peduncle
Leucichthys:			
johannæ	(38) 41–44 (46)	(31) 33–37 (38)	(22) 24–26 (27)
alpenæ	(40) 41–43 (45)	(30) 33–35 (36)	(23) 24–26 (27)
zenithicus	40–42 (46)	(30) 32–34 (36)	(23) 24–25 (26)
reighardi	(38) 40–43 (46)	(30) 32–35 (39)	22–24 (26)
nigripinnis	(41) 42–44 (45)	(32) 33–35 (36)	(23) 24–26 (27)
kiyi	(39) 41–44 (46)	(32) 33–35 (37)	(23) 24–25 (26)
hoyi	(38) 40–42 (44)	(31) 32–34 (35)	(22) 23–25 (26)
artedi	(39) 43–46 (49)	(32) 34–37 (38)	(23) 24–26 (27)
nipigon [1]	(41) 43–45	(32) 33–34 (35)	(23) 24–25 (27)
Coregonus clupeaformis	(46) 48–50 (52)	(36) 37–39 (40)	25–27 (28)
Prosopium quadrilaterale	(40) 42–45 (46)	(31) 33–35 (36)	(24) 25–27 (28)

Lake Nipigon specimens.

It appears that only *clupeaformis* and *hoyi* have a distinctive number of scale rows—the one with the highest, the other with the lowest count. The range of both, however, overlaps, more or less, that of at least some of the other species. Within each species there may be variations in the number of scale rows in the various lakes and among the several races within the same lake. Thus, *johannæ* has fewer scale rows in Huron than in Michigan; *zenithicus, reighardi, nigripinnis,* and *hoyi* have fewer in Nipigon; *hoyi* has slightly fewer in Superior than in the other lakes; the predominant *artedi* of Erie, Ontario, and Nipigon have fewer rows than the predominating herring races of the other lakes; and the Erie whitefish has fewer than the whitefish of the other lakes. The *manitoulinus* subspecies in Huron has many fewer rows than the *artedi* subspecies, and the *albus* subspecies of Erie has fewer than the *artedi* form in that lake. This is true also of these two races in Lake Superior. It seems, in general, that the number of scale rows varies directly with the number of lateral-line scales.

Pearl Organs

Pearl organs are present during the breeding season in at least the males of each species. Not enough material is available to determine to what extent this character is of systematic importance to separate the species, but it appears that it will separate the three groups. In Leucichthys pearls are present on the head as well as on the sides of the body and are of virtually uniform thickness. They have been found well developed only in males. In Coregonus they are distributed more or less as in Leucichthys but are present on males and females and are conspicuously thicker in the middle. All the specimens of Prosopium seen differ from Leucichthys and Coregonus in having no pearls on the head. The form of the pearl is approximately as in Coregonus, and both males and females have pearls.

Fins

DORSAL

The ratio between the height of the dorsal and its base (the dorsal coefficient of the tables) is variable in all species and even in all races. There are no distinguishing features about this character, but it is interesting to point out that the dorsal base appears to average longest, relatively, in the various races of *clupeaformis, quadrilaterale,* and *artedi,* and shortest, relatively, in *hoyi* and *kiyi.*

The number of dorsal rays also is not distinctive except possibly between the forms with extreme numbers. *Quadrilaterale,* which has the highest number (11 to 13), overlaps but seldom the range of *hoyi,* with usually 9 or 10. *Kiyi* and *reighardi* also usually have a low dorsal ray count.

The number of rays seems to vary among the races of a species as well. Thus, the Superior and Nipigon forms of *reighardi* have more dorsal rays, on the average, than the typical form. *Hoyi,* in Nipigon, tends to have a greater number than the forms elsewhere in the Great Lakes.

ANAL

The anal coefficient is variable and distinguishes only Prosopium absolutely from most of the species of Leucichthys. The anal base is relatively shortest in *quadrilaterale, hoyi,* and *kiyi* and longest in *johannæ* and *artedi.* In the Leucichthys species (except *hoyi* and *kiyi*) the AC value frequently is less than 1, while in these species and in *clupeaformis* and *quadrilaterale* the value usually is more than 1.

The number of anal rays also is variable and is distinctive in none of the forms. The usual number is 10 to 12 but may vary within the species. Thus, *reighardi* of Superior has slightly more rays than the typical race.

PECTORALS

The length of the pectorals in relation to the pectoral-ventral distance is of systematic importance, but none of the species are absolutely separable by this character, as may be seen in Table 10. The races of *kiyi* have relatively the longest pectorals and those of *reighardi* the shortest.

Within each species there is enormous variation in this character. Thus, the pectorals of the Huron race of *johannæ* average longer than those of the Michigan race; in *zenithicus* they are shorter in Michigan and Huron than in Superior and Nipigon; in *reighardi* they are longer in Superior and Nipigon than in Michigan and Ontario; in *nigripinnis* they are longer in Huron and Nipigon than in Michigan and Superior; in *kiyi* they are longer in Superior and shorter in Ontario than in Michigan and Huron; in *hoyi* they are longer in Nipigon, Superior, and Ontario than in the other lakes; in *artedi* the predominant race of Nipigon has longer pectorals than the predominant races in the other lakes; in *quadrilaterale* the pectorals are longer, on the average, in Superior and Huron than in Lake Michigan.

Within the same lake there are differences in the length of the pectorals in the case of the species *artedi*. The *manitoulinus* form in Huron has much longer pectorals than the *artedi* form, and in Lakes Superior and Erie the *albus* form has longer pectorals than the *artedi* form.

The number of pectoral rays is not distinctive, but some species tend to have a lower number, on the average, than others. Within the species, also, the number may vary. Thus, the *hoyi* of Ontario and the *clupeaformis* of Erie seem to have a lower average number than their relatives in the other lakes; and *johannæ* in Huron has more than in Michigan.

The shape of the pectoral often has some value as a systematic character. In typical *nigripinnis* and in *johannæ* the dorsal margin frequently is decurved and most frequently is relatively straight in other species.

VENTRALS

The relative length of the ventrals is of more systematic importance than that of the pectorals. (See Table 11.) They are longest in the *kiyi* and shortest in the races of *quadrilaterale*, *artedi*, and *clupeaformis*, but only the figures for the *kiyi* and the *quadrilaterale* are quite distinctive. The overlapping between the ranges of the *kiyi* and the *artedi* in the same lake usually is very slight, however.

The same variation occurs within the species as in the case of the pectorals, though it is not so extensive. In *zenithicus* the Michigan and Huron races seem to have somewhat shorter ventrals than those from other lakes; in *reighardi* they appear to be somewhat longer in Nipigon than in the others; in the case of *nigripinnis* they are somewhat longer in Huron; in *kiyi* they are shorter in Ontario and longer in

Superior; in *hoyi* they are longer in Nipigon and Superior than in the other lakes; in *quadrilaterale* the races of Superior and Michigan seem to have longer ventrals than the race of Lake Michigan.

Within the species of a lake it is evident that the same sort of variation in ventral length occurs as in pectoral length, as illustrated by the fact that the *manitoulinus* race of Lake Huron and the *albus* races of Lakes Superior and Erie have longer ventrals than the *artedi* races of these lakes.

The number of ventral rays does not appear to be characteristic of any species. The rays number from 10 to 12 in virtually all, though some more often have 10 than 12, and vice versa. There is also no conspicuous variation in this character within a species.

CAUDAL

There are no satisfactory ways of measuring the caudal; and while it appears that in the case of certain species this member may be more broadly forked, the eye may easily be deceived by the course of other contour lines in estimating the extent of the cleft. It is sufficient to point out that in no species is the tail fin conspicuously different in the extent of its development.

ADIPOSE

As may be seen from an examination of the Tables 17 to 101, the size of the adipose is extremely variable and has little value as a systematic character. The species of Coregonus seem to have a longer adipose than the species of the other genera, but this character is not always distinctive.

Caudal Peduncle

The length of the caudal peduncle, measured from the anterior end of the base of the adipose to the first caudal rays, is too variable within each species to have specific value. The depth has not been measured. For an expression of the proportion see column L/AT in Tables 17 to 101. It also appears to vary decidedly within a species. The deep-bodied forms, *manitoulinus* and *albus* of *Leucichthys artedi* (especially the former), have a shorter and relatively deeper caudal peduncle.

Flesh

The species within a lake are quite different in their food value. In this respect *artedi*, with its varieties, must be rated lowest and *clupeaformis* highest. *Prosopium quadrilaterale* and the other species of Leucichthys are intermediate, the first nearest to *artedi*, the last nearest to *clupeaformis*.

In Lake Nipigon none of the Leucichthys are yet marketable, so it is not known how much they will be esteemed.

The quality of flesh within a species also may be variable with the environment. Thus, Lake Superior whitefish may be most esteemed by some buyers, while others may prefer the Lake Erie product. The differences are nowhere as great as in the case of the Erie *artedi*, which has richer flesh than members of the species in the other lakes. It regularly competed in late years with the deep-water forms of Leucichthys or "chubs" of other lakes in the smoked-fish trade, and large individuals very often are sold as whitefish.

Color

Color, which in most groups of fishes serves as a character to separate even closely related species, is of little value in distinguishing between the species of coregonids in the Great Lakes. While faint color may be present in living fish, the fish die very soon after capture (in fact, the deep-water forms are dying when lifted from the nets), and after death the color fades very soon, leaving a nearly uniform silvery appearance to all the forms. In life Leucichthys and Coregonus are tinted with a green or blue-green, the intensity of the coloration varying with the species. It is deepest in the *artedi*, especially the *manitoulinus* form, and usually in *nigripinnis*, and in these forms (particularly the first two) may often become intensified for a short time after death. In life Prosopium differs strikingly from the rest in coloration. The blue-green of the others is replaced in *quadrilaterale* by a greenish bronze, and the sides have a decided pinkish cast.

Pigmentation also varies, and usually directly with color—that is, the fish with most intense colors usually have more pigment on the head, especially the anterior parts, and on the body and fins. *Manitoulinus* and most of the forms of *nigripinnis* are much more pigmented than any of the other forms.

The degree of pigmentation varies among the forms of a species. In *zenithicus* the Nipigon race is much paler and that of Michigan and Huron somewhat paler than the typical race; in *reighardi* the Nipigon race is much paler throughout than the typical Michigan form, while the forms of Superior and Ontario are somewhat less pigmented; the *nigripinnis* of Superior is paler than that of the other lakes; the *kiyi* of Ontario appears to be a trifle more pigmented than the races of the other lakes; the *hoyi* of Superior shows a little more pigment on the fins than the forms of the other lakes; the typical *artedi* form is darker than the *albus* form of *Leucichthys artedi*, and the *manitoulinus* form is darkest of all; the Lake Erie *clupeaformis* seems to be the palest of the races of Coregonus.

Vertebræ

The number of vertebræ in the vertebral column is given for a few individuals of each species, chiefly from Lake Huron.

Species	Number of specimens counted	Number of vertebræ	Species	Number of specimens counted	Number of vertebræ
Leucichthys:			Leucichthys—Continued.		
johannæ	11	57-60	hoyi	17	55-60
alpenæ	12	57-59	artedi	9	57-60
zenithicus	8	55-58	nipigon [2]	2	58-60
reighardi [1]	6	57-59	Coregonus clupeaformis	8	60-63
nigripinnis	8	58-60	Prosopium quadrilaterale	12	59-63
kiyi	10	57-59			

[1] Lake Michigan specimens. [2] Lake Nipigon specimens.

It appears that the number of vertebræ varies for each species and that, on the average, Leucichthys has a lower number than Coregonus or Prosopium.

Pyloric cæca

The number of pyloric appendages is rather variable within the species, but the averages show interesting differences in a few cases. They are counted below chiefly for specimens from Lake Huron.

Species	Number of specimens	Range	Species	Number of specimens	Range
Leucichthys:			Leucichthys—Continued.		
johannæ	8	142-222	hoyi	29	88-164
alpenæ	6	126-181	artedi	8	109-165
zenithicus	7	92-150	nipigon [2]	2	109-145
reighardi [1]	5	115-142	Coregonus clupeaformis	8	208-264
nigripinnis	8	132-194	Prosopium quadrilaterale	8	87-117
kiyi	7	116-167			

[1] Lake Michigan specimens. [2] Lake Nipigon specimens.

It appears that in Leucichthys *hoyi* and *zenithicus* have, on the average, the fewest cæca, while *johannæ* has the most. The ranges of the former overlap that of the latter, and more counts probably will show that overlapping occurs to a greater extent than appears in the table. Coregonus has, on the average, more cæca than either Leucichthys or Prosopium and thereby is differentiated sharply from the latter, which has fewer cæca than most Leucichthys. It is possible that this character is influenced by nutrition.

Head Form

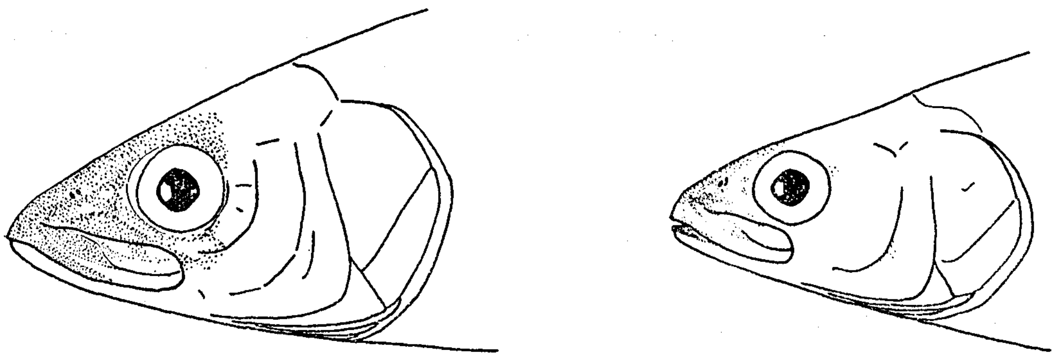
The head in all forms presents four surfaces—a dorsal, a ventral, and two lateral. The dorsal surface is bounded approximately by a line running from the articulation of the maxillary caudad along the dorsal edge of the orbit, and the ventral by a line running caudad along the inner edge of the dentary.

In Leucichthys the dorsal surface has the form of a trapezoid with two equal sides, due to the shape and position of the premaxillaries, and is more or less convex from side to side, the degree of convexity becoming greatest in the region of the occiput. A faint carina, which becomes more conspicuous on drying, runs through its length. The lateral surfaces are nearly flat and converge distinctly in a downward direction. In shape they are roughly triangular, depending again on the shape and position of the premaxillaries. In *alpenæ* the apex is rather rounded, in *reighardi* truncated, and in the rest rather acute or obtuse as the angle made by the premaxillaries with the body axis becomes greater than 45°. The ventral surface, like the dorsal, is convex and corresponds to it in shape.

The depth and width of the head is greatest in *artedi* and *nigripinnis*. The depth is least in *reighardi* and *zenithicus*. The proportion of the head length to that of the whole fish, expressed by L/H, is but slightly different for the forms of this group and therefore has little systematic value. (See Table 8.) Its significance is reduced further by the fact that it changes with the growth of the individual. The races of *artedi*, however, tend to have proportionally the shortest heads among the forms of Leucichthys.

The relative head length varies within the species, often to a conspicuous extent. Making allowance for difference in size between the groups of individuals compared, it seems that in *johannæ* and *alpenæ* the head is somewhat larger in Huron; in *zenithicus* it seems smaller in Michigan and Huron and larger in Nipigon than in Superior; in *reighardi* it is longer in Nipigon and Superior and shorter in Ontario than in Michigan; in *nigripinnis* it is larger in Nipigon, Superior, and Huron than in Michigan; in *kiyi* it appears to be smaller in Ontario than in the other lakes; in *hoyi* it appears to be smaller in Michigan than in the other lakes.

Within the species group *artedi* the races differ in the average value of L/H. Thus, the *manitoulinus* race has a much larger head, relatively, than the *artedi* race of Lake Huron, and the *albus* races of Superior and Erie tend to have a relatively longer head than the *artedi* races associated with them.



A B

FIG. 11.—Comparison of the heads of *Leucichthys zenithicus* (A) and *L. reighardi* (B) of Lake Michigan

The shape of the head in Coregonus is approximately as in Leucichthys, but the dorsal surface is triangular, due to the shortness of the premaxillaries, and is strikingly convex in the region of the nostrils and occiput. A carina, which is heaviest over its

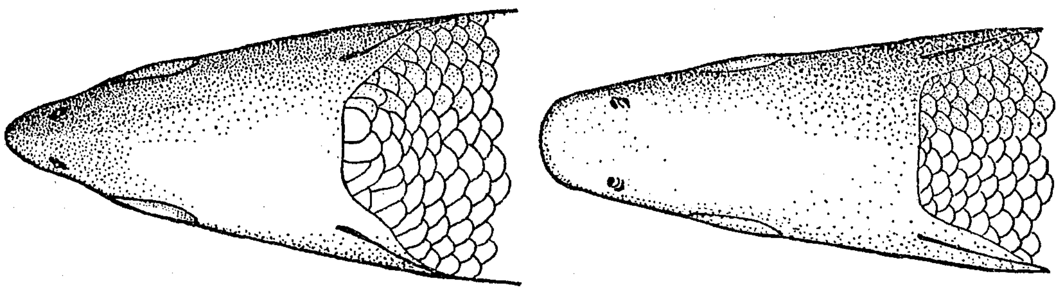


FIG. 12.—Comparison of the dorsal view of the head in Prosopium (A) and Coregonus (B)

anterior extent, bisects the triangle. The lateral surfaces also are triangular in shape, obtuse, or acute at the apex, as the angle made by the premaxillaries with the body axis becomes greater than 90°. The ventral surface is like the doral in shape but is only slightly convex from side to side.

The head in Prosopium is quite different from that in the other two genera. The dorsal surface is acutely triangular, owing to the compression of the entire preorbital region, and is not strongly convex from side to side except in the occipital region. A short but heavy medium keel runs forward from a point approximately above the caudal margin of the eye to its center. A fainter keel originates on each side of it.

slightly farther craniad, and extends to the nares. The lateral surfaces are roughly ovoid in shape. They are nearly flat to a line on a level with the superior edge of the maxillaries and from thence converge sharply in a downward direction, the more sharply as the snout is approached. The ventral surface also is acutely triangular in form but is strongly convex from side to side.

It appears from Table 8 that the head is smallest in proportion to the total body length in this genus. There seems to be variation in this character; the race of Michigan seems to have a proportionally smaller head than those of Superior and Huron.

Brain Box

An examination of the bones of the skull shows the prefrontal bone to extend almost completely over the orbit in Leucichthys and the carina of the frontals to extend to the frontal-parietal suture. In Prosopium the prefrontal is but little developed and does not extend much beyond the anterior edge of the pupil; the cranial carina does not extend to the frontal-parietal suture. In Coregonus the development of these structures is about as in Leucichthys.

Premaxillaries

The shape and position of the premaxillaries serve to separate the three generic groups and to aid in the separation of *reighardi* and *zenithicus* from the other species of Leucichthys. In Leucichthys the premaxillaries are longer than wide and make an angle not in excess of 90° with the horizontal axis of the body behind them. This angle usually is between 60° and 75° for typical *reighardi* and *zenithicus* and 45° and 60° for the others, including the *dymondi* form of *reighardi*. In Coregonus and Prosopium they are wider than long and the angle is always in excess of 90°. The angle may vary within the species; the premaxillaries are less perpendicular in the *dymondi* race of *reighardi* than in the typical one.

Snout

The shape of the snout depends, of course, upon its length and on the position of the premaxillaries. It is more blunt or more pointed, according as the premaxillaries are more vertical or more horizontal. The relative length of the snout, as compared with the length of the head, is variable and is not distinctive for any species. It is longest, on the average, in *zenithicus*.

The usual length may vary within a species. *Johannæ* has a longer snout in Huron than in Michigan; *zenithicus* has a somewhat longer snout in Nipigon than in Superior and a somewhat shorter one in Michigan and possibly Huron; the *reighardi* of Nipigon and of northern Lake Michigan has a somewhat longer snout than the typical form, and the Superior form has a somewhat shorter one; the *cyanopterus* subspecies of *nigripinnis* has a relatively longer snout than the other races; *kiyi* in Superior has a somewhat shorter snout than in the other lakes.

Maxillary

The shape and size of the maxillary and the supplementary maxillary (jugal) are more or less distinct for the three groups. In Leucichthys both of these bones are elongated more than in the other two groups. While in Leucichthys the maxillary, in proportion to the head, is relatively shortest in *artedi* and *reighardi*, the figures are not exclusive. Coregonus has a shorter maxillary than most forms of Leucichthys, but the range overlaps slightly. Prosopium has relatively the shortest maxillary of all, and its figures overlap but little those of Coregonus. The usual value for H/M in typical *artedi* and the *albus* form is 2.7 to 2.9; in typical *reighardi*, 2.6 to 2.8; in the other forms of Leucichthys, 2.3 to 2.6; in Coregonus, 3.1 to 3.4; and in Prosopium, 4.0 to 4.2.

The maxillary length also varies within the species, so that in *zenithicus* it is somewhat shorter in Michigan and Huron; in *reighardi* it is longer in Superior and Nipigon than in Michigan and somewhat shorter in Ontario; in *hoyi* it is longer in Superior and Nipigon. In the species of one lake it also varies. Thus, *reighardi* of northern Lake Michigan has, on the average, a proportionally longer maxillary than that of the south, and the *manitoulinus* race of *artedi* has a much longer maxillary than the typical race.

Mandible

In Leucichthys the lower jaw is approximately equal to the upper; in the other genera it is always distinctly shorter. In the case of *reighardi* and *zenithicus* it is usually (in *artedi* often) somewhat shorter than the upper; in *alpenæ* and *kiyi* it is usually longer than the upper; in *hoyi* it is seldom shorter; in the others it is variable, though most often about equal. It also varies in position within the species, as evidenced by the fact that the forms of *zenithicus* in Michigan and Huron more often have the mandible included; the *dymondi* race of *reighardi* often has the mandible not so conspicuously included; the *cyanopterus* form of *nigripinnis* has the lower jaw shorter than the upper more frequently than the other *nigripinnis* races; and the deep-water *hoyi* of Huron and the *hoyi* of Nipigon and Ontario seem to have longer jaws than their relatives elsewhere.

Within the group Leucichthys there is nothing distinctive about its shape, degree of development, or relative length compared with that of the head. The degree of bony development, however, is most pronounced in *alpenæ* and probably least in *reighardi*. In Leucichthys the value obtained by dividing the mandible into the head never is more than 2.3 and may be as low as 1.7. In Coregonus the value usually is 2.4 to 2.7; in Prosopium it is 2.7 to 3.1.

Eye

The size of the eye varies with the age of the individual and consequently is of ready systematic value only in forms of comparable size or state of development. The values obtained by dividing the eyeball into the head are given in Table 9, first for the adults of the larger forms and then, so far as possible, for their young, for comparison with the former and with the smaller species of the group. As is usual in fishes, the eye appears to be relatively larger in the young than in the adult and the values are not very different for any of the species.

The eye size also varies within the species. The *alpenæ* of Huron seems to have a proportionally smaller eye than that of Michigan; *zenithicus* of Nipigon seems to have a somewhat larger eye than that of other lakes; the *reighardi* of Ontario and Nipigon seem to have a smaller eye than those from other lakes; *nigripinnis* in Nipigon and Huron have relatively larger eyes, and those in Superior have relatively smaller eyes than the form in Michigan; in *hoyi* the eye is proportionally larger in the Superior and Nipigon forms and smaller in the Ontario race; in *artedi* the *manitoulinus* form has a relatively larger eye than the other subspecies of *artedi*.

Teeth

Vestigial teeth have been found in the forms of all species except *quadrilaterale*. They are present more or less regularly on the premaxillaries, the palatines, the mandible, and on the tongue, and are least in evidence in the larger individuals of each species. Those on the tongue appear to be retained longest. The absence of teeth then serves to separate Prosopium from the other genera.

Branchiostegal Membrane and Rays

The outline of this membrane and the number of its rays have no taxonomic value in this group, except that Prosopium differs from the other two groups in both of these respects. In the latter the membrane is saber-shaped and usually contains 8 to 10 rays. In Prosopium it is trapezoidal in outline, and there are only 7 or 8 rays.

Gill Rakers

The number of gill rakers is of great systematic importance. Leucichthys has the most and longest rakers and Prosopium the fewest and shortest. The range of the latter overlaps that of none of the other species; that of Coregonus overlaps but rarely the range of any species other than *johannæ*.

Leucichthys may be divided into three groups: (1) Gill rakers on the first arch commonly less than 33 (*johannæ*); (2) usually more than 32 and usually less than 44 (*alpenæ, zenithicus, reighardi, and kiyi* (except in Ontario); (3) usually more than 43 (*nigripinnis* except in Superior, *artedi* and *nipigon*). The range of *hoyi* and Ontario *kiyi* is about intermediate between 2 and 3. Superior *nigripinnis* falls about in Group 2. As has been indicated above, there may be some variation in the number of gill rakers on the first branchial arch within a species. The *alpenæ* of Huron have somewhat fewer gill rakers than those of Michigan; they are somewhat fewer in the *zenithicus* of Nipigon and Huron than in those of other lakes; they are somewhat fewer in the *reighardi* of Nipigon; in the *nigripinnis* of Nipigon they are more numerous, and they are fewer in the Superior form; they are more numerous in the *kiyi* of Ontario; they are more numerous in the *hoyi* of Nipigon and Ontario.

Within the species of a lake no striking variation tendencies have been noted in any of the races. It is noticeable, however, that in the case of *alpenæ* and *zenithicus* small fish have somewhat fewer gill rakers, due, no doubt, to the imperfect development of those on the ends of the arches.

Nares

The structure of the nares is a distinctive feature in Prosopium. In Leucichthys and Coregonus the anterior opening is through a short tube obliquely truncated toward the front, and a rather broad membranous flap is present at the anterior end of the posterior opening. In Prosopium this flap is wanting. (See fig. 27.)

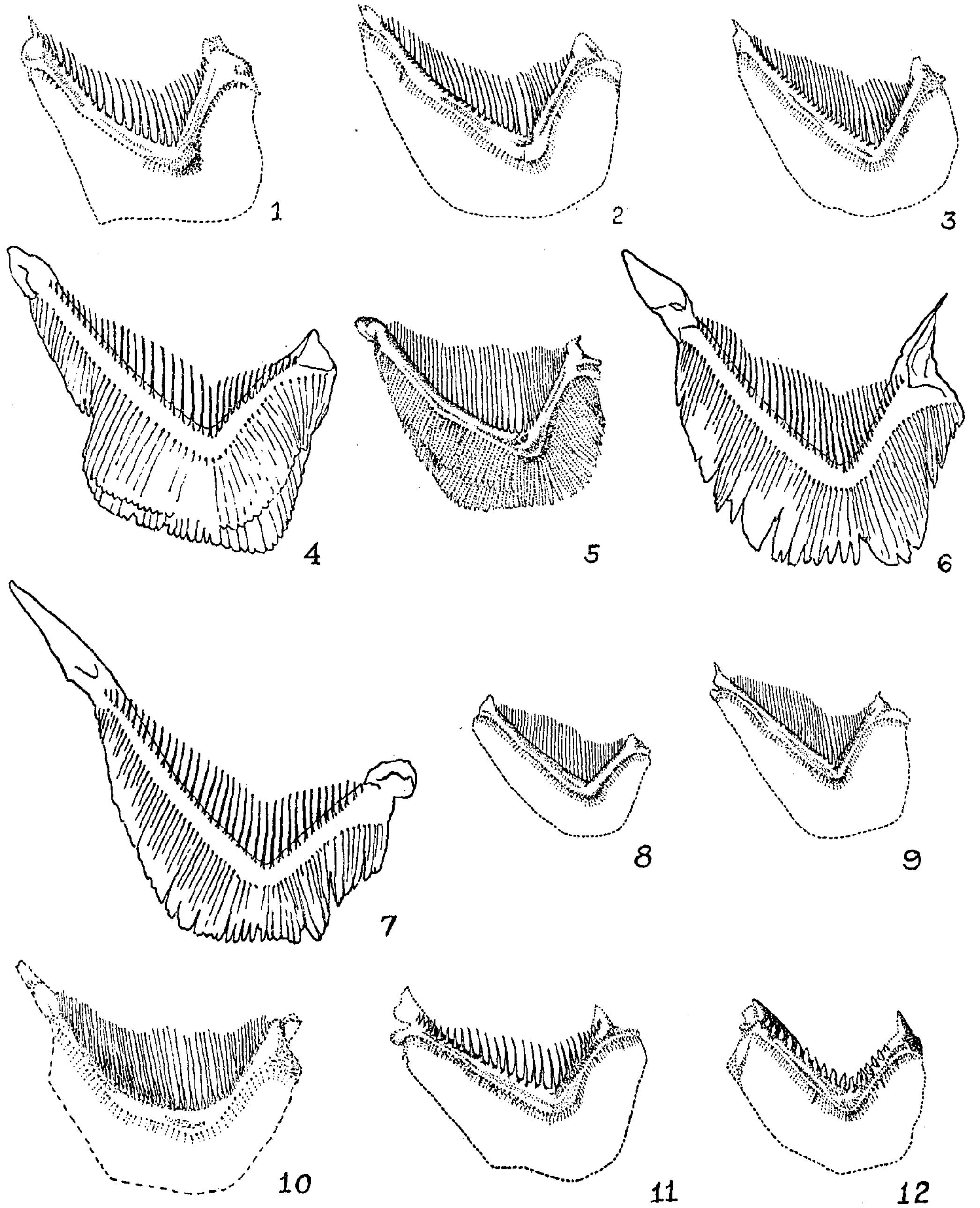


FIG. 13.—Left branchial arch of 12 forms of Coregonidæ found in the Great Lakes (Nos. 4 and 7 are drawn from the type specimens from Lake Michigan; No. 6 from a Lake Superior individual; the rest are from Lake Huron specimens.) 1. *Leucichthys johannæ*. 2. *L. alpenæ*. 3. *L. zenithicus*. 4. *L. reighardi* (type). 5. *L. nigripinnis*. 6. *L. nigripinnis cyanopterus*. 7. *L. kiyi* (type). 8. *L. hoyi*. 9. *L. artedi*. 10. *L. nipigon*. 11. *Coregonus clupeaformis*. 12. *Prosopium quadrilaterale*.

DISCUSSION OF VARIABILITY

Interspecific Variations

From the foregoing analyses it is evident that while there are adequate characters to distinguish between the three genera, such as shape of the head and premaxillaries, size of maxillary and mandible, teeth, branchiostegal membrane, number and length of gill rakers, structure of nares, pearl organs, etc., there are comparatively few characters that can be used to separate the species within a group. It has been shown that the number of rakers on the first branchial arch is of greatest value in distinguishing the specific forms. Separated by this character, most of the coregonid forms fall into four groups: (1) Rakers usually less than 20 (*quadrilaterale*); (2) rakers usually more than 20 and less than 33 (*clupeaformis* and *johannæ*); (3) rakers usually more than 32 and less than 44 (*alpenæ, zenithicus, reighardi, kiyi,* and *nigripinnis* of Superior); (4) rakers usually over 43 (*nigripinnis* except Superior, *artedi* and *nipigon.*)

Both *quadrilaterale* and *clupeaformis* are distinct from the other forms in the Great Lakes and from each other, and each is the sole representative of a genus. It is unnecessary, therefore, to consider them in the subsequent discussion.

There remain for consideration the species of Leucichthys, which have hardly any other character than gill rakers by which the species, wherever they may occur, may be separated. Within a lake a few other characters may be of use to distinguish one or two species from the rest (see analyses on pp. 335 to 339), but even these are not very constant, and each taken alone certainly could not be relied upon. The few characters that are fairly constant for each species are repeated below:

1. *Body contour.*—The form of the body is, in general, fairly constant. In *alpenæ, zenithicus, reighardi, hoyi, artedi,* and *nipigon* the body outline, as seen from the side, is generally elliptical; in *johannæ, nigripinnis,* and *kiyi* it is more or less ovate as a rule.

2. *Length of the lower jaw.*—The mandible in *alpenæ* usually projects beyond the upper jaw, while in *zenithicus* and *reighardi* it is generally included within the upper. The other species (except *kiyi* and *artedi*) that normally have equal jaws occasionally may have the lower jaw longer or shorter than the upper. *Artedi* most often has the lower jaw shorter than the upper, while in *kiyi* it is usually a little longer.

3. *Length of the maxillary.*—For *artedi* (except the form *manitoulinus*) the maxillary usually is contained more than 2.6 times in the head length; for the rest (excepting typical *reighardi,* which is intermediate) it usually is contained less than 2.7 times.

4. *Pigmentation of the maxillary.*—This character has more or less systematic value. In *johannæ* and *alpenæ* the maxillary usually is immaculate; in all the rest it most often is more or less pigmented.

The conclusion is unavoidable that those characters that are of greatest importance in the taxonomy of other groups of fishes, such as body proportions, number of scales, fin rays, teeth, etc., are not of prime taxonomic value for the Coregonidæ.

Intraspecific Variations

Analysis of the Great Lakes coregonids shows, in each of the 11 species, a wide range of variation in all the characters that are of taxonomic importance, although in most of the species this variation is possibly no greater than would be found in other unrelated species if the same number of individuals of these were studied in the same way. This variation is exhibited by individuals presumably intimately related—that is, by individuals of the same school in one locality. In many species it has been found that geographically separated races have developed peculiar characters even within a lake, and it is probable, furthermore, that different schools in one locality would show peculiarities. To cite the most conspicuous examples of differentiation where a species has been segregated definitely, geographically, we have the *dymondi* subspecies of *reighardi* in Nipigon and Superior, the *cyanopterus*, *regalis*, and *prognathus* subspecies of *nigripinnis* in Superior, Nipigon, and Ontario, respectively, and the *orientalis* subspecies of *kiyi* in Ontario. Within a lake we have the conspicuously differentiated forms of *artedi*—*manitoulinus* in Huron and *albus* in Erie and Superior and the unnamed deep-water variant of *hoyi* in Huron.

These various forms probably have arisen through isolation and to some degree may be the result of different environmental conditions operating in each generation. It is not clear, however, what environmental factors might operate to develop the various forms that occur in separated lakes. There seems to be no definite direction of variation expressed by the forms in any lake. Thus, while *nigripinnis* in Superior has fewer gill rakers than any of the known races in other lakes, *zenithicus* in that lake seems to have a few more than its relatives elsewhere. Similarly, though *hoyi* and *kiyi* in Lake Ontario have more gill rakers, it is not true of other coregonids in the lake; and in Nipigon *hoyi* seems to have somewhat more lateral line scales than the *hoyi* elsewhere, while all the other forms of Leucichthys seem to have fewer than their relatives in other lakes.

In the case of the varieties of *artedi* there seems to be some clue as to the causes operating to produce certain characteristics of development, but until a study has been made of the forms of *artedi* known to occur in the inland lakes tributary to the Great Lakes any statement regarding the manner in which environment influences the direction of variation is purely hypothetical. We do know, however, that the forms of *albus* and *manitoulinus* both exhibit the same sort of variations—both have deep, abbreviated bodies with relatively longer paired fins and few lateral-line scales. They are not alike, however, in certain other peculiarities, such as the relatively large head and eye and the dark color of the latter. These varieties always occur in the warmest waters of the territory available for occupation. Lake Erie, which is the shallowest and most southerly of the Great Lakes, presumably is the warmest; and it has been shown in Table 13 that Black Bay, in Lake Superior, is much warmer than the open lake. The same probably is true of Cutler Bay, where *manitoulinus* occurs.

It would be expected that, if temperature had a part in this variation, an opposite type of development would result where temperature conditions were reversed, and this appears to be true. The habitat of the Lake Superior herring is almost certainly the coldest in the Great Lakes occupied by the species throughout the year. The *artedi* of the lake are the slenderest, most elongate forms, and they have the most lateral-line scales, though the paired fins are not conspicuously different from those of Michigan and Huron specimens. It is noteworthy, also, that the *clupeaformis* of Lake Erie and Black Bay of Lake Superior also are known to be deeper bodied and fewer scaled than their relatives of colder waters. (Nothing is known about the characteristics of the bay races of whitefish in Lake Huron.)

The *artedi* of Nipigon are nearest to the *albus* type, even though Lake Nipigon lies in the highest latitude of the chain; but Lake Nipigon also is much shallower than any of the lakes except Erie, and its annual heat budget is relatively high (Clemens, 1923).

It should be repeated that facts do not warrant the assignment of temperature as a direct factor in occasioning the variations discussed. The cases cited may be coincidences or temperature may act indirectly in numerous ways. The segregation of these variants presumably is a result of physiological differences, differences that have enabled certain individuals to meet the conditions arising from increased warmth or, in the case of the deep-water variant of *hoyi* in Huron, from increased depth. The segregated variants thus are subjected to unlike physical conditions. They differ in certain structural characters. If we assume that the structural differences result from isolation, they may be, in part, the direct or indirect effect of environment (somatic) and in part the result of germinal changes.

Somatic variations might be the direct effect of the activities of the fish in its relation to the degree of mass movement of the water, the abundance and character of food, or of other factors. These should affect the form and proportions of the body through the degree of induced development of muscles or fat. Differences of this sort are well known between individuals of certain species of fresh-water fish taken from different environments, as in the case of the yellow perch. Such somatic variations may be "adaptive," as in the case of alteration of form or proportions due to the degree of development of body muscles. It is also conceivable that differences in physical conditions affect directly the early-growth stages of fish in different environments in such a way as to give rise to somatic variations that are nonadaptive, indifferent, or even harmful. Such variation may appear in "passive" structures such as the skeleton (Jordan, 1892). The monstrosities that often arise from ova developed in hatcheries probably are, in part, an extreme instance of this type of "variation," as are the monsters produced under experimental conditions.

At the same time isolation presumably is accompanied by germinal changes that become manifest in heritable somatic alterations. As in the case of mutations, the adaptiveness of these is wholly contingent. They may or may not prove to be useful. It is possible that the variation in number and form of the gill rakers is of this type. A detailed study of the food of the Lake Huron forms described in this paper indicates that within the genus Leucichthys the relation between the number and form of the gill rakers and the character of the food is very loose. All the deep-water forms of the genus have long, slender rakers, but these differ in number and length in such a way as to be characteristic of species and varieties and thus afford one of the most valuable diagnostic characters. Yet there appears to be very little difference in the food of these forms, which consists chiefly of the schizopod crustacean *Mysis relicta*. Living with the deep-water coregonids is the lawyer, *Lota maculosa*, virtually devoid of gill rakers but often found with its stomach filled with Mysis. The little knowledge that we possess thus suggests that the mean differences in gill rakers characteristic of the coregonid forms are of germinal origin and not primarily of individually adaptive nature. In that case such relation as they now bear to the size of the customary food organisms is contingent and secondary and the gill-raker characters have the greater value in taxonomy. The differences in form and position of the bones of the upper and lower jaws, as well as other characters exhibited by the different forms, may ultimately prove to belong in the same category

Experimental study of the effect of environmental factors on fishes in their various stages, together with breeding experiments, are, of course, essential to a full understanding of the characters shown by the coregonid forms. The production, by artificial rearing, of very abnormal characteristics in the whitefish indicates that this field may be very fruitful. Meantime, more critical analysis of the accumulated data on variation may throw light on these problems.

The only conclusion that can be drawn safely from a consideration of the variations in these forms is that only certain characters are modifiable by environmental conditions or tend to vary, and that these characters are virtually the same for all the forms. Thus, the variants of all species may differ from the typical forms in respect to head length, number of scales in the lateral line, length of pectorals, number of gill rakers, etc. Furthermore, so many characters are variable that the varieties may be more strikingly differentiated from their nearest relatives than are the species within a group from one another.

SPECIATION IN THE GREAT LAKES COREGONIDS

ORIGIN OF THE COREGONIDS IN THE BASIN

In this paper I have presented evidence to show that 11 distinct species and 7 possible subspecies of the family Coregonidæ are found in the Great Lakes chain.

There are 9 species included in the genus Leucichthys and 1 each in the genera Coregonus and Prosopium. Lake Michigan has 10 of the 11 species, Lake Huron 9, Lakes Superior and Nipigon 8 each, Lake Ontario 7 (though 1 now seems to be extinct), and Lake Erie 2. The distribution of the various species in each lake is shown in Table 5. In general there is little difficulty in correlating the relationships of the various species in the different lakes, but in a few cases the individuals of a species have varied so far, structurally and even physiologically, from the typical form as to appear to merit designation as a distinct species. There is no doubt about the relationships within the species *artedi* (the most variable of all) nor within the species *johannæ*, *alpenæ*, *zenithicus*, *kiyi*, *hoyi*, *clupeaformis*, or *quadrilaterale*. In the case of *reighardi* it might be questioned whether the *dymondi* form of Lakes Nipigon and Superior actually should be included within that species group, and in the case of *nigripinnis* whether the *cyanopterus* of Lake Superior and the *prognathus* of Lake Ontario were grouped properly within *nigripinnis*. The case of the *dymondi* and *cyanopterus* races seems the more confused, as, in addition to marked structural differences (though the habitat selection is about the same), the time of spawning is very different. In this connection it may be pointed out that time of spawning may vary two weeks from year to year for any school of any coregonid, and the time of spawning of races of many species (namely, *clupeaformis* within Lake Michigan, *zenithicus* of Lake Huron, *kiyi* of Lake Ontario, et al., all of them of virtually certain identification) may be a month or two earlier or later than for related races elsewhere in the basin. It is even reported that within recorded time certain species have changed their time of spawning by a period as great or greater. Inasmuch, then, as spawning time is so variable, the deviation in this particular of the *reighardi* and *nigripinnis* forms loses significance as a specific character. In spite of marked changes in a few systematic characters, the varieties still closely resemble the typical members of their species group; in fact, the resemblance is far closer than that between the whitefish artificially reared in the New York Aquarium and their parents. In the case of *reighardi,* individuals in northern Lake Michigan even show a tendency to vary from the typical form (which occurs in the southern part of that lake) in precisely the same direction that has produced the *dymondi* type.

The systematic scheme here outlined presupposes the presence of 10 distinct species in the Great Basin before the close of the glacial period. The facts of the geological history of the lakes do not contradict the assumption. Two species of coregonids, *artedi* and *clupeaformis,* are distributed in all six of the Great Lakes. Lake Erie is so shallow and warm over most of its extent that probably it is unsuited for any but the most adaptable coregonids; in fact, the bulk of its population is made up of species that thrive best in the bays of other lakes. Three more, *nigripinnis, hoyi,* and *quadrilaterale,* occur in each of the other five lakes; *reighardi* and *kiyi* are found in four of the lakes, *johannæ* and *alpenæ* occur in only two and *nipigon* in only one.

Most of the facts of the distribution of the species can be explained by assuming the presence in the basin of an original stock of 10 coregonids. Only 2 of the 10 survived in all the lakes. None of the rest survived in the warmest lake, but three species found suitable conditions in the other five lakes. One (*reighardi*) survived in all the lakes but Huron, and one (*kiyi*) survived in all but Nipigon. Why their range was thus limited is not clear from any known geological facts. One (*zenithicus*) is absent from Lake Ontario; it may have been unable to return after the late marine inundation of old Admiralty Lake. Two (*johannæ* and *alpenæ*) occur only in Lakes Huron and Michigan; they may have originated in one or other of the lakes subsequent to the Lake Algonquin stage, as these lakes are rather intimately connected, or they simply may have perished in the other lakes from competition or from failure to find suitable conditions.

The restriction of *nipigon* to Lake Nipigon (though it is known to occur also in Lake Winnipeg) seems to support the view that Lake Agassiz was not contemporaneous with Lake Algonquin, which joined intimately Nipigon with Superior and the other lakes but came later. In that case the elevation of the basin of Lake Nipigon with the resultant falls that now prevent exchange between the fish faunas of the two lakes has operated to prevent the spread of *nipigon* into the other lakes.

It seems, thus, that the Great Lakes coregonids were differentiated specifically before the Great Lakes attained their present form. The present distribution of the species, considering Lake Erie to be unfit for most coregonids, can be explained by assuming the extinction of three forms, one in each of the three lakes, by the survival of two forms only in two of the lakes or by their late origin in one or the other of the lakes, and by the assumption that Lake Agassiz came later than the Algonquin stage of the Great Lakes. As we know that the last period of glaciation fell within relatively recent time, geologically speaking, it is likely that many of the present racial distinctions originated during the 20,000 years that geologists estimate have elapsed since the formation of something like the present lakes.

PHYSIOLOGICAL BARRIERS BETWEEN THE SPECIES

It does not appear to be profitable, in the present state of our knowledge of the coregonids of other waters, to speculate further on the origin and precise relationships of the forms in the Great Lakes; but two points are clear—first, that from whatever source the species may have originated, certain factors are operating now to keep them distinct; and second, as I have already indicated, tendencies that may result in the formation of new species are manifesting themselves in at least some of the species already formed.

The factors that keep the species apart apparently are physiological differences between the individuals of different species, differences that result (*a*) in the selection of different habitats and (*b*) in breeding taking place at different seasons, at different depths, and on different bottom.

Segregation Through Different Habitat Selection

The physical conditions in the lakes vary, and the adaptability of the species also is different, so that it is not possible to generalize too strictly about the habitat selection of any species in the basin. In some lakes species that regularly inhabit shallow water elsewhere may be driven, by competition on the shoals or by absence of shoals, to find a living in deeper water; and, being adaptable, they may thrive there (Lake Ontario). In other cases species that regularly inhabit deep water have been known to occur abundantly in shallow water only (Lake Nipigon); but, in general, in any lake there are certain groups of species that are found in shallower water than others. In general, *artedi*, *clupeaformis*, and *quadrilaterale* are shoal-loving forms; *alpenæ*, *zenithicus*, *reighardi*, and *hoyi* also like comparatively shallow water; but *johannæ*, *nigripinnis*, and *kiyi* are found chiefly in the deeper waters.

The bathymetric distribution of the species or groups of species is zonal. Each occupies a rather broad zone defined by the depth of water at its margins. At the center of the zone each has its greatest density of population, and this density diminishes toward the margin of the zone. Only a few stragglers are found beyond their zones, except during the breeding migration. The zones overlap at their margins, so that the different forms are intermingled there in relatively small numbers.

There are no data to indicate why these zones have been selected by the various species or groups of species. Nothing is known about their reactions to the various physical and chemical factors of their environment. Possibly the selection is influenced by the character of the bottom. Throughout the area inhabited by the shoal group, the hydrographic map shows rock, gravel, and sand, and in the deeper parts of the lakes clay and mud. While each species may range over all these types of bottom within its zone, of course it is not only possible but probable that there are differences in the character of the areas designated on the chart as mud, clay, etc., and that these differences influence, indirectly, the distribution of the fish. Certainly all the forms except *artedi* (which is a plankton feeder and therefore normally takes its food above the bottom), so far as known, are confined to a bottom stratum of water of a thickness of not more than 5 feet. In this stratum they find their food, which consists (in all the forms) chiefly of various species of Crustacea and Mollusca. The character of the food available probably is determined directly by the character of the bottom, and therefore a knowledge of the food regularly taken by each species would be helpful in defining this factor of the habitat.

Segregation Through Different Breeding Habits

Most of the species are separated from one another by spawning at different seasons or on different grounds. The three shoal forms (*clupeaformis*, *quadrilaterale*, and *artedi*), wherever they occur in the basin, spawn at approximately the same season—that is, in November and early December—but it is not known that they congregate on the same grounds at the same time. These forms, however, are so far removed from one another that it is not likely that hybridism would occur commonly. What is known of the spawning habits of the other species indicates that within each lake each species has a distinct breeding time or place, or both. To be sure, little is known about this part of the life history of the Nipigon forms, and there are gaps in our knowledge of the breeding habits of some of the forms in the other lakes.

In Lake Michigan *hoyi* is the earliest spawner. It spawns in March at depths of about 20 to 30 fathoms. *Reighardi* spawns in May, probably in shallower water. *Johannæ* spawns in August or September, presumably at depths of 60 fathoms. *Kiyi* is said to spawn in October, also at great depths. *Zenithicus* and *alpenæ* spawn in November, but it is not known that they spawn on the same grounds. Data indicate that the former spawns in deeper water. *Nigripinnis* spawns in January at depths of about 60 fathoms.

In Lake Superior it is not known when or where *hoyi* spawns, but certainly it is not before December. *Nigripinnis* spawns in 60 fathoms in September. *Kiyi*, *zenithicus*, and *reighardi* all spawn in November, as do *artedi*, *clupeaformis*, and *quadrilaterale*, but no one knows that any two spawn on the same grounds at the same time.

In Lake Huron the breeding habits of its species are about like those of related forms in Michigan, except that *zenithicus* spawns in late September and early October and *kiyi* may spawn in early November.

In Ontario *reighardi* is known to spawn some time in spring, probably in May. *Kiyi* spawns in August, probably in deep water. *Nigripinnis* is said to have spawned at about 60 fathoms in January. It is not known when *hoyi* spawns, but the season may be as in Lake Michigan.

The data just reviewed indicate that whatever rôle physiological differences between the various species may have played in species formation they now are an important factor in keeping the species distinct. Thus, habitat preferences separate the species or groups of species into different zones, and differences in breeding behavior cause each species to deposit its eggs at a different time or in a different place.

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SPECIES OF COREGONIDÆ IN THE GREAT LAKES

ANALYSES OF THE SPECIES

LAKE NIPIGON

A. Two flaps between the openings of a nostril; exposed area of the scales of the lateral line not conspicuously smaller than that of the adjacent rows; gill rakers more than 23, relatively long and slender; maxillary usually contained less than 3.8 times in the head; vestigial teeth usually present on the premaxillaries, palatines, mandible, and tongue; body usually laterally compressed.

B. Premaxillaries longer than wide, usually oblique in position, never retrorse; lower jaw contained not more than 2.3 times in the head; gill rakers relatively long and usually more than 31; maxillary seldom contained more than 3 times in the head---Genus Leucichthys

a. Gill rakers usually less than 40.

1. Gill rakers usually more than 36; snout usually contained less than 3.5 times in the head and usually less than 2.2 times in the head depth; the head depth usually contained more than 6.2 times in the head; mandible usually shorter than the upper jaw---*zenithicus*

2. Gill rakers usually not more than 36; snout usually contained not less than 3.5 times in the head and usually more than 2.1 times in the head depth; the head depth usually contained not more than 6.2 times in the head; mandible usually shorter than the upper jaw---*reighardi dymondi*

aa. Gill rakers usually more than 40 and less than 54.

b. Paired fins conspicuously black; body shape in side view ovate; fish commonly attaining a length of 300 millimeters (12¾ inches) or more.

3. Gill rakers usually 48–51; pectorals usually contained 1.4–1.6 times in the pectoral-ventral distance; ventrals usually contained 1.2–1.5 times in the ventral-anal distance---*nigripinnis regalis*

bb. Paired fins pale, or at least not conspicuously pigmented; body shape in side view elliptical; fish not known commonly to attain a greater length than 250 millimeters (8 inches).

4. Gill rakers usually not more than 46; maxillary usually contained less than 2.6 times in the head; mandible usually superior and hooked---*hoyi*

5. Gill rakers usually more than 46; maxillary usually contained more than 2.6 times in the head; lower jaw usually equal to or shorter than the upper, never hooked---*artedi*

aaa. Gill rakers seldom less than 54.

6. Fish attaining a length of more than 300 millimeters (12¾ inches); fins moderately pigmented---*nipigon*

BB. Premaxillaries wider than long, retrorse in position; maxillary usually contained not less than 3 times in the head, but less than 3.8; lower jaw usually contained 2.4–2.7 times in the head; gill rakers less than 32 and more than 20 .... *Coregonus clupeaformis*

AA. A single flap between the openings of a nostril; exposed area of the scales of the lateral line conspicuously smaller than that of those of adjacent rows; gill rakers less than 20, the length of the longest not more than 5 per cent of the head; maxillary usually contained more than 3.8 times in the head; premaxillaries wider than long, retrorse in position; mandible contained not less than 2.7 times in the head; no vestigial teeth; body subterete .... *Prosopium quadrilaterale*

LAKE SUPERIOR

A. Two flaps between the openings of a nostril; exposed area of the scales of the lateral line not conspicuously smaller than that of the adjacent rows; gill rakers more than 23, relatively long and slender; maxillary usually contained less than 3.8 times in the head; vestigial teeth usually present on the premaxillaries, palatines, mandible, and tongue; body usually laterally compressed.

B. Premaxillaries longer than wide, usually oblique in position, never retrorse; mandible contained not more than 2.3 times in head; gill rakers relatively long and usually numerous; maxillary seldom contained more than 3.1 times in the head .... Genus Leucichthys

a. Lower jaw usually longer than the upper and more or less hooked; fish seldom longer than than 200 millimeter (7⅞ inches); body usually conspicuously bloated.

1. Body shape in side view ovate; gill rakers usually less than 41; lateral-line scales usually more than 75; pectorals usually contained less than 1.6 times in the pectoral-ventral distance .... *kiyi*

2. Body shape in side view elliptical; gill rakers usually more than 40; lateral-line scales usually less than 76; pectorals usually contained more than 1.5 times in the pectoral-ventral distance .... *hoyi*

aa. Lower jaw usually equal to or shorter than the upper, seldom conspicuously longer and hooked; fish attaining length of 300 millimeters or more (12¾ inches).

b. Gill rakers usually more than 43.

3. Lateral-line scales seldom less than 80; pectorals seldom contained less than 2 times in the pectoral-ventral distance; ventrals seldom contained less than 1.6 times in the ventral-anal distance; head in adults usually contained 4.3–4.6 times in the total length; maxillary usually contained 2.7–3 times in the head; body subterete .... *artedi artedi*

4. All figures given above tend to be less and the body deeper and more compressed in .... *artedi albus*

bb. Gill rakers usually not more than 43.

c. Body shape ovate in side view; fish spawning in September.

5. Sum of the head depth and the anal base divided by the sum of the maxillary and the snout usually 1.65–1.75; body usually deeper than under *cc;* mandible tip usually conspicuously pigmented .... *nigripinnis cyanopterus*

cc. Body shape elliptical in side view; fish spawning in November or later; lower jaw usually shorter than the upper; mandible usually immaculate or faintly pigmented.

6. Gill rakers usually less than 39; snout usually contained 3.6–3.9 times in the head; eye in adults usually contained 3.9–4.2 times in the head; length of the pectoral fin usually contained 1.8–2 times in the pectoral-ventral distance ... *reighardi dymondi*

7. Gill rakers usually not less than 39; snout usually contained 3.3–3.6 times in the head; eye in adults usually contained 4.2–4.6 times in the head; the sum of the head depth and anal base divided by the sum of the maxillary and snout usually 1.45–1.55 .... *zenithicus*

BB. Premaxillaries wider than long, retrorse in position; maxillary usually contained more than 3.1 but less than 3.8 times in the head length; mandible usually contained 2.4–2.7 times in the head; gill rakers 24–31; ventrals usually contained less than 1.9 times in the ventral-anal distance .... *Coregonus clupeaformis*

AA. A single flap between the openings of the nostril; exposed area of the scales of the lateral line conspicuously smaller than that of those of adjacent rows; gill rakers 15–20, the length of the longest not more than 5 per cent of the head; maxillary usually contained more than 3.8 times in the head; premaxillaries wider than long, retrorse in position; mandible contained not less than 2.7 times in the head; no vestigial teeth; body subterete; ventrals usually contained not less than 1.9 times in the ventral-anal distance..... *Prosopium quadrilaterale*

LAKE MICHIGAN

A. Two flaps between the openings of a nostril; exposed area of the scales of the lateral line not conspicuously smaller than that of those of the adjacent rows; gill rakers more than 23 relatively long and slender; maxillary usually contained less than 3.8 times in the head; vestigial teeth usually present on the premaxillaries, palatines, mandible, and tongue; body usually laterally compressed.

B. Premaxillaries longer than wide, usually oblique in position, never retrorse; lower jaw contained not more than 2.3 times in the head; gill rakers relatively long and usually numerous; maxillary seldom contained more than 3.1 times in the head.......... Genus Leucichthys

a. Gill rakers usually less than 33.

1. Maxillaries and premaxillaries usually unpigmented; mandible usually equal to the upper jaw; pectorals usually contained 1.6–1.8 times in the pectoral-ventral distance.......... *johannæ*

aa. Gill rakers usually more than 32 and less than 45 (except *hoyi*, which may often have 45).

b. Lower jaw shorter than the upper.

2. Gill rakers usually 38–42; pectorals usually contained 2–2.2 times in the pectoral-ventral distance; mandible usually immaculate, or at least not conspicuously pigmented; snout and maxillary relatively long, usually contained 3.4–3.7 and 2.4–2.6 times in the head.......... *zenithicus*

3. Gill rakers usually 34–38; pectorals usually contained 2–2.5 times in the pectoral-ventral distance; mandible usually conspicuously pigmented; snout and maxillary relatively short, especially in the southern half of the lake.......... *reighardi*

bb. Lower jaw seldom shorter than the upper, usually longer.

c. Maxillary usually immaculate; mandible well developed; fish commonly attaining size of more than 250 millimeters (about 10 inches).

4. Gill rakers usually 36–43; pectorals usually contained 1.9–2.2 times in the pectoral-ventral distance; body shape in side view usually elliptical.......... *alpenæ*

cc. Maxillary seldom immaculate; mandible usually frail; fish seldom longer than 250 millimeters (about 10 inches).

5. Body shape in side view ovate; pectorals usually contained 1.4–1.7 times in the pectoral-ventral distance; ventrals usually contained 1–1.3 times in the ventral-anal distance; gill rakers usually less than 41; lateral-line scales usually more than 77; fall spawners.......... *kiyi*

6. Body shape in side view elliptical; pectorals usually contained 1.7–2 times in the pectoral-ventral distance; ventrals usually contained 1.2–1.4 times in the ventral-anal distance; gill rakers usually more than 40; lateral-line scales usually less than 78; spring spawners.......... *hoyi*

aaa. Gill rakers usually more than 44.

7. Body shape in side view broadly ovate; flesh fat and soft; pectorals usually contained 1.6–1.8 times in the pectoral-ventral distance; ventrals usually contained 1.3–1.5 times in the ventral-anal distance; maxillary usually contained less than 2.7 times in the head; paired fins usually conspicuously pigmented.......... *nigripinnis*

8. Body shape in side view elongately elliptical; flesh firm; pectorals usually contained 1.9–2.2 times in the pectoral-ventral distance; ventrals usually contained 1.6–1.8 times in the ventral-anal distance; maxillary usually contained more than 2.6 times in the head; paired fins not conspicuously pigmented.......... *artedi*

BB. Premaxillaries wider than long, retrorse in position; maxillary usually contained more than 3.1 but less than 3.8 times in the head; mandible usually contained 2.4–2.7 times in the head; gill rakers 24–31; ventrals usually contained less than 2 times in the ventral-anal distance.......... *Coregonus clupeaformis*

AA. A single flap between the openings of a nostril; exposed area of the scales of the lateral line conspicuously smaller than that of those of adjacent rows; gill rakers 15–19, the length of the longest not more than 5 per cent of the head; maxillary usually contained more than 3.8 times in the head; premaxillaries wider than long, retrorse in position; lower jaw contained not less than 2.7 times in the head; no vestigial teeth; body subterete; ventrals usually contained not less than 2 times in the ventral-anal distance------*Prosopium quadrilaterale*

LAKE HURON

A. Two flaps between the openings of a nostril; exposed area of the scales of the lateral line not conspicuously smaller than that of those of the adjacent rows; gill rakers more than 23, relatively long and slender; maxillary usually contained less than 3.8 times in the head; vestigial teeth usually present on the premaxillaries, palatines, mandible, and tongue; body usually laterally compressed.

B. Premaxillaries longer than wide, usually oblique in position, never retrorse; lower jaw contained not more than 2.3 times in the head; gill rakers relatively long and usually numerous; maxillary seldom contained more than 3.1 times in the head----------Genus Leucichthys

a. Gill rakers usually less than 33.

1. Length of the pectoral fin usually 1.5–1.8 times in the pectoral-ventral distance; pectoral rays usually 17 or 18; jaws usually equal; body shape in side view rather ovate; fish spawning in August and September----------------------*johannæ*

aa. Gill rakers 31–45, seldom less than 33 or more than 43.

b. Body outline in side view ovate; pectorals usually contained 1.4–1.7 times in the pectoral-ventral distance; ventrals usually contained 1–1.2 times in the ventral-anal distance.

2. Mandible usually projecting and strongly hooked; maxillary pigmented; fish seldom over 200 millimeters long (7⅞ inches); usually conspicuously bloated; lateral-line scales usually 75–83; gill rakers usually 36–40--------------------------*kiyi*

bb. Body outline in side view elliptical; pectorals usually contained more than 1.7 times in the pectoral-ventral distance; ventrals usually contained more than 1.2 times in the ventral-anal distance.

c. Gill rakers usually 40–43; mandible frail and usually projecting; fish seldom over 200 millimeters long (7⅞ inches); snout short; the head in side view sharply triangular; spring spawners.

3. Maxillary pigmented; fish usually conspicuously bloated--------------------*hoyi*

cc. Gill rakers usually 33–37; mandible well developed, either longer or shorter; snout longer and rounded or truncated, so that the head in side view is not distinctly triangular. Fish attaining adult size of 300 millimeters and more (12¾ inches); spawning in fall; pectorals relatively short.

4. Mandible strong; usually projecting beyond the upper jaw; maxillary usually immaculate; premaxillaries less vertical in position; fish spawning in late November--*alpenæ*

5. Mandible moderately developed and usually shorter than the upper jaw; maxillary usually pigmented; premaxillaries nearly vertical; fish spawning in September–October--*zenithicus*

aaa. Gill rakers usually more than 43.

bbb. Body shape in side view ovate; flesh soft and fat; fish seldom found at depths of less than 35 fathoms.

6. Abdominal fins usually conspicuously black; Pv/P seldom more than 1.8; Av/V usually less than 1.5; H/M usually less than 2.7-------------------*nigripinnis*

bbbb. Body shape in side view elliptical; flesh firmer and with little oil; fish seldom found as deep as 35 fathoms.

7. Abdominal fins not conspicuously black; Pv/P usually more than 1.8; Av/V usually more than 1.5; L/D usually more than 3.9; H/M usually more than 2.8--*artedi artedi*

8. Abdominal fins usually conspicuously black; Pv/P usually less than 1.8; Av/V usually less than 1.5; L/D usually less than 3.9; H/M usually less than 2.8--*artedi manitoulinus*

BB. Premaxillaries wider than long, retrorse in position; maxillary usually contained more than 3.1 times in the head length, but usually less than 3.8; lower jaw usually contained 2.4–2.7 times in the head; gill rakers 24–31; Av/V usually less than 1.9---*Coregonus clupeaformis*

AA. A single flap between the openings of a nostril; exposed area of the scales of the lateral line conspicuously smaller than that of those of the adjacent rows; gill rakers 15–19, the length of the longest not more than 5 per cent of the head; maxillary usually contained more than 3.8 times in the head; premaxillaries wider than long, retrorse in position; lower jaw contained not less than 2.7 times in the head; no vestigial teeth; body subterete; Av/V usually more than 1.9 ---------- *Prosopium quadrilaterale*

LAKE ERIE

A. Premaxillaries longer than wide, oblique in position, never retrorse; lower jaw contained not more than 2.3 times in the head; gill rakers long and never less than 40 --- Genus Leucichthys

1. L/D usually more than 3.7; Pv/P usually more than 2; Av/V usually more than 1.7; lateral-line scales usually more than 79 ---------- *artedi artedi*
2. L/D usually less than 3.7; Pv/P usually less than 2.1; Av/V usually less than 1.8; lateral-line scales usually less than 79 ---------- *artedi albus*

B. Premaxillaries wider than long, retrorse in position; maxillary usually contained more than 3.1 times in the head; lower jaw usually contained more than 2.3 times in the head; gill rakers always less than 40 ---------- *Coregonus clupeaformis*

LAKE ONTARIO (L. NIGRIPINNIS PROGNATHUS EXCEPTED)

A. Two flaps between the openings of a nostril; exposed area of the scales of the lateral line not conspicuously smaller than that of those of the adjacent rows; gill rakers more than 23, relatively long and slender; maxillary usually contained less than 3.8 times in the head; vestigial teeth usually present on the premaxillaries, palatines, mandible, and tongue; body usually laterally compressed.

B. Premaxillaries longer than wide, usually oblique in position, never retrorse; mandible contained not more than 2.3 times in the head; gill rakers relatively long and usually numerous; maxillary seldom contained more than 3.1 times in the head ---------- Genus Leucichthys

a. Gill rakers usually less than 41.

1. Mandible included within the upper jaw; body little compressed laterally; pectorals usually contained more than 2.1 times in the pectoral-ventral distance; ventrals usually contained more than 1.4 times in the ventral-anal distance; spring spawners ---------- *reighardi*

aa. Gill rakers usually more than 40.

b. Body shape in side view usually ovate; fish spawning in summer.

2. Lateral-line scales usually more than 75; adipose usually contained less than 3.8 times in the head; lower jaw usually longer than the upper; ventrals usually contained less than 1.5 times in the ventral-anal distance ---------- *kiyi orientalis*

bb. Body shape in side view usually elliptical; fish spawning in late fall.

3. Gill rakers seldom more than 47; lateral-line scales seldom more than 76; ventrals usually contained less than 1.6 times in the ventral-anal distance; maxillary usually contained less than 2.8 times in the head; mandible usually longer than the upper jaw ---------- *hoyi*
4. Gill rakers often more than 47; lateral-line scales often more than 76; ventrals usually contained more than 1.5 times in the ventral-anal distance; maxillary usually contained more than 2.7 times in the head; mandible seldom longer than the upper jaw ---------- *artedi*

BB. Premaxillaries wider than long, retrorse in position; maxillary usually contained not less than 3.1 times in the head, but less than 3.8; lower jaw usually contained 2.4–2.7 times in the head; gill rakers less than 32 and more than 20 ---------- *Coregonus clupeaformis*

AA. A single flap between the openings of a nostril; exposed area of the scales of the lateral line conspicuously smaller than that of those of adjacent rows; gill rakers less than 20, the length of the longest not more than 5 per cent of the head; maxillary usually contained more than 3.8 times in the head; premaxillaries wider than long, retrorse in position; mandible contained not less than 2.7 times in the head; no vestigial teeth; body subterete.
Prosopium quadrilaterale

DESCRIPTIONS OF THE COREGONIDÆ IN THE GREAT LAKES

Genus LEUCICHTHYS Dybowski

Argyrosomus Agassiz, 1850, p. 339 (*clupeiformis* of DeKay, not of Mitchill–*artedi*). Not of de la Pylaie.
Leucichthys Dybowski, 1874, p. 390; Dybowski, 1876, p. 18 (*Coregonus omul* Pallas).
Allosomus Jordan, 1878, p. 361 (*Coregonus tullibee* Richardson).
Thrissomimus Gill, in Jordan and Evermann, 1911 (*Coregonus artedi* LeSueur).
Cisco Jordan and Evermann, 1911 (*Argyrosomus nigripinnis* Gill).

Dybowski (1874) proposed the name Leucichthys for *Coregonus omul* Pallas and *Coregonus tugun* Pallas, coregonids with "der Mund vorderständig oder halb oberständig. Die Symphyse des Unterkiefers mit einer höckerartigen Anschwellung." There is nothing in the descriptions of either *omul* or *tugun* to indicate that they differ from our lake herrings, except that he says for *tugun* "Oberkiefer mit einer Reihe schwacher Zähnchen besetzt." It is apparent at once that no fish held to be a *Coregonus* would likely have toothed maxillaries, and reference to the original paper, which Dybowski (1874, p. 383) says was presented for publication to the Siberian division of the Geographic Society in Irkutsk in the winter of 1871, but which did not, in fact, appear in the publications of the society until February, 1876, suggests that Dybowski meant "Unterkiefer" instead of "Oberkiefer." The Russian edition says of *tugun* "mandible provided with a row of faint teeth." Dybowski, in his original paper, rated Leucichthys as a subgenus together with *Coregonus sensu strictiore* under the genus Coregonus. European ichthyologists generally have not recognized Leucichthys as a genus or even as a subgenus.

Jordan and Evermann (1911) substituted the name Leucichthys for the genus Argyrosomus established by Agassiz to include the lake herrings, but which (the authors quote Gill here) was preoccupied, the name having been used in 1835 by de la Pylaie for the "maigre" (*aquila*) of the Mediterranean. Under Leucichthys three subgenera—Allosomus, Thrissomimus, and Cisco—are recognized. The representatives of the subgenus Allosomus I regard as subspecies of certain species in the Thrissomimus group. I find, further, no possibility of distinguishing structurally between the species of the latter group and those of Cisco and therefore do not subdivide the genus Leucichthys.

The Great Lakes representatives of the genus Leucichthys are fish of medium size, seldom larger than 1½ pounds in weight. The premaxillaries are longer than wide and oblique or nearly vertical but never retrorse in position. There are two flaps between the openings of each nostril. The exposed area of the scales of the lateral line is not conspicuously smaller than that of those of the adjacent rows. The gill rakers are relatively long and numerous (*johannæ* excepted). The maxillary usually is contained less than 3 times in the head. The mandible is contained not more than 2.3 times in the head. Vestigial teeth usually are present on the premaxillaries, palatines, mandible, and tongue. The prefrontal bone is elongated and extends almost completely over the orbit. The carina of the frontals extends to the frontal-parietal suture.

The species described in the following pages fall into three ecological groups whose relations are considered in another place. These groups are, in the order in which they are considered in the text, (1) the chubs *johannæ, alpenæ, zenithicus,* *reighardi*, and *nigripinnis*, and in some lakes the bloaters (*hoyi*) and the kiyi (*kiyi*), all of which occur in deep water; (2) the lake herring *artedi* and possibly *nipigon*, shallow-water forms feeding chiefly above the bottom; and (3) the whitefishes *clupeaformis* and *quadrilaterale*, shallow-water forms feeding chiefly on the bottom. The natural history of most of these forms is treated in connection with descriptions that follow. The chubs and bloaters, however, are a commercial group, the members of which are handled by the fishermen as a unit, as all are taken in gill nets set in deep water. It is convenient, therefore, to analyze here the data concerning them, obtained chiefly from fishermen's records, and to see what conclusions they warrant. What follows in this section has reference chiefly to chubs but contains incidental references to commercially valueless bloaters that are taken with them. The reading of this section may be undertaken more profitably, perhaps, after page 476.

The term "chubs" is said first to have been applied to deep-water Leucichthys by the Chicago markets. The fishermen also call them "longjaws," "bluefins" (abbreviated to "jaws" and "fins"), "tullibees," "mooneyes," and "ciscoes." All of these names are used locally in varying senses and are not applied to the same fish by fishermen in different parts of the lakes; but wherever any of the above colloquial names is current any one of them may be used to designate a catch containing all the species. All are fat, herringlike fish, which inhabit the deeper waters.

In the Federal statistics all species of Leucichthys have been grouped together as "ciscoes," and the total of "ciscoes" has been from one-third to one-fourth of the entire output of the Great Lakes. The chubs have made up a variable but considerable part of this total.

Chubs occur in all the lakes except Erie. In Lake Nipigon, though certain species apparently are abundant, they have not yet become marketable. In Lake Ontario there are now only three species that probably are abundant enough to be taken in commercial quantities, but few examples of these species ever attain sufficient size to be captured by the 3-inch gill net (which is the minimum mesh allowed), so that these fish here have no economic significance. In Lake Superior the bluefin (*nigripinnis*) was commercially very important for a few years at the beginning of the century, but now it is commercially extinct. Of the other species, *zenithicus* is the only large chub that is common enough to be caught in commercial quantities. It has had little favor with the markets because of its thin body and only a few have ever been caught. The chub-fishing industry for years has been important on Lake Michigan, where it is supported by no less than seven species—*johannæ*, *alpenæ*, *zenithicus*, *reighardi*, *nigripinnis*, *kiyi*, and *hoyi*. It is important on Lake Huron, also, where it is sustained by four species only. *Reighardi* is not known to occur in the lake, and *kiyi* and *hoyi* do not grow large enough regularly to gill in chub nets.

Chub fishing started on Lake Ontario as early as 1860. The fish taken at this time were called ciscoes and bloaters instead of chubs. This fishery was carried on chiefly off the western and southern shores of the lake and did not attain sufficient proportions to affect more than the local fish trade. By 1900 the fishery was exhausted, and one of the species that sustained it apparently was exterminated. On Lake Michigan, so far as can be learned, chubs were being taken as early as 1869.

The first fish of this kind were caught for the salt-fish trade, and not until there was a demand for smoked fish did chub fishing flourish. Toward the end of the last century the chub supply of Lake Michigan could no longer easily supply the demand and the bluefins were marketed from Lake Superior. For about 10 years, or up to about 1907, these fish were caught and then suddenly became commercially extinct. About 1902 the use of small-meshed nets was begun on Lake Huron, and since about 1910 chubs have been sold at some time out of every port that could produce them. Lakes Michigan and Huron remain, then, the source of the chub supply. What follows pertains particularly to these two lakes.

Chubs are not sold fresh in the markets at any of the ports where taken. However, if properly cooked, the fresh flesh is not inferior to that of the whitefish, according to many. The bulk of the catches has been forwarded to Chicago or other midwestern cities for smoking. Thus prepared, the flesh is very palatable.

In late years the chub supply exceeded the demand largely because of the substitution of species of Lake Winnipeg Leucichthys and the Lake Erie herring. The former are inferior in quality and were used only in winter, when the Great Lakes supply was largely shut off. Since the wide use of 2½-inch netting for chubs on Lake Michigan and the consequent capture of small fish, the Erie herring, or cisco, competed strongly with the chubs, even to the extent of displacing them in the Chicago markets.

With the failure in 1925 of the Erie cisco, of which some 15,000,000 to 40,000,000 pounds had been marketed annually, the New York markets lost their supply of fish for smoking and Chicago buyers faced the competition of New York buyers in the chub market. Contracts for chubs were let at fancy prices, and where two years before the fishermen had to fish chubs at the pleasure of the buyers, in 1926 the tables were turned completely and chubs became the principal product of the lakes that could supply them. Where formerly only occasional fishermen had chub gangs, in 1926 everyone who could acquire the netting began the pursuit of the severely depleted schools.

Gill nets, which in Wisconsin,[3] Illinois, and Indiana are of 2½-inch, in Michigan of 2¾-inch, and in Canada of 3-inch stretched mesh, are used to catch the fish. The nets commonly employed are about 5 feet deep when in use and are set on the bottom at depths of 10 to 100 fathoms. In Lake Huron the nets are set, by preference, in water of 60 to 75 fathoms, where water of such depth is accessible. At the northern and southern ends of the lake 50 fathoms is the maximum depth easily reached by the fishermen. While there is deeper water in the two lakes and the fishermen have taken chubs in it, they prefer to keep their nets out of it. Unless the lines of the nets are new, there is danger that they will part from the strain that is imposed on them in lifting them from more than 75 fathoms of water.

"Mud" bottom is preferred by all chub fishermen. This bottom (judging from the samples brought up in the slits of the leads and from the descriptions of the fishermen) has the physical properties of clay and may be gray, blue-gray, yellow, or red in color. It is designated as clay on the United States Lake Survey charts, though in some areas, especially in Georgian Bay and in Lake Huron off Tobermory and Southampton, the chub nets are set in areas designated on the chart as mud.

[3] The new Wisconsin law reads that after July 1, 1926, the mesh may not be less than 2⅝ inches.

The bottom here is mucky in character and black, according to the fishermen. The most favorable bottom is soft; so soft that the sounding lead (a window weight of 3 to 4 pounds is commonly used) sinks for several inches into it. The leads of the nets likewise may sink into the mud and often drag the lower portions of the net with them. The extent to which the nets have been buried in the bottom is indicated sometimes by the adherence of bottom material to its threads. The boats may run as far as 50 miles from their harbor in search of suitable bottom and water of appropriate depth. The nets are lifted every third to fifth day.

The fishermen believe that the chubs swim in schools. This belief is based on the occurrence of the fish in numbers in some parts of the nets while they may be absent or less abundant in other parts. The coregonids of Europe (Fatio, 1890; Smitt, 1895) are known to be gregarious, as are also the other coregonids of the Great Lakes, and it is not improbable that the opinions of the fishermen are correct in this particular.

These schools are believed to be very sensitive to currents. The chub catchers welcome unsettled weather, when the existence of strong currents is supposed to drive the fish into the deepest water from the shallow water, or, if the fish are swimming high, from the upper layers to the bottom. We know that there are undercurrents in every lake subjected to wind action, which are the return flow of waters accumulated by the wind, and it is entirely consistent to believe that the more violent the wind the more violent will be these currents. The fishermen certainly find that during heavy storms all manner of débris and even logs are carried into their nets by the currents in the shallower waters, and they likewise believe that these violent winds increase the catches of the chub nets. If it can be determined to what depths these wind-produced currents penetrate, then, if the fishermen are correct in their assumption that the chubs avoid them, the lower limits of the stratum to which the chubs rise when they are not on the bottom will be defined.

Harrington (1895) showed the direction of the prevailing surface currents of the Great Lakes. There is no other literature on currents in the Great Lakes, so far as I am aware. The fishermen, in their experience, have obtained some data on the depths to which currents are active. For example, it is a matter of common knowledge among gill netters of the upper lakes that during storms their nets off open shores are not safe from destruction by current-carried débris in less than about 20 fathoms. In certain localities, as in channels and around islands, currents commonly are evident at greater depths. The depths to which these wind-produced currents are felt depend probably on the season of the year. When the difference in temperature between surface and bottom waters is least (as in spring and fall) the resistance of the water to mixing is slight, and at such times it is conceivable that in a lake as large as one of the Great Lakes the winds might affect the waters even to a depth of 60 fathoms. On the other hand, in the summer it is improbable that, at least in the upper lakes, such currents are conspicuous in their effect in water much deeper than 20 fathoms. In Lake Ontario it is certain that in summer the currents off open shores may be strong enough to damage nets in water as deep as 30 fathoms. A vertical series of temperature readings made in the lakes in summer would show, by the location of the thermocline, to what depths currents were active.

Drummond (1890) published a series of temperatures taken in Georgian Bay on July 27, 1888, which indicates that the thermocline for the bay was around 10 fathoms. A few temperature readings that I took in Lake Huron in September of the years 1917 and 1919 (see Table 12) indicate that the thermocline was somewhere between 15 and 35 fathoms, but probably a great deal higher than 35 fathoms, as Drummond's records indicate for Georgian Bay. Figures given in the same table show that the thermocline in Lake Nipigon in late July, 1922, was around 12 fathoms and in Lake Michigan in August, 1920, above 24 fathoms. Records for Lake Superior (in Table 13) indicate that on August 5 and 10, 1922, it was around 5 fathoms, except in Black Bay, where, on July 20, there was no evidence of a thermocline at 8 fathoms. Figures given by Coleman (1922) show that in Lake Ontario, on October 3, 1922, the thermocline was around 20 fathoms.

In Lake Nipigon, on July 28, 1922, there was no evidence of warming at 56 fathoms. The studies of Clemens, however, show that winds may lower the thermocline considerably and the bottom waters may be warmed slightly even to greater depths. In Lake Michigan the deepest temperatures recorded in August and October, 1920, at 40 and 49 fathoms, respectively, showed a fraction of a degree above the temperature of maximum density; and in August, 1894, Ward (1896) found about the same temperature there down to 72 fathoms. In Lake Huron the temperature of maximum density was reached on September 12, 1917, at 65 fathoms and on September 18, 1919, at 60 fathoms. In Lake Superior, the temperature of 4° was obtained on August 24, 1921, at 54 fathoms and on June 14, 1922, at 25 fathoms. Coleman's (1922) figures for Lake Ontario show no warming at 50 fathoms on October 3, 1922. It may be noted that bottom temperatures of 4° in depths of more than 50 fathoms also have been recorded in summer from Cayuga and Seneca Lakes in New York.

These data indicate that during the warmest part of the year there is little mixing of water by wind action in any of the lakes below 20 fathoms, and at depths of 40 fathoms currents had not brought about the admixture of warmer surface water and bottom water in volume sufficient to raise the bottom temperature more than a fraction of a degree above 4° C., the lowest temperature that could occur on the bottom in summer. Of course, temperature penetration depends largely on the amount of wind action, and the more continued and violent the winds in summer, the deeper would be their effects.

It appears from the foregoing that in summer the wind-produced currents are relatively ineffective in more than 40 fathoms. In the spring and fall, when the water is colder, currents are possible, of course, to greater depths. With no more data on currents or temperatures than are at present available it does not seem profitable to speculate further on the probable effect of these factors on the movements of the chubs, especially as it is not known how sensitive they are to differences in the rate of water movement in their environment.

The chub fishermen know relatively little about the spawning season of any of the species. In several localities on Lake Michigan and Lake Huron *alpenæ* and *zenithicus* become the objects of special fisheries during their spawning season, and out of a few ports on Lake Michigan the spawning *hoyi* are sought for; but only occasional persons here and there know anything about spawning runs of other species of chubs. In fact, many of the fishermen believe that the chubs spawn all the year round. This belief is based on the observation that eggs are found free in the body cavity of an occasional specimen during the greater part of the fishing season. Of course, in Lake Michigan, where some species may be spawning during every month except June and July, such observations may well pertain to individuals spawning normally; but in Lake Huron, where the spawning season of the four species falls between August and January, some other explanation must be sought. It does not follow that such specimens are spawning. In most bony fishes the eggs are formed within a membranous ovisac and are carried from this to the genital opening by means of an oviduct continuous with the ovisac. There are no openings connecting ovisac or oviduct with the body cavity, and therefore the eggs can not get into the body cavity on their way to the genital opening.

In Coregonidæ the oviduct is short and not continuous with the ovisac, so that the eggs, after leaving the ovary, can get into the body cavity. It has been supposed that the normal course of the eggs after leaving the ovaries was to fall into the body cavity and thence to find their way out through the short oviduct. Kendall (1921) has shown that the eggs probably pass along a trough formed by the mesovarium, and that normally they do not escape into the body cavity. Should any eggs get into the body cavity and remain there after the fish have left the spawning grounds they would be noticed easily when the fish are dressed. Certain fishermen have told me that they sometimes find eggs in the body cavity of the lake trout in summer. Such eggs, they state, are much enlarged at this time. The retention of eggs in the body cavity has been recorded at least once in literature. B. G. Smith (1916) states that in many specimens of Cryptobranchus a few eggs are still to be found in the body cavity after spawning. It is probable, therefore, that what the fishermen observe outside of the spawning season are eggs that have been thus retained in the body cavity, and there is then no evidence that the chubs deposit their eggs at irregular intervals throughout the year.

It has already been stated that four species of chubs are found in Lake Huron and seven in Lake Michigan. Virtually every haul from the chub nets contains at least a few representatives of each species, together with the smaller chubs and bloaters that may be caught in nets with meshes of any size, even though they could pass through a mesh 10 abreast. Large chubs, also, not rarely become entangled in nets of mesh too coarse to gill them. Little is known concerning the proportion in which the various species occur at the various locations in the lakes at different seasons. What observations I have made will be recorded under each species concerned. The fishermen themselves make no distinction between the species, and consequently their records show nothing but the weight of the lift and sometimes the location of the gang lifted. Some of these records show marked fluctuations in the abundance of the chubs from month to month. In certain instances, with the aid of the results of the examinations of the chub lifts, these fluctuations can be ascribed definitely to the changes in the behavior of certain of the species of chubs. In Tables 14 and 15 are given statistics prepared from these records for 5 tugs from 5 ports on Lake Huron and for 3 tugs from 3 ports on Lake Michigan, each of which operated large chub gangs. For each tug the total and average weights of the catches are given for each month as long as fishing operations were continued during the year. Such conclusions bearing on the behavior of the fish as appear warranted from the data at hand are added.

Off Cheboygan (35 to 50 fathoms) chubs are not present on the grounds until May. The lifts increase slightly in weight in June and then fall off until September. From the middle of September until the middle of October the biggest lifts are made. After the latter date the lifts dwindle to almost nothing (see p. 399), and the nets are pulled out. Trout and whitefish are then running toward shore, and the 2¾-inch nets are laid up until the following May. The increased lifts for September and October point to a spawning run. Examination of the lifts taken during the September–October period shows that only *zenithicus* is being caught and that all the fish are spawning. It appears from the foregoing that the chub schools leave the shallow area at the north end of the lake in the fall and that they do not return until the following summer. Furthermore, only one species, *zenithicus*, is left on the grounds after the middle of September, and this species seeks these grounds to spawn. Further details of the spawning habits of this species will be found in another place.

Records of the Alpena, Southampton, and Duck Islands tugs present a different aspect. The tugs from these three ports fish in the vast central basin of the lake, which lies within the 60-fathom contour line. (See fig. 5.) The conditions in this area, as shown on the hydrographic map, are fairly uniform as to bottom and depth, and it is not surprising, therefore, that the records are similar for the three ports. The most striking feature of these records is the decline in the average weight of the lifts in September. The Duck Islands boat usually pulls in her nets before September, and the Southampton tugs neglect their nets in September for the trout. Both ports fish only large-meshed nets thereafter. This sharp decline is due apparently to the departure of most of the fish from the grounds. Examinations of the lifts made during September off Alpena showed that *johannæ* was the predominant element in the catches but that virtually all these chubs were individuals that, judging from the development of the sex glands, would not spawn until another season. Only an occasional ripe female was found. The inference follows that the schools of mature fish had moved to their spawning grounds, leaving the immature fish behind. Additional data to support this inference are given under the discussion of the breeding habits of the species in question. The Alpena lifts increase again in November, and this increase may be due to their return to the grounds. The fluctuations from month to month before September follow no constant course and can not be explained at present.

Unlike the other records, those for Harbor Beach show no marked increase or decrease in the average size of the lifts for the season. A general decline is apparent, however, from August until the nets are pulled out at the end of October. No explanation for this decrease suggests itself.

It is probable, from the foregoing, that the chub schools in the northern, southern, and central sections of the lake are differently constituted and that the successful catches of the boats fishing in these areas do not always depend on the same species. Many more observations must be on the proportions in which the four species are found in the lifts at different times and places before more can be read from the records of the commercial boats.

On Lake Michigan there are many more ports that fish chubs than on Lake Huron, but I have been able to obtain records from only three boats. Two of these fish in the northern basin, and several examinations of their catches indicate that they depend on the same species of chubs, the longjaw predominating. At Charlevoix the records show an even average through the season until November, when the lifts fall off. The Northport records indicate that the summer fishing is light (the gangs were pulled in in July and August), but the November and December lifts are relatively heavy. The records may be explained by assuming that the Charlevoix boat did not find the longjaw in the spawning season in November, while the Northport boat did.

The other records are for the southern basin, where several species of chubs are known to occur abundantly at times. The interesting features are the heavy lifts in August, October, and November. It is not known what occasioned the increased lifts in August, but in the fall the longjaw and the short-jawed chub (especially the latter) are known to spawn on these grounds. In February and early March the bloaters spawn here, too, but there are no figures of production for these periods.

The various records may not be set against one another to compare the relative abundance of chubs at each port. First, the nets employed by the Ontario boats are 3-inch, by the Indiana boats 2½-inch, and by the rest 2¾-inch. The statistics are not of the same years; they do not show the length of the nets operated nor the period of time each net was in the water before lifting; nor is any allowance made for the superior ability of the pilots of certain vessels in operating their nets. Each fisherman has his own ideas as to how many leads there should be on a given piece of net, how it should be seamed on the lines, at what speed the boat should run to set, in what direction the gang should run, etc. The data presented are sufficient, however, to give an idea of the value of these fish from the commercial point of view.

Conservation legislators nowhere have recognized the chubs, except to regulate the size of the mesh used to catch them. In spite of unrestricted fishing, the chubs still hold forth, but in much diminished numbers, so far as can be learned from the fishermen's statements. Unfortunately, no statistics are available for comparing catches of different periods of years. Unless accurate records were available for a considerable number of years on the same grounds, and unless these showed the weight of the catches, the length of the nets employed, and the location of the fishing grounds, no judgment could be formed as to the past and present abundance. While records that answer most of these requirements are available for the last four or five years, they show nothing conclusive. Every fisherman recognizes the fact that one season may bring very poor fishing for various reasons, while the next may bring more fish than have been known for several preceding years. Hence, average catches for different periods of years long enough to eliminate annual fluctuations, and expressed in terms of net length, must be compared in order to determine whether catches have increased or diminished over a particular area.

No statistics of production are necessary to show that chubs are much less abundant now than formerly. A few facts of the history of the industry will show to what extent they have been depleted. The first chub fishermen used nets of 3 to 4 inch mesh. Little by little the meshes employed grew smaller as the fish grew less abundant, until many of the chub fishermen are now using about the smallest mesh that will take a marketable fish. In 1920 chubs were so scarce in Lake Michigan that many boats had to quit fishing for them, even with a minimum mesh. In Lake Huron the schools are less depleted because the drain on their numbers has been less severe, but here the same sort of situation obtains. The Canadian fishermen, with their minimum 3-inch mesh, have had to give up fishing on grounds where the American fishermen competed with their 2¾-inch nets; and even where 3-inch nets were used exclusively, as in Georgian Bay and at Southampton, the production has dwindled. Chub fishing was begun from Southampton about 1910, 10 to 12 miles WNW. of the city. After three years the catches began to fall off on these grounds until a point was reached at which the nets were operated on a narrow margin of profit. Efforts of the tugs to find new grounds have proved unsuccessful so far. Inside Georgian Bay and at Tobermory matters appear to be still worse. Here the industry began about 1912, and at no time have more than four or five small gasoline boats per year been engaged in chub fishing. At every port on the bay fishermen say that four nets now will not catch what one caught formerly. They say that the nets on the old chub grounds now are filled with the lawyer (*Lota maculosa*). Whether the lawyer preys on the chub and is responsible for the disappearance of the latter is a question. While the decrease in the abundance of the fish has not been marked on the American shore, nevertheless the consensus of opinion among American fishermen indicates that the fish are becoming less abundant. Since about 1917, it has been necessary for every tug to increase the length of its gangs to maintain the weight of its catches at the average level of preceding years.

Drastic protective measures must be enacted if the chubs are not to be exterminated completely. One of their number, the blackfin, already is extinct in three of the four lakes where it was commercially important, and their close relative, the Erie herring, which existed for years in almost fabulous abundance, is virtually gone. It seems quite impossible that the already seriously reduced schools should long withstand the drains of the present fisheries, the most intensive in the history of the lakes.

LEUCICHTHYS JOHANNÆ Wagner

THE CHUB (FIG. 14)

Argyrosomus johannæ Wagner, 1910, pp. 957–958, Lake Michigan; not of Jordan and Evermann, 1911.

Argyrosomus hoyi Evermann and Smith, 1896, pp. 310–312, in part, Lake Michigan.

Leucichthys johannæ, the chub, has been described from Lake Michigan and is known to occur in Michigan and Huron only of the Great Lakes series. In both lakes the species is represented by pale fish, which seldom attain more than moderate size for the genus, and which have few gill rakers on the first branchial arch, a more or less ovate body shape, as seen from the side, and a rather long snout and paired fins. The species prefers the deeper waters and spawns in late summer. The Huron race appears to differ from the typical form in having somewhat fewer scales in the lateral line and fewer scale rows, more pectoral rays, a somewhat longer head, snout, and paired fins, and to be somewhat more pigmented.

Type

The type is a male specimen (catalogue No. 87353, U. S. National Museum) 265 millimeters in length, taken "some 18 miles off Racine, Wis., in Lake Michigan, in about 25 fathoms on July 3, 1906." Counts of certain multiple parts and proportional lengths for this specimen are shown in Table 17 and are repeated in the text description that follows.

Leucichthys johannæ of Lake Michigan

The chub is moderate in size, seldom longer than 3 decimeters (12 inches), with a maximum weight of about 1½ pounds. The fish is roughly fusiform in shape, moderately compressed, and elongate. The greatest depth is just in front of the dorsal and usually comprises 22 to 27 per cent of the total length. The width is about 48 to 53 per cent of the depth. The anterior dorsal profile rises rapidly and in nearly a straight line for about two-thirds the distance from the tip of the premaxillaries to the dorsal and continues to the dorsal in a curve with only a slight upward trend. From the insertion of the dorsal the contour slopes into the caudal peduncle in a more or less straight line. The ventral profile from the tip of the snout to the caudal peduncle is rather uniformly curved. The head is relatively long and of little depth, rather acutely triangular in side view. Its length is contained 4.2 [(3.8) 4–4.2 (4.4)] [4] times in the total length. The snout likewise is elongate, narrow, and acute in side view, and is contained 3.4 [(3.2) 3.3–3.6 (4)] [5] times in the head length. The premaxillaries usually are little or not at all pigmented and are oblique in position, meeting the horizontal axis of the head at an angle of 50° to 60°. The maxillary seldom is pigmented and never extends to the center of the eye. The lower jaw is moderately developed and usually equal to the upper, though often longer or shorter. The eye is moderate in size and is contained 4.5 [(4) 4.4–4.6 (4.9)] times in the length of the head. The gill rakers on the first branchial arch number 10+19 [(9) 10–12 (14)+(16) 17–20 (22)]=(26) 27–32 (36).[6] Scales in the lateral line number 82 [(74) 80–90 (95)]. Rows of scales around the body in front of the dorsal and ventrals number 41 [(38) 41–44 (46)], [7] in front of the adipose and anus 33 [(31) 33–37 (38)],[7] and around the caudal peduncle at its commencement 26 [(22) 24–26 (27)][7].

The dorsal rays are 10 [9–10 (11)];[8] anal rays 12 [(10) 11–13 (16)];[8] pectoral rays 17 [(14) 16–17 (20)]; ventral rays 11 [11–12].[9] The length of the pectoral fin is contained 2 [(1.5) 1.6–1.8 (2.1)] times in the distance from the pectorals to the ventrals. The dorsal margin of the distal third of the pectoral usually is strongly decurved. The length of the ventrals is contained 1.5 [(1.1) 1.2–1.5 (1.6)] times in the distance from their origin to the origin of the anal.

The color in life is silvery, with a more or less faint pinkish to purplish iridescence, which is strongest above the lateral line and absent on the belly. Close examination reveals a pale slaty bluish to pea green on the back below the silvery layer. This color is most pronounced in front of the dorsal. It changes to blue-green halfway to the lateral line, and that color continues to the white belly. The slaty tone is

[4] The figures in brackets, unless otherwise stated, are based on an examination of 74 specimens, ranging in length from 212 to 288 millimeters.

[5] Forty-seven specimens.

[6] One-hundred and twenty-two specimens.

[7] Thirty specimens.

[8] Forty-seven specimens.

[9] Ten specimens.

due in part to the presence of heavy pigment deposits bordering the exposed surfaces of the scales on the dorsal area. The top of the head is cartilaginous white, usually obscured with abundant, fine pigment dots, with four small patches of green lying in the frontal bones on each side of the carina. Three of these patches are situated posterior to the center of the eye and are nearly contiguous, extending backward to the occiput. The first is the largest and is rounded triangular in shape. The other patch is situated on the side of the carina and is club-shaped. Its narrow end extends backward and inward to meet its companion of the other half of the head. There is also a small bit of green in the heavily pigmented cartilage on the side of the head in front of the eye. The cheeks are silvery, without color, excepting a small patch of green on the dorsal angle of the operculum. The maxillaries, usually the premaxillaries, preopercula, and mandible are whitish and usually unpigmented, though all but the maxillaries (not including the jugals) and the preopercula often show a few pigment dots.

The fins are whitish, translucent, all but the ventrals more or less pigmented. The cranial margin and a wide distal band of the dorsal, the lateral borders, the distal third of the longest and half of the shortest rays of the caudal are smoky to black in hue. The dorsal margin and inner surface of the pectoral often are sprinkled sparingly with black. Often pigment dots are present on the membranes that connect the anal rays.

All color fades after death, and after preservation the silvery tone usually disappears, leaving characters of pigmentation more conspicuous. The pigment, which in life is evident on the entire dorsal surface, is revealed in diminished abundance on the sides above the lateral line. Below the lateral line and on the cheeks pigment is scattered.

Most, if not all, of the males acquire pearl organs in the breeding season. All the males taken off Rock Island, Wis., on August 19, 1920 (record 1), and most of those taken later in that year out of other ports showed pearls. Pearls are present on all the scales, except often on those of the dorsal and ventral surfaces caudad of the dorsal and ventral fins, and also on the four surfaces of the head, including the mandible and maxillary. There are indications on some specimens that faint pearls are developed on at least some of the fins, especially on the abdominal ones. The pearls on the head are smallest, are irregular in shape and size, and are irregularly distributed. With the exception of the dorsal and ventral areas and the scales of the lateral line (where the pearls may be irregular in shape and distribution, unequal in size, and sometimes two or more in number), there is only one pearl on each scale. The lateral-line scales have two pearls each, one on each side of the pore, the two often fusing over it. The pearls on the belly anterior to the ventrals are borne on a somewhat thickened epidermis. On the sides, pearls are well developed on the first three or four rows above the lateral line and on the first five or six below. In shape these pearls are rounded to oval, usually longer than wide, flattened, situated at or near the tip, and extending from one-half to two-thirds the length of the exposed portion of the scale. They are largest on the anterior two-thirds of the two rows on each side of the lateral line, where they occupy one-fourth to one-third of the exposed surface, and diminish more or less gradually in size dorsad, ventrad, and caudad.

VARIATIONS

Racial variations.—Specimens collected from no area in the lake show distinctive characteristics, and there are not enough specimens in my collection to show whether there are races distinguished by average differences in systematic characters.

Size variations.—Only two specimens smaller than 200 millimeters have been seen. These measured 181 and 190 millimeters. There was one of each sex, and both were sexually mature.

COMPARISONS [10]

Johannæ resembles most closely *alpenæ.* It is distinguished from this species principally in having a less elliptical body outline as seen from the side, a more elongated and pointed head, fewer gill rakers on the first branchial arch, longer paired fins, and more lateral-line scales. It has also, on the average, a larger head, a shorter mandible, and spawns about three months earlier, so that at certain seasons, at least, the state of ripeness of the sex products will serve as a distinguishing character to separate the two species. The comparative figures for some of the above-mentioned characters follow:

Gill rakers:
- *johannæ,* (26) 27–32 (36).
- *alpenæ,* (33) 36–43 (46), with 86 per cent more than 36.

Lateral-line scales:
- *johannæ,* (74) 80–90 (95), with 35 per cent more than 85.
- *alpenæ,* (71) 78–85 (96), with 10 per cent more than 85.

Pv/P:
- *johannæ,* (1.5) 1.6–1.8 (2.1), with 16 per cent more than 1.8.
- *alpenæ,* (1.6) 1.9–2.2 (2.5), with 89 per cent more than 1.8.

Av/V:
- *johannæ,* (1.1) 1.2–1.5 (1.6), with 6 per cent more than 1.5.
- *alpenæ,* (1.2) 1.4–1.7 (1.9), with 54 per cent more than 1.5.

Johannæ is distinguished from *zenithicus* principally in the number of gill rakers on the first branchial arch, in the pigmentation of the premaxillaries and maxillary, in the length of the paired fins and mandible, and in body shape. *Johannæ* always has less than 37 gill rakers on the first branchial arch; *zenithicus* has more than 34. The premaxillaries and maxillary, particularly the maxillary, usually are immaculate in *johannæ* and pigmented in *zenithicus.* The value for Pv/P for *johannæ* is (1.5) 1.6–1.8 (2.1), with 16 per cent more than 1.8; for *zenithicus* (1.7) 2–2.2 (2.6), with 89 per cent more than 1.8. The mandible also is shorter than the upper jaw, and the slope of the body contours, as seen from the side, is more gradual in *zenithicus.* The state of development of the ova in the ovaries, also often will serve to separate females, inasmuch as *johannæ* spawns in August and September and *zenithicus* in November.

Johannæ is distinguished from *reighardi* principally by the body shape, which in *reighardi* is much more terete; by the fewer gill rakers on the first branchial arch, longer paired fins, and longer mandible, snout, and maxillary. *Johannæ* also has, on the average, more lateral-line scales, a proportionally larger head and smaller

[10] Figures given in this section for proportions are based on specimens 200 millimeters or more in length, except for *artedi,* where the limit is 225 millimeters. Counts are given for specimens of all sizes.

eye, and is much less pigmented throughout. The mandible, maxillary, and premaxillaries, especially, usually are immaculate or nearly so in *johannæ* and conspicuously pigmented in the other. As *johannæ* spawns in August or September and *reighardi* in May or June, the state of ripeness of the sex glands may be helpful often in separating the species. A comparison of certain characters of the two species follows:

Gill rakers on the first branchial arch:
johannæ (26) 27–32 (36), with 7 per cent more than 33.
reighardi, (30) 34–38 (43), with 90 per cent more than 33.

Pv/P:
johannæ, (1.5) 1.6–1.8 (2.1), with 8 per cent more than 1.9.
reighardi, (1.7) 2–2.5 (2.8), with 96 per cent more than 1.9.

Av/V:
johannæ, (1.1) 1.2–1.5 (1.6), with 7 per cent more than 1.5.
reighardi, (1.2) 1.4–1.7 (1.9), with 42 per cent more than 1.5.

The chub is separable at once from the blackfin by its less numerous gill rakers on the first branchial arch, which in the former are not more than 36 and in the latter not less than 41, and by the absence or sparseness of pigmentation on the premaxillaries, maxillary, mandible, and the ventral fins, which in *nigripinnis* are usually densely pigmented. The chub has a longer snout, also, a narrower and more attenuated head, a smaller eye, and a much paler body and fins. Females often may be distinguished by the state of development of the ovaries. The chub spawns in late August and early September and the blackfin in late December and early January.

Only small *johannæ* are comparable with *kiyi*, as *kiyi* attains less size than most of the species of the genus. Specimens of the two species may be separated by the number of gill rakers on the first branchial arch, which in *johannæ* are never more than 36 and in *kiyi* are not known to be less than 34; and by the paler mandible, premaxillaries, and maxillary, which in *johannæ* are immaculate, or, in the case of the first two, but sparingly pigmented and in *kiyi* abundantly pigmented; and by the character of the body, which in *kiyi* is conspicuously thin and frail. *Johannæ* also has a smaller eye and somewhat shorter paired fins. Females usually can be distinguished by the state of development of the ova, as *johannæ* spawns in August and September and *kiyi* probably in October.

Hoyi also does not regularly grow as large as *johannæ*, and the two species are at once distinguishable by the number of gill rakers on the first branchial arch, which in *johannæ* are not more than 36 and rarely more than 33, and in *hoyi* not less than 37; by the body shape, which in *johannæ* is rather ovate in side view and in *hoyi* elliptical; by the pigmentation rarely present on the premaxillaries, mandible, and maxillary of *johannæ* and always present on those parts in the other; by the more numerous lateral-line scales, which in *johannæ* number (74) 80–90 (95), with 95 per cent more than 77, and in *hoyi* (60) 67–77 (84), with 7 per cent more than 77. The snout in *johannæ* is much longer, so that the head, viewed from the side, is more attenuated. *Johannæ* spawns in August and September and *hoyi* in March, so that the state of development of the sex organs often is a criterion to separate the two species. In *hoyi* the mandible is frailer and more hooked.

Johannæ is at once separable from *artedi* by the fewer gill rakers on the first branchial arch, which are not known to be more than 36 in the former and not less than 41 in the latter; by the body shape, which in *johannæ* is less elliptical, as seen from the side; and by the longer paired fins. The comparative values for Pv/P and Av/V follow:

Pv/P:
johannæ, (1.5) 1.6–1.8 (2.1), with 16 per cent more than 1.8.
artedi, (1.6) 1.9–2.2 (2.6), with 94 per cent more than 1.8.

Av/V:
johannæ, (1.1) 1.2–1.5 (1.6), with 6 per cent more than 1.5.
artedi, (1.4) 1.6–1.8 (2.3), with 89 per cent more than 1.5.

Johannæ has usually no pigment on the maxillary, premaxillaries, and mandible, while in *artedi* these parts are pigmented; the general color of the latter, including the fins, is much darker. *Johannæ* has a relatively longer snout and maxillary, a smaller eye, larger head, more body depth, and more pectoral rays. *Johannæ* spawns in August to September and *artedi* in November, so that often at least the females can be separated by the state of development of the sex organs.

GEOGRAPHICAL DISTRIBUTION

Data on the occurrence of the chub in Lake Michigan are assembled in Table 16 and are shown platted on a map of the lake in Figure 4. There are 17 records made by me from the commercial chub nets of 2½ to 2¾ inch mesh set out of 13 ports on the lake. Comparison with a similar table prepared for *hoyi* (Table 56) makes obvious the fact that while the chub may be taken out of most of the ports visited, it is by no means always present in all the lifts made from these ports. The conclusion may be drawn, however, that the chub occurs throughout the lake at suitable depths and on suitable bottom.

BATHYMETRIC DISTRIBUTION

The records in Table 16, from the commercial nets set for deep-water Leucichthys or "chubs," show *johannæ* to have been taken at depths of 30 to 90 fathoms. Certain other examined lifts of these small-meshed nets, made at depths of 22 to 50 athoms, took no *johannæ*, but some of these were made on or near the spawning grounds of other species, and it is understandable that *johannæ* should not have occurred among them. Lifts of this kind were made on March 24, 1919, off Milwaukee, Wis., in 50 fathoms, and on March 2, 1921, 21 miles NNW., and on March 4, 1921, 15 miles NW. by N. ½ N. of Michigan City, Ind., in 28 to 30 fathoms on the spawning grounds of *hoyi;* on November 15, 1920, 20 miles ESE. of Milwaukee in 28 to 35 fathoms, and on November 19, 1920, 10 miles NNW. of Michigan City, Ind., in 18 fathoms, and 17½ miles NW. by N. ¾ N. in 32 fathoms on the spawning grounds of *zenithicus.* Sets of nets of suitable mesh, but which were probably in too shallow water or on grounds unsuitable for *johannæ,* were made on August 16, 1920, in Green Bay off Little Sturgeon and 8 miles south of Green Island, Wis., in 11 and 16 fathoms; on August 18, 1920, 4 miles west of Boyer Bluff, off Washington Harbor, Wis., in 18 to 24 fathoms; on September 24, 1920, 9 miles NNE. of Milwaukee, Wis., in 22 to 25 fathoms; on November 8, 1920, 18 miles NNW. of Michigan City, Ind., in 30 to 38 fathoms; on November 19, 1920, 17 miles NNW. in 28 to 32 fathoms; on August 10, 1923, 8 miles NNW. of Big Rock Point, Mich., in 45 to 50 fathoms, and on August 21, 1923, off Charlevoix at probably the same depth.

Besides the 2½ and 2¾ inch nets that are fished for Leucichthys, there are other sources of data on the occurrence of Leucichthys, which however, have yielded nothing bearing on *johannæ*—the 4 to 4½ inch whitefish and trout nets and the 1½-inch bait nets, both usually set at depths less than 40 fathoms. In the 4 to 4½ inch nets no chubs could gill, as no specimen of this species has been known to grow so large; but no individuals ever have been seen by me to have been entangled in its meshes. Fish caught thus are only accidental inclusions, however, and even small fish might actually be present in numbers and yet not be caught, so that the want of data from this source is not conclusive.

In the 1½-inch nets small individuals could gill along with the small *hoyi* and other Leucichthys, but no specimens of this species were seen in lifts of these nets made from 26 to 40 fathoms on June 23, 1920, off Northport, Mich.; on July 18, 1923, in West Grand Traverse Bay; on August 27, 1920, 4 miles west of Manistee, Mich.; on September 25, 1920, 5 miles E. ½ S. of Port Washington, Wis.; on September 28, 1920, 5 miles SE. by E. of Sheboygan, Wis.; on October 8, 1920, off Racine, Wis.; and on March 2, 1921, 14 miles NNW. of Michigan City, Ind.

No specimens occurred either in the special 1½-inch nets lifted from 4 to 16 fathoms on July 25, 1923, off Traverse City, Mich., from 8 to 12 fathoms on July 21, 1923, and from 15 to 25 fathoms on July 23, 1923, in Platte Bay, and from 8 to 10 fathoms on July 30, 1923, off South Manitou Island, Mich.

All the data thus show that at certain seasons, at least, the chub does not occur at depths of less than 30 fathoms and that it ranges to depths of 90 fathoms. It is likely that it goes even deeper. The small individuals, it appears, either do not consort with the small *hoyi* or else may not be found outside the 40-fathom contours.

RELATIVE ABUNDANCE

Throughout the summer and fall of 1920 small lifts were made from the chub nets at every port on the lake. Lifts examined during the season, including the lifts made out of Milwaukee and Michigan City on the spawning grounds of *zenithicus*, ranged between 20 and 180 pounds of fish to the mile of net when lifted after five nights. As never more than three fish are required to make a pound, it is obvious that fish were uncommon along the bottom. Lifts in which no fish of this species were taken are enumerated in the preceding section. Lifts in which only an occasional chub was taken were made as follows: On June 22, 1920, and on July 31, 1923, 5 miles northwest of Cathead Light, Mich., in 40 to 60 fathoms; on June 29, 1920, 5 miles N. by E. and on August 11, 1923, 3 miles NW. ½ W. of Charlevoix, Mich., in 35 to 65 fathoms; on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms; on August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms; on September 23, 1920, 27 miles ESE. of Milwaukee, Wis., in 60 fathoms; on September 25, 1920, 18 miles E. ½ S. of Port

Washington, Wis., in 65 to 48 fathoms; on September 3 and October 11, 1920, 22 miles NW. by N. ½ N. and 20 miles N. by W. ¾ W. of Michigan City, Ind., in 30 to 40 fathoms (records 3, 5, 7–9, 14–18). Out of Frankfort, Mich., 9 miles north of Point Betsie, on October 4, 1920, in 60 to 70 fathoms, chubs made up 7 per cent of a lift of 1,400 pounds (record 13). On August 23, 1920, 12 miles E. by S. of the mouth of the Sturgeon Bay ship channel, in 60 to 70 fathoms, chubs made up 22 per cent of the total lift (record 2), but as its weight was only 50 pounds, few chubs were taken. Chubs were found abundantly only in one lift examined—when the nets were lifted on August 19, 1920, 20 miles E. ½ N. of Rock Island, Wis., in 71 to 90 fathoms (record 1). Out of a total lift of 900 pounds, about one-third were chubs and the rest *kiyi*.

According to the records, then, the chub has not been common in the chub hauls from less than 70 fathoms. The only set that took the fish in numbers was made from a depth of 71 to 90 fathoms, the deepest lift examined.

BREEDING HABITS

Only an occasional fish was seen previous to August, 1920, and these fish were not sexually mature. The specimens taken on August 19, 1920, 20 miles E. ½ N. of Rock Island in 71 to 90 fathoms, were chiefly pearled males, from which milt flowed freely. Females were not common and those taken were not yet ripe. While it is certain that these fish would spawn soon, it is not certain that they would spawn on the grounds where taken. Many of the stray fish taken up to October from other ports were either males with pearls or spent females. It is safe to state, then, that the spawning time for the species lies somewhere between the middle of August and the last of September. It is not known at what depths and on what bottom the species spawns.

Leucichthys johannæ of Lake Huron

The *johannæ* of Lake Huron is like the typical form in body shape but differs somewhat from it chiefly in the matters of certain proportions and of counts of certain multiple parts. A comparison of some of the systematic characters follows:

Gill rakers on the first branchial arch:
- Michigan, (26) 27–32 (36).[11]
- Huron, (25) 27–31 (35).[12]

Lateral-line scales:
- Michigan, (74) 80–90 (95).
- Huron, (67) 77–87 (91).

L/H:
- Michigan, (3.8) 4–4.2 (4.4).
- Huron, (3.4) 3.8–4.1 (4.3).

H/E:
- Michigan, (4) 4.4–4.6 (4.9).
- Huron, (3.9) 4.3–4.8 (5.3).

[11] These figures for Lake Michigan are given for 122 specimens. Unmarked figures are given for 74 specimens ranging in length from 212 to 288 millimeters.

[12] Figures for gill rakers are based on 441 specimens, those for scales on 258 specimens. All other figures for Lake Huron, unless marked, are based on 219 specimens ranging in length from 200 to 332 millimeters.

H/S:
- Michigan, (3.2) 3.3–3.6 (4).[13]
- Huron, (3) 3.2–3.5 (3.6).

Pv/P:
- Michigan, (1.5) 1.6–1.8 (2.1).
- Huron, (1.3) 1.5–1.8 (2.1).

Av/V:
- Michigan, (1.1) 1.2–1.5 (1.6).
- Huron, (1) 1.2–1.4 (1.6).

Pectoral rays:
- Michigan, (14) 16–17 (20).
- Huron, (15) 17–18 (19).

Scale rows:
- Michigan, (38) 41–44 (46), (31) 33–37 (38), (22) 24–26 (27).[14]
- Huron, (36) 40–42 (45), (30) 32–35 (36), (22) 24–26.[15]

It appears that the Huron race has, on the average, somewhat fewer lateral-line scales and scale rows, more pectoral rays, a somewhat longer head and possibly snout, and paired fins. The number of specimens compared for proportions is 219 for Huron and 74 for Michigan, with those from Huron averaging longer. Inasmuch as in most fishes the head decreases in relative size with age, the smaller size of the Michigan specimens makes the difference in proportion more significant. The Huron form also shows more pigment. The premaxillaries are never immaculate, as in the Michigan form, but usually are as densely pigmented as the top of the head, and the fins (except the ventrals) are, on the average, somewhat more pigmented. Specimens from Georgian Bay sometimes have pigmented maxillaries, but the maxillaries of those from Lake Huron proper usually are immaculate.

The color in life is as in the Michigan form except for the details of pigment recorded above.

Males of the species in Lake Huron also acquire pearls in the breeding season. Males taken on October 6, 1919, in 70 fathoms off White Bluff in Georgian Bay still had traces of pearls. The females taken on this date were spent. It is assumed, then, that the breeding season was past and that the pearls of the males were declining. There were no features of the state of development observed to indicate that the full nuptial adornment of the Huron males would be different from that described for the males of Lake Michigan.

VARIATIONS

Racial variations.—Virtually all the specimens collected originated in Lake Huron off Alpena and in Georgian Bay. Making allowance for the greater size of the fish from Georgian Bay, where the net mesh is larger than in Lake Huron, there are no discernible differences in the systematic characters of the two groups except the detail of pigmentation previously referred to.

Size variations.—In Table 19, 20 specimens are extensively compared, half of them less than 200 millimeters in length and half of them more than 200 millimeters. In Tables 8 to 11 certain systematic characters are given for all the specimens of the collection similarly separated according to size. From these tables it may be seen

[13] Forty-seven specimens. [14] Thirty specimens. [15] Sixty specimens.

that the only differences recognizable in the two classes are differences of proportion. The head, expressed in terms of body length, is relatively though but slightly larger in smaller specimens. The most striking difference is shown in the ratio that exists between the measurements of the head and eye in the two groups. The complete data in Table 9 show that for the smaller specimens the eye is contained (3.6) 4–4.3 (4.5) times in the head length, while for the larger specimens the proportion is (3.9) 4.3–4.8 (5.3). The relation between the length of the head and its other parts appears to remain unchanged by growth. The pectoral and anal fins show a decrease in relative length with increased size. The larger fish are relatively deeper.

Most individuals that have attained a length of 195 millimeters have been found to be sexually mature. No mature specimens have been seen smaller than 165 millimeters. Maturity probably is determined by age rather than by the size of the specimen.

COMPARISONS [16]

Johannæ may be mistaken most frequently for *alpenæ*, though small specimens might be confused with bloaters or kiyis. *Johannæ* has fewer gill rakers on the first branchial arch, longer paired fins, more pectoral rays, a shorter and less-developed mandible, a less fusiform body shape (as seen from the side), and its head is more acutely triangular in side view. The chub spawns in September, while the longjaw spawns in November, so that the state of development of the sex organs often may serve to separate the two forms. The longjaw attains a greater size. A comparison of certain characters of the two species follows:

Gill rakers on the first branchial arch:
johannæ, (25) 27–31 (35), with 7 per cent more than 31.
alpenæ, (31) 34–40 (44), with 99 per cent more than 31.

Pv/P:
johannæ, (1.3) 1.5–1.8 (2.1), with 23 per cent more than 1.7.
alpenæ, (1.6) 1.8–2.1 (2.3), with 89 per cent more than 1.7.

Av/V:
johannæ, (1) 1.2–1.4 (1.6), with 9 per cent more than 1.4.
alpenæ, (1.3) 1.4–1.7 (1.9), with 72 per cent more than 1.4.

Pectoral rays:
johannæ, (15) 17–18 (19), with 43 per cent more than 17.
alpenæ, (14) 15–17 (18), with 3 per cent more than 17.

Johannæ differs from *zenithicus* in respect to length of mandible, which in the former usually is equal to the upper jaw and in the latter shorter; in the pigmentation of the maxillary, which is usually immaculate in the former and pigmented in the latter; in the shape of the body, which in side view is less elliptical in the former; in the fewer gill rakers on the first branchial arch; and in the longer head and paired fins. *Johannæ* also has, on the average, a longer snout and more pectoral rays and spawns about a month earlier. A numerical expression of the more significant characters follows:

Gill rakers:
johannæ, (25) 27–31 (35).
zenithicus, (34) 37–40 (44), with 89 per cent more than 35.

[16] Figures for proportions in this section are given for specimens 200 millimeters or more in length, except those for *artedi*, where the limit is 225 millimeters, and for *kiyi* and the specimens of *johannæ* compared with it, all of which are under 200 millimeters long. Counts are given for specimens of all sizes.

L/H:
- *johannæ*, (3.4) 3.8–4.1 (4.3), with 20 per cent more than 4.
- *zenithicus*, (3.9) 4.1–4.3 (4.5), with 77 per cent more than 4.

Pv/P:
- *johannæ*, (1.3) 1.5–1.8 (2.1), with 10 per cent more than 1.8.
- *zenithicus*, (1.6) 1.9–2.1 (2.3), with 82 per cent more than 1.8.

Av/V:
- *johannæ*, (1) 1.2–1.4 (1.6), with 11 per cent more than 1.4.
- *zenithicus*, (1.2) 1.5–1.6 (1.8), with 77 per cent more than 1.4.

Johannæ differs from *nigripinnis* in about the same manner as the chub of Lake Michigan differs from the Lake Michigan blackfin. They differ less, however, in the degree of pigmentation of the premaxillaries in Lake Huron. There is some pigment on the premaxillaries of *johannæ*, but they average much paler than in *nigripinnis*.

Only small *johannæ* are comparable with *kiyi*, for *kiyi* in Lake Huron is not known to grow large. *Johannæ* may be separated from *kiyi* by the fewer gill rakers, smaller eye, and less pigmentation. The number of gill rakers on the first branchial arch in *johannæ* is (25) 27–31 (35), in *kiyi* (34) 36–40 (44); H/E for *johannæ* is (3.6) 4–4.3 (4.5), with 72 per cent more than 4, and for *kiyi* (3.3) 3.6–3.8 (4). The maxillary in *kiyi* is almost always pigmented over at least half its surface, while in *johannæ* it is almost always white. *Kiyi* has also, on the average, longer paired fins, and the mandible is frailer, darker, and usually longer. The state of development of the ova will aid in separating females at certain seasons, for *johannæ* spawns at least a month earlier.

Johannæ is absolutely separable from *artedi* by the number of gill rakers, which in the former are not known to number more than 35 and in the latter not less than 40; and by the body shape, which is elliptical in side view only in *artedi*. *Johannæ* also has a longer, more attenuated head, longer snout, maxillary, and paired fins, and a smaller eye. The maxillary is always pigmented in *artedi* and seldom shows pigment in *johannæ*, and the body is generally much darker throughout in the former. The state of development of the sex organs also is an aid in separating the two, as *johannæ* spawns in September and *artedi* in November. The proportional characters referred to above are compared below:

L/H:
- *artedi*, (4) 4.3–4.6 (5),[17] with 80 per cent more than 4.2.
- *johannæ*, (3.4) 3.8–4.1 (4.3), with 1 per cent more than 4.2.

H/E:
- *artedi*, (3.7) 3.9–4.3 (4.7), with 19 per cent more than 4.2.
- *johannæ*, (3.9) 4.3–4.8 (5.3), with 87 per cent more than 4.2.

H/S:
- *artedi*, (3.5) 3.7–4 (4.3), with 82 per cent more than 3.6.
- *johannæ*, (3.1) 3.3–3.5 (3.6).

Pv/P:
- *artedi*, (1.7) 2–2.2 (2.6), with 72 per cent more than 1.9.
- *johannæ*, (1.3) 1.5–1.8 (2.1), with 2 per cent more than 1.9.

Av/V:
- *artedi*, (1.4) 1.6–1.8 (2.1), with 90 per cent more than 1.4.
- *johannæ*, (1) 1.2–1.4 (1.6), with 11 per cent more than 1.4.

The differences between *johannæ* and *hoyi* are given on page 461.

[17] Figures for *artedi* do not include the *manitoulinus* form.

GEOGRAPHIC DISTRIBUTION

In Table 18 are assembled all my data on the occurrence of the chub in Lake Huron. In Figure 5 these data are shown platted on the chart of the lake.

Lake Huron proper.—There are 33 records made by me for Lake Huron. Excepting records 7 and 9, these were made from boats that fished nets expressly for chubs and show the chub to range throughout the deeper American waters of the lake. Aside from the fact that conditions are similar on the Canadian side of the boundary line (from which it may be safely concluded that the species ranges in the Canadian waters also) there is evidence derived from the comparison of the records of the Southampton and Duck Islands boats, which fish in these waters, and those of Alpena tugs (see p. 346) that indicate that the chub actually is taken abundantly in this area.

North Channel.—No chubs have been seen from this region. Though the fishermen report Leucichthys off Gore Bay Light and off Meldrum Bay in 20 to 28 fathoms, there is nothing in the description of these fish to indicate that they belong to this species. On the contrary, in view of the large size of the fish reported and of the shallow water in which they are taken, it seems safe to conclude that they are not chubs.

Georgian Bay.—Records 34 to 39 establish the occurrence of the chub in Georgian Bay in summer and fall at depths corresponding to those at which it occurs in Lake Huron. There is no reason to believe that it does not range throughout Georgian Bay at similar depths at these seasons. From these data it appears that the chub ranges throughout Lake Huron and Georgian Bay, but that none occur in the North Channel.

BATHYMETRIC DISTRIBUTION

The records just reviewed deal mainly with the occurrence of chubs in the 2¾ and 3 inch chub nets set at 35 to 100 fathoms. In less than 35 fathoms no chub nets are set, so that the only sources from which evidence can be derived of the occurrence of the chub at depths less than 35 fathoms are (1) the 4½-inch trout and whitefish nets, (2) the four nets of 2¾-inch mesh that were set under my direction with the 4½-inch nets, and (3) the 1½-inch nets. (See p. 373.)

1. *The 4½-inch trout and whitefish nets.*—Record 7 shows a single specimen taken on September 7, 1917, in 16 to 20 fathoms. This fish was too small to be gilled in the nets.

2. *The 2¾-inch nets set with the trout and whitefish gangs.*—The nets lifted with the 4½-inch nets on September 17, 1917, in 15 fathoms, on September 19, 1917, in 30 fathoms, September 26, 1917, in 17 fathoms, and November 2, 1917, in 15 fathoms, to determine whether the chub occurred in greater numbers than was shown by the captures in the 4½-inch nets themselves brought in no chubs. The net of the 19th brought in 9 longjaws and 6 short-jawed chubs.

3. *The 1½-inch bait nets.*—From the 1½-inch bait nets at 30 fathoms only one specimen was taken (record 9). Other lifts of these nets at a similar depth at Cheboygan, Mich., on October 15, 1919, at Alpena, Mich., on September 16, 1919, and at Harbor Beach, Mich., on December 9, 1917, and on March 15, 1919, revealed no examples of this species.

Thus my records show that the extreme range of the species when not spawning extends from 16 to 100 fathoms. Examples are taken but rarely in less than 35 fathoms, and therefore 15 fathoms probably is the lower limit of the range. There are no data that fix the upper limit. Probably the chub occurs also in the deepest waters of the lake.

RELATIVE ABUNDANCE

From the chub nets in 50 fathoms and deeper lifts were examined on 22 occasions. (Examinations of the lifts off Cheboygan, Mich., and Rogers, Mich., at 35 to 50 fathoms, in which only spawning *zenithicus* were taken, have no value in determining the abundance of other species of chubs at these depths, and therefore they are not included in this number.) The majority of chubs seen in Lake Huron were yielded by lifts out of Alpena, Mich. Lifts made at the center of the lake in 60 to 80 fathoms northeast and east of Alpena on September 7, 1917 (record 8), September 10, 1917 (record 10), September 12, 1917 (record 11), September 14, 1917 (record 12), September 17, 1917 (record 13), September 26, 1917 (record 20), and October 17, 1917 (record 21); on August 7, 1920, 19 miles NE. ½ N. of Thunder Bay Island in 60 to 65 fathoms (record 27); on August 30, 1919, 18 miles N. by E. ½ E. of Thunder Bay Island in 60 to 64 fathoms (record 23); on September 3, 1919, 28 miles E. ¼ S. of the can buoy in 60 to 64 fathoms (record 24); and on June 30, 1923, 17 miles NE. ¾ N. of Thunder Bay Island in 65 to 70 fathoms (record 29), contained 50 to 90 per cent chubs. Lifts from the center of the lake made on September 21, 1917 (record 18), September 24, 1917 (record 19), October 20, 1917 (record 22), and on June 28, 1923, 19 miles northeast of Thunder Bay Island in 60 to 70 fathoms (record 28), and on July 7, 1923, 13 miles NE. ½ N. of Thunder Bay Island in 60 fathoms (record 32) had 20 to 47 per cent chubs. Relatively few chubs were taken on July 2, 1923, 20 miles E. by N. of the can buoy in 60 to 70 fathoms (record 30), and on July 5, 1923, 18 miles NE. ¾ E. of Thunder Bay Island in 80 to 100 fathoms (record 31).

A single lift from 50 fathoms 35 miles NE. by N. ¾ N. of Harbor Beach, Mich., on October 27, 1917 (record 33), had 50 per cent chubs. On the Ontario shore of the lake lifts were examined only in Georgian Bay. Though no chubs were collected or examined from the Duck Islands and Southampton boats, the fact that the movements of the fish caught by these boats and by the Alpena boats (as shown by their records) are similar and the fact that all three boats fish in approximately the same zone of latitude in the lake give circumstantial evidence that the lifts at the three ports can not be widely different in their components. (See Table 14 and discussion on p. 346.) In Georgian Bay, off Cape Croker, in 52 fathoms on July 28, 1919 (record 37), and on July 30, 1919, 21 miles east of Surprise Shoal in 60 fathoms (record 34), chubs made up half the catches. In a single lift made on October 6, 1919, off White Bluff in 70 fathoms (record 35), only a few chubs were taken.

In other types of netting chubs were recorded only as follows: In the trout nets lifted on September 7, 1917, 26 miles SE. by E. ¼ E. of the Alpena can buoy in 16 to 20 fathoms and in the 1½-inch nets lifted on September 8, 1917, 26 miles SE. by E. ¼ E. of that point. In both lifts chubs were rare.

All observations show the chub to range from 16 to 100 fathoms. In less than 35 fathoms it has been taken rarely. In the chub nets from 35 to 50 fathoms it is taken in some numbers, but how abundantly the records do not show. In the chub lifts of 50 fathoms and deeper the species has been very common. In 14 of the 22 lifts made at these depths the chub made up 50 to 90 per cent of the catches, while in five lifts it comprised 20 to 47 per cent; in only three lifts was it found to be scarce. The chub population appears, therefore, to attain its greatest density at depths of 50 to 80 fathoms. The maximum depth range of the species is not indicated by the records, and it may be found even deeper than 100 fathoms.

BREEDING HABITS

The spawning grounds of the species have not yet been located in Lake Huron. Evidence from three sources establishes the time of spawning:

(1) The records of the tugs *Roy* of Alpena, *J. B. McLeod* of Southampton, and *Osprey* of the Duck Islands, given in part in Table 14, show an abrupt decline in the size of the lifts during the last week of August and during September. This decline can be explained only by assuming that this species (which, it has been shown, makes up the bulk of the chub hauls) leaves its summer feeding grounds at this time. That the fish have gone to the spawning grounds may be inferred from the facts that follow.

(2) Observations on the development of the ova of chubs at various times from the last of July to the last of October, and the finding of pearl organs on males, yield evidence of another kind. On July 28 and 30, 1919, at Wiarton and Lions Head in Georgian Bay, female chubs with well-developed ova were found. One fish, even, was ripe. On August 7, 1920, at Alpena, the females of a lift of about 3,500 pounds of chubs had nearly ripe ova. From the last of August and until the last of October examination of the ovaries revealed three conditions: (*a*) Ova in the body cavity (all ova may or may not have been liberated from the ovary); (*b*) no ova in the body cavity and only minute ova in the ovary; the ovary dark in color, still swollen, having not yet completely contracted after releasing the ova; (*c*) ova minute or at least never more than half as large as the mature ova, always large enough to give the ovary a yellow appearance; the ovary firm. Females with ovaries in the condition described under (*a*) are called spawning fish, under (*b*) spent fish, under (*c*) nonspawning fish. Of course, the ovaries of a spent female come after a time to look like those of a nonspawner, but if the fish has spawned recently, it can not be confused with one that has not spawned. Among the spawning runs of *zenithicus* and *alpenæ* no females were found that would be classed as nonspawners, while spent fish were common.

In lifts of whitefish and blackfins taken before their spawning season many nonspawning females have been seen. Out of 174 chubs examined from the catches previously referred to and made on August 30 and September 3, 1919, at Alpena, 112 were females; of these, 30 were spawning or ready to spawn, 2 were spent, and the rest nonspawning. Among 40 females examined September 21, 1917, at Alpena, 15 had a few eggs in the abdominal cavity and the rest were nonspawners. Chubs taken at Lions Head, Ontario, October 6, 1919, were spent females and males with only faint indications of pearls. These were the only pearled males seen. The large proportion of the nonspawning fish is interesting. The size of these fish ranged between 24 and 32 centimeters. As they were not different from the spawners in respect to size, it can hardly be argued that they were too small to spawn. It appears that a certain proportion of the fish spawn biennially.

(3) The third source of evidence as to the spawning season is the testimony of several fishermen who have taken spawning runs of chubs in September. Fishermen at Tobermory and Lions Head on Georgian Bay assert that many of the fish taken in their nets during the month of September off the Saugeen Peninsula in 60 fathoms on mud bottom are full of loose spawn and that at this period their lifts are often nearly doubled in weight. This would seem to indicate that a spawning run had entered the nets. *Zenithicus* is the only fish in the lake known to spawn in September, but its spawning season in Lake Huron does not begin before the middle of September and continues until the middle of October, and it is not likely, therefore, that these fish are of this species. Besides, *zenithicus* is not known to be common in Georgian Bay. *Nigripinnis* and *alpenæ* do not spawn before November, so that these species certainly are not concerned in the phenomenon described, and the spawning fish can only be chubs.

There can be no question then that the spawning period of the chub begins the last of August and continues into September: (1) The schools of fish begin to leave their feeding grounds the last of August and are absent during September. Only the nonspawning individuals and a few spawning fish remain behind. (2) Fish caught in July and early August have eggs in an advanced state of maturity. From the last of August and through September females have either only ripe or only undeveloped eggs. In October the fish taken have only undeveloped ovaries. Pearled males were taken on October 6, 1919. (3) A spawning run of fish, which must belong to this species, has been reported in Georgian Bay in September.

It remains to find the spawning grounds. If the Georgian Bay fishermen actually get the fish where they are spawning and not while they are moving to the spawning grounds, then the situation of at least one of the spawning places in Georgian Bay is established. (It is interesting to note, in this connection, that a lift examined on October 6, 1919, on these reported spawning grounds (record 35) had very few chubs in it and that these were spent.) We still have, then, the Lake Huron individuals to account for. It is not likely that the schools from the lake traverse the shallow water off Cape Hurd to get into Georgian Bay. In that case they must spawn somewhere in the lake. With no more data than are now available it is not profitable to speculate as to where these spawning grounds might be. It is better for the fish, of course, that this gap in our knowledge of their habits has not been bridged.

FOOD

Carl L. Hubbs, of the Museum of Zoology, University of Michigan, has examined a series of stomachs of coregonids collected by me on Lake Huron, and his report is given under this heading for each of the Lake Huron species. Doctor Hubbs finds, in an examination of 34 stomachs of *johannæ* collected off Alpena, Mich., in 65 to 70 fathoms in September and October, 1917, that the chief article of diet is Mysis. This animal constitutes from 80 to 100 per cent of the food in most of the stomachs. Pisidium and Pontoporeia are present in about one-third of the examinations, usually only in relatively small quantities. Half of all specimens had ingested sand, cinders, and wood fragments. Other objects casually swallowed include adult insects, larval and pupal Chironomidæ, and fish scales.

LEUCICHTHYS ALPENÆ Koelz

THE LONGJAW (FIG. 15)

Leucichthys alpenæ, Koelz, 1924, pp. 1–5; Lakes Michigan and Huron.
Argyrosomus prognathus Evermann and Smith, 1896, pp. 314–317; in part, Lakes Michigan and Huron.
Leucichthys johannæ Jordan and Evermann, 1911, pp. 24–25, in part, Lakes Michigan and Huron

The longjaw is described from Lake Michigan and is known to occur only in Huron of the other lakes of the Great Basin. In both lakes the species is characterized by the large size it may attain, its pale color, its long mandible, relatively short paired fins, and the moderate number of gill rakers on the first branchial arch. It seems to prefer moderate depths in both lakes and spawns in late November. The Huron form has been found to differ from the typical form only in having on the average somewhat fewer gill rakers and lateral-line scales and a somewhat longer head.

Type

The type is a female specimen (catalogue No. 87352, U. S. National Museum) 269 millimeters long, collected on June 15, 1923, 22 miles NNE. of Charlevoix, Mich., off Ile aux Galets in 25 to 47 fathoms.

Leucichthys alpenæ of Lake Michigan

The longjaw is the largest Leucichthys in Lake Michigan. Specimens not infrequently attain a length of 38 centimeters (15 inches) and a weight of 2 pounds. The body is compressed, fusiform, and rather elongate. The greatest depth, through a point just in front of the dorsal, comprises in adult specimens 23 to 26 per cent of the total length. Gravid females are often deeper, of course. The width is about 50 to 55 per cent of the depth. The anterior dorsal profile of the body usually rises gradually from the occiput to the insertion of the dorsal, but it is sometimes somewhat steeper over its anterior half, particularly in the largest specimens. Behind the dorsal the line continues in a very faint curve to the caudal peduncle. The ventral profile is rather strongly and uniformly curved from the tip of the snout to the caudal peduncle. There is a tendency for the contour line between the ventrals and the anal to become straight and parallel to the lateral line, however. The head, which is relatively short and deep, is contained 4.4 [(3.8) 4.1–4.4 (4.6)][18] times in the total length of the fish. In side view it is broadly triangular. The dorsal profile usually is faintly convex and forms a smooth arc continuous with that of the first half of the predorsal body contour. The degree of its convexity is greatest in those specimens in which the premaxillaries approach a vertical position. The premaxillaries may be immaculate but usually are more or less pigmented and are directed forward, ordinarily making an angle of 45° to 60° with the horizontal axis of the head. The snout, seen from the side, is broad and rounded. It is contained 3.7 [(3.3) 3.4–3.6 (4)] [19] times in the head. The maxillary is nonpigmented in about 90 per cent of over 500 specimens examined and extends beyond the anterior edge of the pupil but seldom

[18] The figures given in brackets, unless stated otherwise, are based on an examination of 289 specimens (paratypes) ranging in length from 205 to 386 millimeters.
[19] Seventy-five specimens.

to its center. The lower jaw is well developed and usually projects beyond the upper.[20] The eye is moderate in size and is contained 4.6 [(3.8) 4.2–4.6 (5.2)] times in the head length. The gill rakers on the first branchial arch number 14+25 [(11) 13–15 (17) + (20) 22–27 (30) = (33) 36–43 (46)].[21]

The scales in the lateral line number 75 [(71) 78–85 (96)].[22] Rows of scales around the body just in front of the dorsal and ventrals number 41 [(40) 41–43 (45)]; [23] just in front of the adipose and the anus 34 [(30) 33–35 (36)]; [24] around the caudal peduncle at its commencement 26 [(23) 24–26 (27)].[24] Dorsal rays number 10 [(9) 10–11)]; [25] anal rays, 11 [(9) 11–12 (13)]; [25] pectoral rays, 16 [(12) 15–17 (18)]; [25] ventral rays, 11 [(10) 11 (12)].[23] The pectorals are contained 2.2 [(1.6) 1.9–2.2 (2.5)] times into the distance from the pectorals to the ventrals. The dorsal edge of pectoral is usually nearly straight. The length of the ventrals is contained 1.8 [(1.2) 1.4–1.7 (1.9)] times in the distance from their origin to that of the anal.

The color in life is about the same as in *johannæ*. The form is also about as little pigmented, except possibly on the premaxillaries.

During the breeding season males develop pearl organs, as in the case of other Great Lakes coregonids. No individuals were taken on the spawning grounds, so that no description of the full nuptial dress can be given. Probably the full development of pearl organs is not different from that of the Lake Huron form.

VARIATIONS

Racial variations.—Most of the fish in the collection were taken in the northern part of the lake; but probably there are enough specimens from the southern part for comparison. There are no differences discernible between the two groups, however, except that those from the south appear to average still less pigmented on the premaxillaries and abdominal fins.

Size variations.—The usual changes in proportion between the large and small specimens obtain. Ten large and nine small specimens are compared extensively in Table 21. There are only 13 collected specimens less than 200 millimeters in length, and nothing can be stated definitely concerning changes with growth; but it appears that the head, eye, and paired fins are somewhat longer, relatively, in small fish. The depth and width, of course, become greater as the fish approaches maturity. I have seen no sexually mature specimens smaller than 206 millimeters.

COMPARISONS [26]

Alpenæ resembles *johannæ* most closely. The differences between the two species are discussed on page 351.

From *zenithicus*, *alpenæ* differs chiefly in the length of the mandible and maxillary, pigmentation of the premaxillaries and maxillary, depth of the head and body, and in maximum size attained. The mandible in *alpenæ* usually is longer than the

[20] In 68 per cent of 638 examined specimens.
[21] Three hundred and eighty-three specimens.
[22] Three hundred and twenty-nine specimens.
[23] Twenty specimens.
[24] Fifty specimens.
[25] Seventy-five specimens.
[26] Figures for proportions given in this section are based on specimens 200 millimeters or more in length, except *artedi*, where the limit is 225 millimeters. Counts are given for specimens of all sizes.

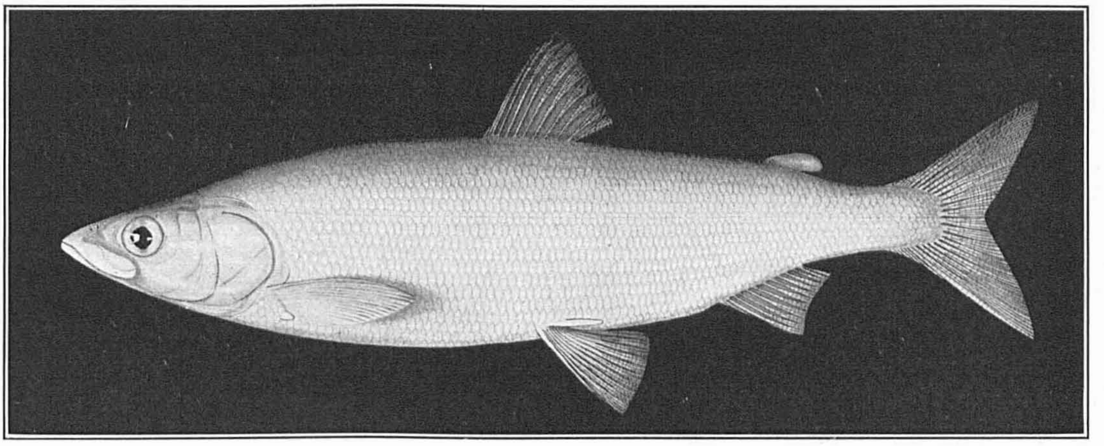

FIG. 14.—*Leucichthys johannæ* Wagner, the chub. Male, 243 millimeters long, taken in Lake Michigan off Michigan City, Ind., in 30 to 40 fathoms on September 3, 1920

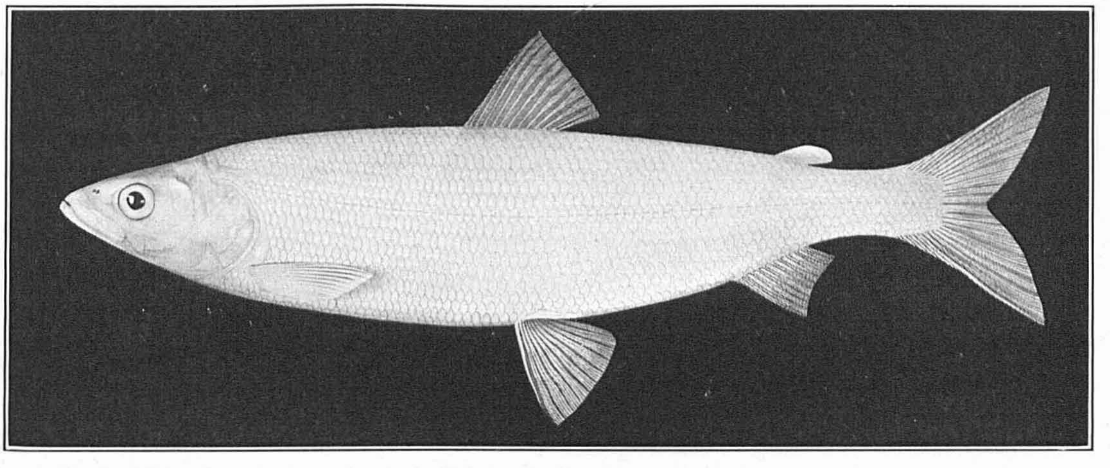

FIG. 15.—*Leucichthys alpenæ* Koelz, the longjaw. Male (type), 269 millimeters long, taken in Lake Michigan, off Charlevoix, Mich., in 25 to 47 fathoms on June 15, 1923

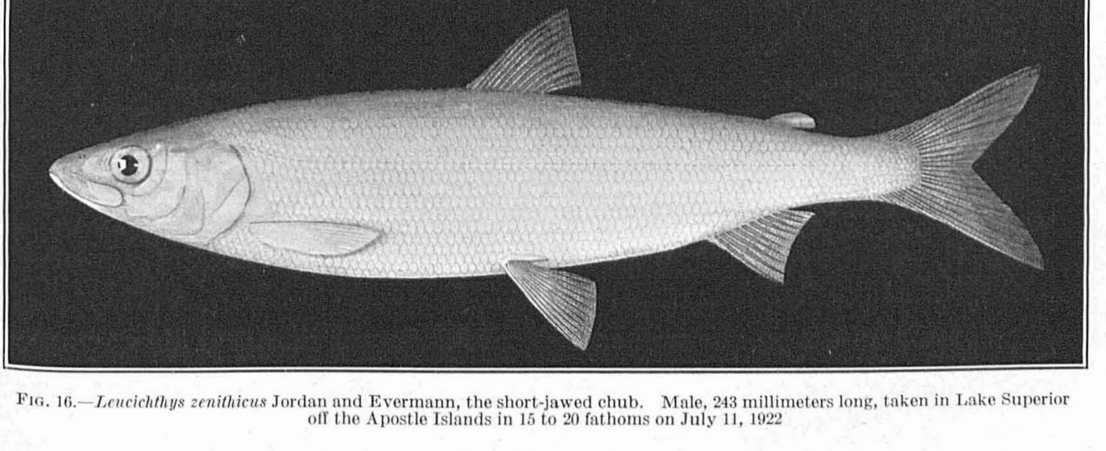

FIG. 16.—*Leucichthys zenithicus* Jordan and Evermann, the short-jawed chub. Male, 243 millimeters long, taken in Lake Superior off the Apostle Islands in 15 to 20 fathoms on July 11, 1922

upper jaw, while in *zenithicus* it is usually shorter and included within it. In the former the premaxillaries are immaculate or but faintly pigmented in half of the specimens examined and the maxillary is almost always immaculate; the premaxillaries and maxillary usually are pigmented in the latter. The depth of the head is greater and the length of the maxillary less in *alpenæ*, so that the value of the head depth (HD) divided by the maxillary length (M) is (1.4) 1.5–1.7 (1.8), with 79 per cent more than 1.5 for *alpenæ*, and (1.3) 1.4–1.6 (1.7), with 25 per cent more than 1.5 for *zenithicus*. The depth of the body in *alpenæ* is likewise more; L/D equals (3.3) 3.9–4.3 (4.9), with 11 per cent more than 4.3 in *alpenæ*, and (3.6) 4.2–4.6 (5), with 58 per cent more than 4.3 in *zenithicus*. *Zenithicus* seldom is larger than 300 millimeters, while examples of *alpenæ* that exceed this limit are met frequently. The dorsal contour of the head is straighter, also the shape of the head in side view less broadly triangular, and the body slightly wider in *zenithicus*.

Alpenæ differs from *reighardi* in about the same way that it differs from *zenithicus*—in points of pigmentation and length of mandible—but pigmentation is still more abundant in *reighardi*; and in addition to being present on the premaxillaries and maxillary it is also abundantly present on the mandible and occasionally on the abdominal fins. Moreover, *alpenæ* has more gill rakers on the first branchial arch, longer pectoral fins, a narrower body, more lateral-line scales, and attains a greater size. *Alpenæ* spawns in November while *reighardi* spawns in May or June, so that the state of ripeness of the sex products often may serve as a distinguishing character. A comparison of certain of the above-mentioned characters follows:

Gill rakers:
- *alpenæ*, (33) 36–43 (46), with 66 per cent more than 38.
- *reighardi*, (30) 34–38 (43), with 13 per cent more than 38.

Lateral-line scales:
- *alpenæ*, (71) 78–85 (96), with 47 per cent more than 81.
- *reighardi*, (66) 72–81 (96), with 12 per cent more than 81.

Pv/P:
- *alpenæ*, (1.6) 1.9–2.2 (2.5), with 9 per cent more than 2.2.
- *reighardi*, (1.7) 2–2.5 (2.8), with 41 per cent more than 2.2.

The differences between *alpenæ* and *nigripinnis* are about the same as between *nigripinnis* and *johannæ*. The difference in the number of gill rakers is not so sharp, however; while *nigripinnis* may have 41 but seldom less than 44, *alpenæ* may have 46 but seldom more than 43. In addition, *alpenæ* has shorter paired fins, a heavier and much paler mandible, and a much more elliptical body outline (as seen from the side) than *nigripinnis*. The comparative figures for fin length follow:

Pv/P:
- *alpenæ*, (1.6) 1.9–2.2 (2.5), with 89 per cent more than 1.8.
- *nigripinnis*, (1.5) 1.6–1.8 (2.2), with 18 per cent more than 1.8.

Av/V:
- *alpenæ*, (1.2) 1.4–1.7 (1.9), with 80 per cent more than 1.4.
- *nigripinnis*, 1.2–1.5 (1.6), with 28 per cent more than 1.4.

Alpenæ also spawns a month earlier than *nigripinnis*.

Alpenæ grows much larger than *kiyi*, so that only the smaller specimens are comparable with *kiyi*. The species differ chiefly in body shape, which in *alpenæ* is wider and more fusiform, in the development of the mandible (which is much frailer in *kiyi*), in details of pigmentation, and in the length of the paired fins. The maxillaries (which usually are immaculate in *alpenæ*) are pigmented in *kiyi* as a rule, and the latter also has, on the average, more pigment on the premaxillaries, mandible, and abdominal fins than *alpenæ*. Comparative values are given:

Pv/P:
  alpenæ, (1.6) 1.9–2.2 (2.5), with 89 per cent more than 1.8.
  kiyi, (1.1) 1.4–1.7 (2.1), with 10 per cent more than 1.8.
Av/V:
  alpenæ, (1.2) 1.4–1.7 (1.9), with 95 per cent more than 1.3.
  kiyi, (0.96) 1–1.3 (1.4), with 2 per cent more than 1.3.

Alpenæ also has a smaller eye, and females of this species will show less developed ova than *kiyi* taken at the same time, as *kiyi* spawns a month earlier.

Alpenæ grows larger than *hoyi*. The mandible in *alpenæ* is heavier and less conspicuously hooked, the head is less sharply triangular (seen from the side), and the maxillary usually is immaculate, while it is always pigmented in *hoyi*. In addition, *alpenæ* has, on the average, fewer gill rakers on the first branchial arch, more lateral-line scales, a smaller eye, longer snout, and shorter paired fins than the bloater. It spawns in November, while the other spawns in March, so that the state of development of the sex organs may also be a character to separate the forms. Those characters that can be numerically expressed are compared below. The specimens of the two species are not comparable for those characters dealing with proportions, however, as the *hoyi* are smaller than the others, so that these differences, which concern proportions, are probably greater than they would be in specimens of like size.

Gill rakers on the first branchial arch:
  alpenæ, (33) 36–43 (46), with 24 per cent more than 41.
  hoyi, (37) 41–44 (48), with 71 per cent more than 41.
Lateral-line scales:
  alpenæ, (71) 78–85 (96), with 83 per cent more than 77.
  hoyi, (60) 67–77 (84), with 7 per cent more than 77.
H/E:
  alpenæ, (3.8) 4.2–4.6 (5.2), with 81 per cent more than 4.2.
  hoyi, (3.8) 3.9–4.2 (4.5), with 8 per cent more than 4.2.
H/S:
  alpenæ, (3.3) 3.5–3.6 (4), with 13 per cent more than 3.6.
  hoyi, (3.5) 3.7–3.8 (4.1), with 76 per cent more than 3.6.
Pv/P:
  alpenæ, (1.6) 1.9–2.2 (2.5), with 48 per cent more than 2.
  hoyi, (1.6) 1.8–2 (2.3), with 21 per cent more than 2.
Av/V:
  alpenæ, (1.2) 1.4–1.7 (1.9), with 54 per cent more than 1.5.
  hoyi, (1.1) 1.3–1.5 (1.7), with 9 per cent more than 1.5.

Alpenæ differs from *artedi* chiefly in having fewer gill rakers on the first branchial arch, longer ventral fins, head, snout, and maxillary. The figures for these characters for the two species are given below:

Gill rakers on the first branchial arch:
  alpenæ, (33) 36–43 (46), with 6 per cent more than 43.
  artedi, (41) 46–50 (55), with 97 per cent more than 43.

Av/V:
alpenæ, (1.2) 1.4–1.7 (1.9), witn 27 per cent more than 1.6.
artedi, (1.4) 1.6–1.8 (2.3), with 76 per cent more than 1.6.

L/H:
alpenæ, (3.8) 4.1–4.4 (4.6), with 20 per cent more than 4.3.
artedi, (4.1) 4.3–4.5 (5), with 71 per cent more than 4.3

H/M:
alpenæ, (2.4) 2.5–2.6 (2.7), with 14 per cent more than 2.6.
artedi, (2.5) 2.7–3 (3.3), with 91 per cent more than 2.6.

H/S:
alpenæ, (3.3) 3.4–3.6 (4), with 13 per cent more than 3.6.
artedi, (3.3) 3.7–4 (4.4), with 84 per cent more than 3.6.

Alpenæ is further separable from *artedi* by its less elongate body, less pigmentation on the body, especially the back and abdominal fins, its usually unpigmented maxillary, and by the well-developed and relatively long mandible. *Artedi* is a much darker fish, with much more pigmented premaxillaries, maxillary, and mandible, and a moderately developed and relatively short mandible. Both species spawn at about the same time, so the state of development of the sex organs is of no assistance in separating the species.

GEOGRAPHICAL DISTRIBUTION

My records on the occurrence of this species in Lake Michigan are given in Table 20 and are shown platted on the chart in Figure 4. There are 39 records, all but 5 of them from specimens personally recorded. From these observations it may be concluded that the longjaw is generally distributed over the lake where suitable conditions obtain. It is interesting to note that a long-jawed chub is said to have occurred in commercial quantities in the years 1892 to 1894 on the reef in the center of the lake between Port Washington and Muskegon (record 8). While it is probable that this chub was a longjaw, it can not be asserted positively.

BATHYMETRIC DISTRIBUTION

Data on the depth range of the longjaw have been collected, for the most part, from the 2⅜ to 2¾ inch nets that are set in the main lake for chubs, as a rule from 30 to 60 or even 90 fathoms, and for herring in Green Bay, where the maximum depth is 24 fathoms. However, longjaws have been taken in every kind of gill net in use and even in pounds. They have been seen from virtually all the examined chub lifts from the lake, the only exceptions being the lifts made on March 24, 1919, in 50 fathoms, and on September 24, 1920, in 22 to 25 fathoms, off Milwaukee, Wis. The former lift was made on the spawning grounds of the bloater, and it is not surprising that no longjaws were taken. The last obviously was made on poor grounds, as the total lift of all Leucichthys was but 25 pounds. In Green Bay herring alone are taken, except near the mouth of the bay, where the water is deepest; and even here herring constituted the bulk of the catches made on August 18, 1920. An occasional longjaw was taken in the lift made off Boyer Bluff on Washington Island, Wis., in 18 to 24 fathoms on that date (record 1).

In the 4½-inch nets that are set for trout in waters of 10 fathoms and deeper, longjaws were seen only on one occasion, namely, on August 11, 1920, 13 miles SE. ½ E. of Manistique, Mich., in 20 fathoms (record 38), though fishermen from most of the ports assured me that large white herring (which probably were longjaws) formerly were gilled not infrequently in these nets. The 1½-inch bait nets that are set out of most ports at depths of 26 to 40 fathoms for the purpose of taking bait for the trout hooks take chiefly small bloaters and presumably such juvenile chubs as occur on the grounds with them. Fish were examined from these nets at seven ports (see p. 354), but no longjaws were found among the bait except at Northport, Mich., on June 23, 1920, and Traverse City, Mich., on July 18, 1923, where there were a few, and at Port Washington, Wis., on September 25, 1920, where a single specimen was obtained (records 25, 28, and 7). In the special 1½-inch nets set along the shores of Platte Bay, Mich., in 8 to 12 fathoms on July 21, 1923, and in 15 to 25 fathoms on July 23, 1923, and in Grand Traverse Bay off Lees Point, Mich., in 6 to 16 fathoms on July 25, 1923, a single specimen was taken on each date (records 21, 22, and 29).

In the pound nets set in 5 fathoms off South Manitou Island three longjaws were found on July 30, 1923 (record 23). These observations thus show that when not spawning the longjaw ranges between 5 and 90 fathoms. Whether the fish ever is taken in deeper water is not known. The statements of the fishermen who have fished for the longjaws on their spawning grounds indicate that they come abundantly into water as shallow as 10 fathoms during the spawning season.

RELATIVE ABUNDANCE

But few observations have been made on the proportion of longjaws to the other chubs. Furthermore, those for 1920 are unsatisfactory, as the fishing season for chubs was so unfavorable during that year that few fish of any kind were taken at a lift. Only the examined lifts of the chub nets mentioned in the preceding section took no longjaws. Longjaws were rare in the lifts made on November 19, 1920, 10 miles NNW. of Michigan City, Ind., in 18 fathoms; on August 18, 1920, off Washington Harbor, Wis., in 18 to 24 fathoms; on March 2, 1921, 21 miles NNW. of Michigan City, Ind., in 30 fathoms; and on March 4, 1921, 15 miles NW. by N. ½ N., in 28 fathoms; on November 15, 1920, 20 miles ESE. of Milwaukee, Wis., in 28 to 35 fathoms; on August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms; on September 25, 1920, 18 miles E. ½ S. of Port Washington, Wis., in 65 to 48 fathoms; on September 23, 1920, 27 miles ESE. of Milwaukee, Wis., in 60 fathoms; on August 23, 1920, 12 miles E. by S. of the Sturgeon Bay ship-channel mouth in 60 to 70 fathoms; and on August 19, 1920, 20 miles E. ½ N. of Rock Island, Wis., in 71 to 90 fathoms (records, 16, 1, 17, 18, 10, 4, 6, 9, 3, and 2). At the north end and at one port at the south end of the lake the species was more abundant. Longjaws comprised 22 per cent of a lift made on October 4, 1920, 9 miles north of Point Betsie, Mich., in 60 to 70 fathoms (record 20). Longjaws comprised 45 to 69 per cent of a lift made on July 31, 1923, 5 miles northwest of Cathead Light, Mich., in 40 to 60 fathoms; on August 11, 1923, 3 miles NW. ½ W. of Charlevoix, Mich., in 35 to 60 fathoms; and on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms (records 26, 35, and 39); and 90 to 98 per cent of lifts made on June 22, 1920, 5 miles northwest of Cathead Light, Mich., in 40 to 60 fathoms; June 29, 1920, 5 miles N. by E. of Charlevoix, Mich., in 40 to 55 fathoms; August 10, 1923, 8 miles NNW. and on August 21, 1923, from an unknown locality off that port (records 24, 32, 34, and 36). At Michigan City, Ind., a lift made on September 3, 1920, 22 miles NW. by N. ½ N. in 30 to 40 fathoms, had 10 per cent (record 11); on October 11, 1920, 20 miles N. by W. ¾ W., in 30 to 40 fathoms, had 20 per cent (record 12); on November 8, 1920, 18 miles NNW. in 30 to 38 fathoms, 33 per cent (record 13); on November 19, 1920, 17 miles NNW., in 28 to 32 fathoms, 30 per cent (record 14); and 17½ miles NW. by N. ¾ N., 15 per cent longjaws (record 15). (Records 16, 17, and 18 for this port, in which few longjaws were found, were made on or near the spawning grounds of *zenithicus* and *hoyi*.)

The evidence indicates that the longjaw occurs most abundantly at the northeastern end of the lake between Frankfort, and Manistique, Mich., where the usual depth of the water is less than 70 fathoms. In this area it has been found to comprise 22 to 98 per cent of the hauls and has been taken in the 1½-inch bait nets and in the 4½-inch trout nets. A second area of abundance lies off Michigan City, Ind., at the southern end of the lake, where the water is not over 40 or 50 fathoms deep. It has been found here to comprise 10 to 33 per cent of the lifts of the chub nets. Chub lifts made at other places on the lake at depths of 18 to 90 fathoms took few longjaws, but the data are too inconclusive to determine finally the abundance of the fish there. Longjaws, according to a fisherman, formerly occurred abundantly on the reef in the center of the lake between Port Washington and Muskegon, where the chart shows a minimum depth of 38 fathoms. It appears, then, that the maximum density of the longjaw population when not spawning is between 28 and 70 fathoms only where a depth of 70 fathoms is attained in the vicinity of shallow water. Only stragglers have been found shallower or deeper.

BREEDING HABITS

No breeding fish have been seen, and the time and places of spawning are known only from inference and the testimony of fishermen. Female specimens taken on November 19, 1920, 17 miles NNW. and 17½ miles NW. by N. ¾ N. of Michigan City, Ind., showed well-developed but not ripe ova, and the males showed pearl organs. The fish certainly would spawn soon and probably in the vicinity. The fishermen say that at the north end of the lake longjaws come ashore toward the end of October and spawn during November at depths of about 10 to 25 fathoms. Known spawning grounds are situated off the east shore of Beaver Island and in Big and Little Traverse Bays (records 27, 30, 31, and 37). The bottom visited is composed of mud or clay mixed with rock, according to the fishermen. Chubs of some kind spawn off Leeland, Mich., in November at 10 to 25 fathoms, according to Walter Wilson of Northport; off Manistee, Mich., at the same time, but no shallower than 40 fathoms, according to Charles Henrickson, sr., of Charlevoix, Mich.; and off Ludington and Muskegon, Mich., at the same time in 20 fathoms, according to Will DeYoung and the Vanderberg brothers, respectively. The fishermen are unable to describe these spawning fish, and as nothing is known of the composition of the chub lifts made out of these ports during other seasons, it can not be stated that these fish are longjaws. Other spawning grounds for the species, aside from those definitely known, probably could be found.

Leucichthys alpenæ of Lake Huron

The Lake Huron longjaw closely resembles that of Lake Michigan in appearance. A comparison of the principal systematic characters is given below:

Gill rakers on the first branchial arch:
- Michigan, (33) 36–43 (46).[27]
- Huron, (31) 34–40 (44).[28]

Lateral-line scales:
- Michigan, (71) 78–85 (96).
- Huron, (70) 76–83 (91).

L/H:
- Michigan, (3.8) 4.1–4.4 (4.6).
- Huron, (3.6) 4–4.3 (4.4).

H/E:
- Michigan, (3.8) 4.2–4.6 (5.2).
- Huron, (4) 4.5–4.9 (5.2).

H/S:
- Michigan, (3.3) 3.4–3.6 (4).
- Huron, (3.1) 3.3–3.6 (3.8).

Pv/P:
- Michigan, (1.6) 1.9–2.2 (2.5).
- Huron, (1.6) 1.8–2.1 (2.3).

Av/V:
- Michigan, (1.2) 1.4–1.7 (1.9).
- Huron, (1.3) 1.4–1.7 (1.9).

It appears that Huron specimens have somewhat fewer gill rakers on the first branchial arch, fewer lateral-line scales, a somewhat larger head, and a smaller eye. The L/H ratio is the more significant that the Huron specimens average decidedly larger, and it is usual that the head is proportionally smaller on larger fish. The eye changes so markedly in comparative size with the growth of the individual that the specimens from the two lakes can not be compared satisfactorily for this character.

The color in life is as in the Lake Michigan form. Pigmentation is about as in the form of northern Lake Michigan.

Males taken on the spawning grounds in Colpoy Bay on December 3, 1919, show pearl organs. The degree of development of these pearls varies with the individual, and in the individual the development on the two sides is often unequal. In general, however, the development of the breeding adornment is about like that of *johannæ* described on page 350.

VARIATIONS

Racial variations.—The longjaw is generally distributed throughout Lake Huron and Georgian Bay, and there are probably several distinct schools in these areas. A comparison of fish from the commercial takes of Lake Huron with those of Georgian Bay, and of small fish from Lake Huron taken in less than 60 fathoms with those taken from 60 fathoms or deeper, indicates that on the basis of my material it is not possible to established any definite characteristics for any of these races.

Size variations.—Small specimens differ from large ones chiefly in proportions. Counts of gill rakers, however, show fewer rakers on the first branchial arch in small specimens. They number (31) 33–37 (41) as compared with (31) 37–40 (44) in larger specimens. The head in specimens less than 210 millimeters in length is slightly larger, contained (3.4) 3.8–4.1 (4.2) times in the total length, as compared with (3.6) 4–4.3 (4.4) for large fish. The eye is conspicuously larger in the first class. The ratios for the head divided by the eye are (3.6) 3.8–4.1 (4.4) and (4)

[27] These figures for Lake Michigan are based on an examination of 383 specimens, those for scales on 329, those for H/S on 73; all others are based on an examination of 289 specimens, ranging in length from 205 to 386 millimeters.

[28] These and succeeding figures for Lake Huron, except those for gill rakers and lateral-line scales, are given for 177 specimens, ranging in length from 210 to 368 millimeters. The figures for gill rakers are based on 417 specimens of all sizes, those for scales on 323 specimens.

4.5–4.9 (5.2). The maxillary likewise appears to decrease slightly in relative size, and the ventral fin becomes relatively shorter with increased growth. The values for H/M are (2.3) 2.4–2.6 (2.7) and (2.3) 2.5–2.6 (2.8) and for Av/V are (1.1) 1.3–1.5 (1.7) and (1.3) 1.4–1.7 (1.9) for small and large fish, respectively. The depth and width, of course, become greater as the individual approaches maturity.

Specimens of both sexes 160 millimeters long appear regularly to be approaching sexual maturity. Fish as small even as 145 millimeters have exhibited maturing sex glands.

COMPARISONS

Alpenæ resembles closely only *johannæ* and *zenithicus*. A comparison with the former is given on page 357. *Alpenæ* and *zenithicus* differ most conspicuously in the length of the mandible, the pigmentation of the maxillary, the position of the premaxillaries, and the size attained. In *alpenæ* the lower jaw usually is longer than the upper, whereas *zenithicus* usually has the lower jaw shorter than the upper and included within it, and 6 per cent of the individuals examined had pigment on the maxillary as compared with 83 per cent for *zenithicus*. The premaxillaries in *alpenæ* usually make an angle of 50° to 60° with the horizontal axis of the head, and the dorsal contour of the head usually is a smooth curve, seldom broken at the premaxillary attachment, while in *zenithicus* the angle becomes 60° to 70° and the curve of the dorsal contour of the head is broken at the symphysis with the rostral cartilage. *Zenithicus* seldom grows larger than 300 millimeters, while *alpenæ* commonly exceeds this limit. The state of development of the ova in females often will serve as a valuable character. *Alpenæ* spawns about the middle of November and *zenithicus* during the last of September and the first of October, so that the ovaries of the females of the one species usually show more mature ova than those of the other. *Alpenæ* differs from *zenithicus* in other characters, but the differences are slight. The body of *zenithicus*, as a rule, is more pigmented, the head and body shallower, the maxillary longer, and it usually has not more than 24 scale rows around the caudal peduncle at its commencement, while *alpenæ* most often has more than 24.

The longjaw and blackfin of Lake Huron differ from one another in about the same manner as the two species have been shown on page 365 to differ in Lake Michigan. However, there is another difference observable in the Lake Huron fish—namely, the size of the eye. The values for H/E are for *nigripinnis* (3.6) 3.9–4.2 (4.6), with 3 per cent more than 4.4, and for *alpenæ* (4) 4.5–4.9 (5.2), with 84 per cent more than 4.4.

Small *alpenæ* are comparable with *kiyi* and are distinguishable from them by their shorter paired fins, fewer gill rakers, smaller eye, and less pigmentation. Those characters that can be expressed numerically are compared below for all *kiyi* collected and for all *alpenæ* less than 21 centimeters in length:

Gill rakers on the first branchial arch:
- *alpenæ*, (31) 33–37 (41), with 12 per cent more than 37.
- *kiyi*, (34) 36–40 (44), with 60 per cent more than 37.

H/E:
- *alpenæ*, (3.6) 3.8–4.1 (4.4), with 78 per cent more than 3.8.
- *kiyi*, (3.3) 3.6–3.8 (4.3), with 21 per cent more than 3.8.

Pv/P:
- *alpenæ*, (1.6) 1.8–2 (2.2), with 85 per cent more than 1.7.
- *kiyi*, (1.1) 1.4–1.7 (1.9), with 4 per cent more than 1.7.

Av/V:
- *alpenæ*, (1.1) 1.3–1.5 (1.7), with 93 per cent more than 1.2.
- *kiyi*, (0.9) 1–1.2 (1.4), with 6 per cent more than 1.2.

The proportions involving the head and eye may be taken only to indicate a general trend, as of the two groups of specimens compared the *alpenæ* averaged 3 centimeters larger. The maxillary is almost always immaculate in *alpenæ* and is almost always pigmented over at least half its surface in *kiyi*. The back, also, is darker on the average in the latter. The mandible in *alpenæ* is less pigmented and more powerful than in *kiyi*, and the body shape is more elliptical as seen from the side. A discussion of the difference between *alpenæ* and *hoyi* may be found on page 461.

From *artedi*, *alpenæ* may be distinguished by the character of the mandible, which in *alpenæ* is well developed, pale, and longer, as a rule, than the upper jaw, and in *artedi* frail, more or less conspicuously pigmented, and usually shorter; by the fewer gill rakers on the first branchial arch and the longer head, snout, and maxillary. A detailed comparison of the technical characters follows:

Gill rakers on the first branchial arch: [29]
- *alpenæ*, (31) 34–40 (44), with 16 per cent more than 39.
- *artedi*, (40) 45–50 (53).

L/H:
- *alpenæ*, (3.6) 4–4.3 (4.4).
- *artedi*, (4) 4.3–4.6 (5), with 57 per cent more than 4.4.

H/M:
- *alpenæ*, (2.3) 2.5–2.6 (2.8), with 7 per cent more than 2.6.
- *artedi*, (2.6) 2.8–3 (3.3), with 96 per cent more than 2.6.

H/S:
- *alpenæ*, (3.1) 3.4–3.6 (3.8), with 7 per cent more than 3.6.
- *artedi*, (3.5) 3.7–4 (4.3), with 82 per cent more than 3.6.

Alpenæ also shows much less pigmentation, especially on the dorsal surface and on the maxillary. The latter usually is immaculate in *alpenæ* and always pigmented in *artedi*.

GEOGRAPHICAL DISTRIBUTION

In Table 22 are brought together all my data on the occurrence of the longjaw in Lake Huron. Figure 5 shows these data platted on the chart of Lake Huron.

Lake Huron proper.—With the exception of entries 5, 40, 41, 42, and 45, the 45 records for Lake Huron proper were made by me from boats entering the harbors in Michigan of Cheboygan, Rogers, Alpena, and Harbor Beach. The location in the lake from which these lifts were made is shown on the chart. (Fig. 5.) Twenty-eight of these records are from the boats that used the 2¾-inch nets suitable for chubs, and the rest are from the 4½ or 1½ inch gill nets and pound nets set for other species or from special 2¾-inch nets. Commercial fishing operations thus indicate that the longjaw is found in the deeper American waters from about the

[29] Figures for gill rakers are given for all specimens. The rest are given for specimens 210 millimeters or more in length in the case of *alpenæ*, and 225 millimeters or more in length in the case of *artedi*.

latitude of Goderich to the Straits of Mackinaw. I have not seen longjaws from the Canadian waters of Lake Huron, but A. Purvis, of the Duck Islands, tells me that he not uncommonly takes large "chubs" in 4½-inch gill nets set for trout and whitefish off the Duck Islands in the north end of the lake in 20 to 30 fathoms (record 45). His books show that the trout lifts for several years during the months of May, June, July, and August frequently took from 100 to 200 pounds of gilled chubs. The size of these fish indicates that they were longjaws. In spite of the lack of other records for the Canadian side of the international boundary, an examination of the hydrographic chart of the region shows similar physical conditions on both sides of the boundary line and leaves no doubt that the range of the longjaw extends to near the Canadian shore.

North Channel.—I have seen no longjaws from this region, but John Merrylees, of Gore Bay on Manitoulin Island, tells me that he takes large "chubs" not uncommonly in 4½-inch nets in 20 to 25 fathoms (record 46). A similar statement is made by D. Beneteau, of Thessalon (record 47). There is in the North Channel a maximum depth of 28 fathoms, shown on the chart. As neither chubs nor blackfins are known to occur in quantities in less than 50 fathoms, these Gore Bay and Thessalon fish must be either longjaws or short-jawed chubs.

Georgian Bay.—All but 2 of the 11 records for this area were made by me from the hauls of 3-inch gill nets of boats entering the ports of Lions Head and Wiarton on the eastern shore of the Saugeen Peninsula. They show that the longjaw is found in Georgian Bay in summer and fall at depths corresponding to those at which it occurs in Lake Huron. There is no reason to suppose that it does not range over the whole of Georgian Bay during this season at similar depths. Records 54 and 55 are from my own observation in late November and December, 1919, and show the fish then in shallow water in Colpoy Bay at a depth of 10 to 25 fathoms. The entire catch of the nets at this time was made up of longjaws, and all were spawners and milters. According to the statements of Stanley Boyd, of Oxenden (record 53), this spawning run was already in the bay when he put in his nets on November 19. Record 58 is from the statement of Duncan McInnis, of Meaford. It shows an inshore run of spawning fish in Owen Sound and between Meaford and Cape Rich, both south of Colpoy Bay. These data on spawning fish are discussed in another place.

From the data given in the table it may be concluded that the longjaw ranges over the whole of Lake Huron and over Georgian Bay and that it probably occurs in the North Channel also. It appears further from the records that in Georgian Bay in late November and early December there is an inshore run of spawning fish.

BATHYMETRIC DISTRIBUTION

The records so far discussed have dealt chiefly with catches taken in the chub nets at depths of 35 to 100 fathoms. I have attempted, from other evidence, to determine whether longjaws occur at depths of less than 35 fathoms. For this purpose information is available from the following sources: (1) Catches of 1½-inch gill nets set by hook fishermen off Alpena and Harbor Beach, Mich., for the purpose of taking small fish for bait; (2) catches of 4½-inch gill nets set for trout and whitefish in less than 35 fathoms at Alpena, Mich.; (3) catches of 2¾-inch gill nets set under my direction with the trout and whitefish nets off Alpena, Mich., for the special purpose of determining the inshore range of chubs; (4) the pound nets set alongshore in shallow water.

1. *Catches of 1½-inch bait nets.*—Record 44 shows that such a net set in 31 fathoms at Harbor Beach, Mich., yielded a catch, 21 per cent of which was of small longjaws. On the other hand, lifts of identical nets in 30 fathoms off Alpena on September 8, 1917, and September 16, 1919, were examined by me without revealing more than a single specimen of this species (record 10); and in the lift made off Cheboygan, Mich., on October 15, 1919 (record 3) relatively few examples were found. The evidence from this source is scant and inconclusive and concerns only the immature fish that may be taken in gill nets of small mesh. In what quantities these small longjaws are taken in bait nets, at what seasons, and under what conditions are matters of prime interest. Record 44 shows that they made up 21 per cent of one haul, but in general it is known only that large numbers of small fish of some sort are taken daily to bait trout hooks. If a considerable percentage of these immature fish is longjaws or other species of commercial value when adult, their continued destruction may reduce greatly the supply of marketable fish of the species caught. The matter is worthy of further investigation.

2. *Lifts of 4½-inch gill nets set for trout and whitefish.*—I found large longjaws occasionally at Alpena, Mich., in September, 1917, gilled in 4½-inch trout nets lifted from 20 to 30 fathoms (record 11). Records of Alpena fishing tugs examined by me suggest that similar large fish are caught virtually throughout the season in these nets (record 40). Record 5 shows them taken daily during the last two weeks of September on rock bottom in 12 to 15 fathoms at Rogers, Mich. Record 45 shows similar fish in 20 to 30 fathoms at the Duck Islands, Ontario. Record 46 shows them during the summer off Gore Bay Lighthouse in the North Channel in 20 to 35 fathoms. Record 47 indicates that they are caught in winter at similar depths. The fish recorded under Nos. 5, 45, 46, and 47 were not seen by me, but their size indicates that they were longjaws; only the largest individuals of the species are gilled in nets of this mesh.

The specimens collected by me from 14 to 30 fathom lifts of 4½-inch trout nets at Alpena (records 9, 14, 23, 31, and 39) were small longjaws. They were not gilled in the usual sense of the word but were caught by their jaws becoming entangled in the meshes of the nets, so that their presence in the nets must be regarded as accidental. It is probable that they occur in shallow water in larger numbers than is indicated by their occasional capture in gill nets of large mesh.

3. *Lifts of 2¾-inch gill nets set in less than 30 fathoms.*—These nets were set in an attempt to determine whether gill nets of suitable mesh set on the same grounds as the 4½-inch trout nets referred to in the preceding paragraph would show longjaws in greater abundance than is indicated by their accidental capture in the trout nets themselves, or whether they occurred in localities in which the trout nets did not reveal them. The nets were lifted off Alpena as follows: September 17, 1917, 13½ miles SE. by S. of the can buoy in 15 fathoms with 4½-inch whitefish nets; September 19, 1917, 23 miles SE. by E. ½ E. of the can buoy in 30 fathoms with trout nets; September 26, 1917, 13 miles SE. by S. of the city in 17 fathoms; November 2, 1917, 7 miles E. NE. of the can buoy in 15 fathoms on honeycomb rock. In each

case a box (2,250 feet) of 2¾-inch gill nets was placed. Only 10 longjaws were taken by these nets, and all but 1 were included in the catch of September 19, 1917, in 30 fathoms (record 18). The nets set in 15 and 17 fathoms took only one longjaw on September 26, 1917 (record 26).

4. *Lifts of the pound nets.*—These ordinarily have not yielded longjaws, but relatively few ever have been examined by me. In collecting herring in Saginaw Bay, Dr. John Van Oosten has found stray longjaws on two occasions in the herring lifts made by the pound nets set in the shallow water at the bottom of the bay (records 41 and 42). The fish undoubtedly had strayed into the nets from spawning grounds somewhere along the shore.

From all the observations made by me, it appears that the depth range of the longjaw, when not spawning, is between 14 and 100 fathoms. Records 5, 45, 46, and 47, from the statements of fishermen, suggest also the occurrence of the species in shallow water, but it can not be asserted positively that the fish so reported were longjaws. In the spawning season the species appears to come into the shallowest water.

RELATIVE ABUNDANCE

Concerning the proportion of the longjaw to all the chubs in the chub lifts only the following few scattered observations, based on examination of lifts, are available: At Cheboygan, Mich., on July 21, 1917 (record 1), the longjaw was not rare in 35 to 50 fathoms. What proportion it made of the total catch is unknown. On September 28 and September 29, 1917 (record 2), it was practically absent from the lifts of the same nets. No lifts were examined at Rogers, Mich., except one made on October 14, 1917 (record 6), in 35 to 50 fathoms. This lift of about 1,500 pounds, like the lifts of September 28 and September 29 at Cheboygan, Mich., was made on the spawning grounds of *zenithicus* and contained only half a dozen longjaws. In view of the occupation of the grounds by the spawning *zenithicus*, these records show nothing conclusive concerning the occurrence of the longjaw at these depths. The hauls brought into Alpena, Mich., from depths of 60 to 80 fathoms vary in the number of the longjaws they contain. From the center of the lake, from northeast to east of the city in 1917, only an occasional longjaw was brought in on September 7, 10, 12, 14, 17, 19, 21, 24, and 26, and October 17 and 20 (records 8, 12, 13, 15, 16, 19, 21, 24, 25, 27, and 28). As these were the only catches examined from the center of the lake, it is not known whether longjaws ever occur there in numbers. Longjaws were uncommon also in the catches made from depths of 60 to 70 fathoms on August 7, 1920, 19 miles NE. ½ N. of Thunder Bay Island; in 60 to 65 fathoms in 1923 on June 28, 19 miles NE. of Thunder Bay Island, on June 30, 17 miles NE. by N. ¾ N. of Thunder Bay Island, on July 2, 20 miles E. by N. of the can buoy; and from 80 to 100 fathoms on July 5, 18 miles NE. ¾ E. of Thunder Bay Island (records 33 to 37). In three lifts made August 30 and September 3, 1919, and on July 7, 1923, 18 miles N. by E. ½ E. of Thunder Bay Island in 60 to 64 fathoms, 28 miles E. ¼ S. of the can buoy in 60 to 64 fathoms, and 13 miles NE. ½ N. of Thunder Bay Island in 60 fathoms, respectively (records 29, 30, and 38), longjaws comprised 20 to 22 per cent of the haul. A single lift examined at Harbor Beach, Mich., 35 miles NE. by N. ¾ N. from 50 fathoms on October 27, 1917 (record 43), was composed of slightly less than half of this species. Within Georgian Bay at Wiarton and Lions Head, on July 28 and July 30, 1919, at 52 and 60 fathoms, respectively (records 51 and 48), hauls were less than half longjaws. At Lions Head on October 6, 1919, in 70 fathoms (record 49), there were few longjaws. In Colpoys Bay from November 28 to December 3, 1919, in 10 to 25 fathoms (records 54 and 55), nothing but longjaws was taken. These, which were all spawning fish, are discussed under breeding habits.

The evidence reviewed shows without doubt that the longjaw is found in varying numbers, when not spawning, at depths of 14 to 100 fathoms. Lifts made from water 60 to 80 fathoms near the center of the lake, from 60 to 100 fathoms 17 to 20 miles northerly from the mouth of Thunder Bay, and from 70 fathoms in Georgian Bay show but few individuals of the species. Those made in water of less than 50 fathoms with 2¾-inch nets show either no individuals of the species or very few. With 1½-inch nets small specimens have been taken commonly at 31 fathoms. The heavy hauls of longjaws recorded are from depths of 50 to 64 fathoms, usually near shallow-water areas. These show the species to make up 20 to 50 per cent of the total number of fish taken. Only the catches of the 4½-inch gill nets recorded by me, the use of the special 2¾-inch nets (see p. 374), and the reports of the fishermen indicate the presence of the fish in water of less than 30 fathoms outside of the spawning season. These records indicate that only small quantities of fish are taken. The records thus show that the longjaw population, except in the breeding season, has its greatest density at depths of 50 to 64 fathoms, and that the density decreases toward deeper water and toward shore until only occasional fish are taken at 100 and 14 fathoms. Certainly more data are needed to determine finally the relative density of the longjaw population at different depths.

BREEDING HABITS

Concerning the further natural history of the form little is known. That the species leaves the north end of the lake toward the last of September seems certain, as the boats from Cheboygan and Rogers take practically none at this time. (See Table 14.) Whether the cause of the disappearance is simply an inshore movement, and whether similar movements occur at the other ports of the lake, must remain unknown until facilities for further observation are available. Certainly there is an inshore movement in Georgian Bay when (during the first week of November) swarms of spawning fish enter Colpoys Bay in 10 to 24 fathoms (records 53 to 55). The fish are also said to be present at the same time in Owen Sound and between Meaford and Cape Rich in 16 to 20 fathoms (record 58). The records of stray individuals in 3 fathoms in Saginaw Bay on October 29, 1921, and on November 25, 1925 (records 41 and 42), show that some individuals come into still shallower water at this time. The bottom of the grounds then visited is broken, according to the fishermen—that is, it consists of "mud" mixed with rock and gravel. During the last week in November, 1919, I found spawn flowing freely from the females and pearl organs on the males taken in Colpoys Bay. There can be no doubt that the fish frequent these localities at this time for the purpose of depositing their eggs. In 1919 the fish were caught from November 19 to December 3 in Colpoys Bay. They left during a heavy gale the first week in December. On account of the rough weather at this time of the year the fish are not followed after they move out of the bay.

These are the only known spawning grounds of the species, though others are certainly in existence in Lake Huron and possibly in Georgian Bay. The location of the spawning grounds in Colpoys Bay and Owen Sound and along the shore south of Cape Rich opens the way for further investigation of the life history of the longjaw. It should be practicable to secure eggs for artificial propagation, should such a step be desirable. Something could be learned about the conditions necessary for the development of the egg, also, and for the maintenance of the fry.

FOOD

Thirty stomachs were examined by Doctor Hubbs from specimens taken off Alpena, Mich., in September, 1917, in 60 fathoms and deeper. Mysis constituted the only food found in most of these stomachs. About one-third of the fish had eaten a little sand and plant remains of one kind and another. Pisidium, clay, fish scales, and cased invertebrate eggs of some kind were found in an occasional stomach. One specimen taken off Bay City, Mich., on October 29, 1921, had eaten larvæ of the May fly (Hexagenia) and some cased invertebrate eggs.

LEUCICHTHYS ZENITHICUS Jordan and Evermann

THE SHORT-JAWED CHUB (FIG. 16)

Argyrosomus zenithicus Jordan and Evermann, 1909, pp. 169–171, Lake Superior, off Isle Royale.
Leucichthys zenithicus Jordan and Evermann, 1911, pp. 29–30, Lake Superior; Dymond, 1926, p. 65, Pl. VI, Lake Nipigon.
Argyrosomus hoyi Milner, 1874a, pp. 86–87, in part, Lake Superior; Evermann and Smith, 1896, pp. 310–312, pl. 22, in part, Lake Michigan.
Leucichthys hoyi Jordan and Evermann, 1911, pp. 28–29, fig. 14 and Pl. III (not V), Lake Michigan.

Leucichthys zenithicus has been described from Lake Superior and occurs also in Lakes Michigan, Huron, and Nipigon. In all four bodies of water it is represented by elongate, subterete fishes of relatively moderate size, with short, usually included mandible, relatively long snout and maxillary, shallow head, and a moderate number of gill rakers and lateral-line scales. These forms inhabit moderate depths and spawn in the fall. The Michigan and Huron races differ from the typical race in having a shorter head and pectoral fins and reduced pigmentation, especially on the maxillary. The Huron race also has somewhat fewer gill rakers. The Nipigon race has fewer gill rakers, fewer scales in the lateral line and scale rows, a relatively larger head, eye, and snout, and a slightly deeper body than the typical race. It is also paler in color and less pigmented. The Huron race spawns in September and October; the rest in October and November.

Type

The type is a male specimen (catalogue No. 62517, U. S. National Museum) 278 millimeters in length, taken "in September, 1908, in deep water off Isle Royale." Counts of certain multiple parts and proportional lengths for this specimen are shown in Table 25.

Leucichthys zenithicus of Lake Superior

The short-jawed chub does not attain great size. The largest individual I have ever seen measured only 332 millimeters, and few specimens larger than 300 millimeters have been taken. The body is moderately compressed, elongate, and, as seen from the side, tapers smoothly and regularly to the head and tail from the deepest portion of the body, which is at the front of the dorsal. The depth at this point is quite variable and ranges in adults from 19 to 27 per cent of the length, with the usual range between 21 and 24 per cent. The width is about 50 to 55 per cent of the depth. The head, which is of relatively little depth, is contained 3.7 [(3.6) 3.8–4.1 (4.4)] [30] times in the total length. The dorsal margin of the head, not including the premaxillaries, is more or less straight. The snout is long and is contained 3.5 [(3.1) 3.3–3.6 (4)] times in the head length. It is truncated in side view, due to the nearly vertical position of the premaxillaries, which usually make an angle of 60° to 70° with the horizontal axis of the head. The maxillary likewise is long, is contained 2.5 [(2.1) 2.3–2.5 (2.7)] times in the head, and except in rare cases is more or less pigmented. The lower jaw usually is immaculate or faintly pigmented and included within the upper in about three-fourths of all the specimens seen. The eye is moderate in size and is contained 4.6 [(3.9) 4.2–4.6 (5.1)] times in the head. The gill rakers on the first branchial arch number 17+28 [(13) 14–16 (17)+(21) 24–26 (29)=(32) 39–43 (46)].[31]

The scales in the lateral line number 74 [(69) 74–84 (90)].[32] Rows of scales around the body just in front of the dorsal and ventrals number 40 [(37) 39–42 (45)]; [33] just in front of the adipose and anus 34 [(31) 32–34 (35)]; [34] around the caudal peduncle 24 [(22) 23–25 (26)].[34] There are 10 [(10–11)] [35] dorsal rays, 12 [(10) 11–12 (13)] [35] anal rays, 12 [11–12] [35] ventral rays, and 16 [(15) 16–17 (18)] [35] pectoral rays. The dorsal margin of the pectorals usually is more or less straight, at least not often sharply decurved. The pectoral length divided into the pectoral-ventral distance is contained 1.6 [(1.3) 1.6–2 (2.4)] times. The length of the ventrals is contained 1.3 [(1) 1.3–1.6 (1.9)] times in the distance from their insertion to that of the anal. The sum of the greatest depth of the head and the length of the base of the anal fin divided by the sum of the snout and maxillary length $\frac{(HD+AB)}{M+S}$ equals 1.52 [(1.30) 1.45–1.55 (1.75)].

The color in life is silvery, as in the other species of Leucichthys. The color is like that described for the chub on page 349, except that the dorsal surface is dark blue green to pale pea green. The color is obscured everywhere by somewhat heavier pigmentation, which is most pronounced around the free margins of the scales. There is a distinct purplish iridescence, most intense above the lateral line and paling gradually into the colorless belly. In addition to the patches of green in the frontal bones noted in the description of the chub, there are often two streaks of

30 The figures in brackets, except where otherwise stated, are based on an examination of 787 specimens, ranging in length from 200 to 332 millimeters.

31 Eight hundred and eighty-three specimens.

32 Nine hundred and fifty-six specimens.

33 Two hundred specimens.

34 Twenty specimens.

35 Forty specimens.

green between the nares. The paired fins and often the bases of the others are faintly flesh colored. The dorsal margin and often the distal half of the rays of the pectoral, the cranial margin and a wide distal band of the dorsal and the lateral borders, the distal third of the longest and half of the shortest rays of the caudal are smoky to black in hue. Black may often be present more or less conspicuously on the ventrals and the anal, also.

All color fades after death, and after prolonged preservation the silvery tone usually disappears, leaving characters of pigmentation more conspicuous. The pigment, which in life is evident on the entire dorsal surface, is revealed in diminished abundance on the sides above the lateral line. Below the lateral line and on the cheeks pigment is scattered.

Males, at least, acquire pearl organs during the breeding season, as is indicated by the fact that a few individuals taken several weeks previous to the spawning season have traces of these excrescences. Their full development probably is not different from the development exhibited by the breeding male of Lakes Huron and Michigan.

VARIATIONS

Racial variations.—Specimens have been collected from 12 localities distributed rather uniformly along the shore of the lake. The number of specimens preserved from each port varies, for the most part, between 50 and 200, and the various collections are fairly homogeneous in respect to size. A comparison of the various locality groups shows no differences in any of the characters examined. There are indications that specimens under 200 millimeters vary according to locality and habitat. For example, those small fish that have been taken from depths of more than 60 fathoms appear to have, on the average, a slightly shorter snout and greater body depth (even making allowance for the bloating attendant on bringing the fish to the surface) than those from shallower water.

Size variations.—Rather marked variations are exhibited by the small specimens. In Table 25 are compared extensively 10 specimens of less than 200 millimeters in length and 10 specimens of more than 200 millimeters in length. In addition, there are given in Tables 8 to 11 a comparison of certain characters of all the specimens collected, which in these tables have been separated similarly according to size. The most noteworthy data are summarized below:

Gill rakers on the first branchial arch:
- Small fish, (32) 36–41 (45), with the mode at 38.
- Large fish, (34) 39–43 (46), with the mode at 40.

L/H:
- Small fish, (3.5) 3.7–4 (4.2), with the mode at 3.9.
- Large fish, (3.6) 3.8–4.1 (4.4), with the mode at 4.

H/E:
- Small fish, (3.6) 3.7–4.1 (4.5), with the mode at 3.9.
- Large fish, (3.9) 4.2–4.6 (5.1), with the mode at 4.4.

H/M:
- Small fish, (2.3) 2.4–2.6 (2.7), with the mode at 2.5.
- Large fish, (2.1) 2.3–2.5 (2.7), with the mode at 2.5.

H/S:
- Small fish, (3.1) 3.3–3.7 (3.9), with the mode at 3.5.
- Large fish, (3.1) 3.3–3.6 (4), with the mode at 3.4.

Pv/P:

Small fish, (1.4) 1.7–2 (2.4), with the mode at 2.

Large fish, (1.3) 1.6–2 (2.4), with the mode at 1.8.

Av/V:

Small fish, (1) 1.2–1.5 (1.7), with the mode at 1.4.

Large fish, (1) 1.3–1.6 (1.9), with the mode at 1.5.

On account of the smaller snout and maxillary in small specimens, the $\frac{HD+AB}{M+S}$ value averages higher in this group. It equals (1.30) 1.45–1.65 (1.75), with the mode at 1.55. For larger specimens the value is (1.30) 1.45–1.55 (1.75), with the mode at 1.50. The data summarized above and those in Table 25 indicate that the small specimens have fewer and shorter gill rakers on the first branchial arch, a larger eye, a somewhat shorter snout, maxillary, and pectorals, and a slightly larger head and longer ventrals. The depth, as is usual, is less in small individuals. Specimens 150 millimeters in length usually show maturing sex organs. Individuals less than 200 millimeters are immature occasionally, but less than 1 per cent of more than 1,000 specimens examined of greater size had undeveloped sex organs.

COMPARISONS [36]

Zenithicus resembles closely only *reighardi* and *nigripinnis*. From *reighardi* it may be distinguished by its longer snout, more gill rakers, smaller eye, shallower head, and narrower body. A comparison of such figures as can be accurately expressed in figures follows:

Gill rakers on the first branchial arch:

zenithicus, (32) 39–43 (46), with 80 per cent more than 38.

reighardi, (32) 34–38 (42), with 10 per cent more than 38.

H/E:

zenithicus, (3.9) 4.2–4.6 (5.1), with 80 per cent more than 4.2.

reighardi, (3.6) 3.9–4.2 (5), with 9 per cent more than 4.2

H/S:

zenithicus, (3.1) 3.3–3.6 (4), with 12 per cent more than 3.5.

reighardi, (3.4) 3.6–3.9 (4.1), with 93 per cent more than 3.5.

Zenithicus has, on the average, a longer maxillary, longer paired fins, and more scales in the lateral line. It has also been observed that the ovaries of *reighardi* are almost always yellowish in color, at least in September, while those of *zenithicus* are more often orange.

Zenithicus has, on the average, a longer snout and maxillary, a shorter anal base, less depth of head and body, and fewer scale rows than *nigripinnis cyanopterus*. The cumulative differences of the first four characters combined are expressed by the $\frac{HD+AB}{M+S}$ ratio, which for *zenithicus* is (1.30) 1.45–1.55 (1.75), with 14 per cent more than 1.55, and for *nigripinnis cyanopterus* (1.45) 1.65–1.75 (1.85), with 95 per cent more than 1.55. For *zenithicus* the body depth contained in the total length is (3.6) 4–4.7 (5.4), with 91 per cent more than 3.9, and for *nigripinnis* (3.2) 3.6–4.3 (4.6), with 45 per cent more than 3.9.

[36] The specimens compared in this section for proportions are those 200 or more millimeters long, except *artedi*, which are 225 or more millimeters. Counts are given for specimens of all sizes.

The total number of scale rows around the body just in front of the dorsal and ventrals is, in *zenithicus* (37) 39–42 (45), with 8 per cent more than 42, and in *nigripinnis* (40) 41–45 (47), with 51 per cent more than 40. *Zenithicus* usually shows much less pigment, especially on the tip of the mandible and on the pectorals; the dorsal margin of the pectorals is usually straight, not conspicuously decurved; and the body outline, as seen from the side, is more elliptical than in *nigripinnis*. In the latter the body is distinctly deepest in front of the dorsal, and the dorsal contour rises sharply from the occiput. The state of development of the sex organs, particularly of the ovaries, is also an aid in separating the species at certain times, as *zenithicus* spawns in November and *nigripinnis* in September.

Zenithicus attains a much greater adult size than *kiyi* and *hoyi*. Small specimens may be separated from these two species by their more elongate body shape, less body depth, more elongate head, and included mandible. Small *zenithicus* are distinguished further from *hoyi* by their fewer gill rakers on the first branchial arch, which number (32) 36–41 (45), with 17 per cent more than 40, in small *zenithicus*, and (37) 41–44 (49), with 83 per cent more than 40, in *hoyi*.

Zenithicus may be distinguished readily from *artedi* by the fewer rakers on the first branchial arch, longer snout, maxillary, head, and paired fins, and the more truncated head as seen from the side. Comparative figures for most of these characters follow.

Gill rakers on the first branchial arch:
zenithicus, (32) 39–43 (46), with 4 per cent more than 43.
artedi, (41) 45–48 (53), with 97 per cent more than 43.

L/H:
zenithicus, (3.6) 3.8–4.1 (4.4), with 2 per cent more than 4.2.
artedi, (4.1) 4.3–4.6 (5.1), with 92 per cent more than 4.2.

H/S:
zenithicus, (3.1) 3.3–3.6 (4), with 12 per cent more than 3.5.
artedi, (3.4) 3.6–3.9 (4.3), with 93 per cent more than 3.5.

H/M:
zenithicus, (2.1) 2.3–2.5 (2.7), with 1 per cent more than 2.6.
artedi, (2.5) 2.7–3 (3.1), with 92 per cent more than 2.6.

Pv/P:
zenithicus, (1.3) 1.6–2 (2.4), with 14 per cent more than 1.9.
artedi, (1.7) 2–2.2 (2.8), with 84 per cent more than 1.9.

Av/V:
zenithicus, (1) 1.3–1.6 (1.9), with 15 per cent more than 1.5.
artedi, (1.3) 1.6–1.8 (2.3), with 91 per cent more than 1.5.

GEOGRAPHICAL DISTRIBUTION

My data on the occurrence of *zenithicus* in Lake Superior are assembled in Table 24 and are platted on the chart in Figure 3. Most of the 32 records are derived from special sets of nets of 2½ and 2¾ inch mesh made by me out of various ports of the lake in the course of a survey of the Leucichthys fauna. The records are sufficiently numerous and their sources sufficiently well distributed over the lake to warrant the conclusion that *zenithicus* occurs all along the shores of Lake Superior where suitable conditions obtain.

BATHYMETRIC DISTRIBUTION

The small-meshed nets mentioned in the preceding paragraph were set either with the commercial trout nets or in gangs by themselves at depths of 11 to 100 fathoms. These nets always took *zenithicus* at every set, except the one set made in Moffat Strait on September 25, 1923, in 13 to 14 fathoms; and records 2, 3, 6, 10, 14, 15, 16, 19, 28, 29, 31, and 32 show that some specimens also became entangled in the trout nets themselves. While these data seem to indicate that the species is rather widely distributed, both vertically and horizontally, it is noteworthy that few sets were made more than 15 miles from land (see fig. 3) or, whatever their remoteness from shore, were more than a few miles from 30 or 40 fathoms shoals, from which the descent into depths of 80 fathoms or more is abrupt. It may be stated, then, that *zenithicus* ranges along the shores of Lake Superior at depths of from 11 to 100 fathoms. Whether it goes deeper is not known. It is unlikely that it often comes shallower, at least not in the fishing season, as it is unknown as an accidental inclusion among the *artedi* and *reighardi* that often are taken in the pound nets set at 4 to 10 fathoms out of various ports.

RELATIVE ABUNDANCE

The lifts of the special 2¾ and 2½ inch nets set out of the various ports are the only source of data on the relative abundance of *zenithicus* at any locality or at any depth. While the amount of netting used was relatively insignificant when the expanse of the lake is considered, yet the number of fish taken in a given period indicates in some measure their abundance along the bottom. Out of Sault Ste. Marie, Mich., a gang of 1,800 feet of netting set on June 12, 1922, 10 miles NW. by W. ¼ W. of Point Iroquois Light in Whitefish Bay, and lifted on the 14th, had about 200 fish, or 55 fish per night per 1,000 feet (record 1), of which virtually all were *zenithicus*. Out of Marquette, Mich., 6 miles NE. ¾ N., in 42 to 65 fathoms on August 8, 1921, 2,500 feet of net took about 250 fish after having been set five nights, or 20 fish per night per 1,000 feet (record 4); and the same amount of netting lifted on August 11, 18 miles NE. by N., in 100 to 80 fathoms, after seven nights out, had about 200 fish, or 11 fish per night per 1,000 feet (record 5). All but 10, or 96 per cent, of the fish taken on the 8th and all but 35, or 88 per cent, of those taken on the 11th were *zenithicus*. Out of Ontonagon, Mich., on August 24, 1921, in 2,500 feet of netting lifted 21 miles west in 15 to 45 fathoms, after having been set for seven nights, about 700 fish were taken, or 40 fish per night per 1,000 feet (record 11); and a similar gang lifted on the 25th, 6 miles NNW. in 20 to 38 fathoms, seven nights out, had about 500 fish, or 28 fish per night per 1,000 feet (record 12). Both these gangs took virtually nothing but *zenithicus*. Between Cat and South Twin Islands, of the Apostle group, 2,200 feet of net lifted on July 11, 1922, after one night out, from 15 to 20 fathoms, had about 300 *zenithicus*, or 136 fish per night per 1,000 feet (record 13), and virtually nothing else.

Three thousand feet of net lifted 20 miles NE. by E. of Duluth on July 17, 1922, in 30 to 40 fathoms, after two nights, had about 200 pounds of fish, probably 500 individuals (record 17), of which virtually all were *zenithicus*. Out of Grand Marais, Minn., in 3,500 feet of net set off Terrace Point in 30 to 65 fathoms and lifted on September 14, 1921, after seven nights out, about 2,000 fish were taken, or 81 fish per night per 1,000 feet (record 18), of which all but a few were *zenithicus*. *Zenithicus* was rare in the 2½-inch nets set on September 15, 1923, between Silver Island and the mainland in 14 fathoms (record 20). There was a single fish among the 32 Leucichthys taken in one net (500 feet) set one night. In Thunder Bay a net lifted on September 15, 1923, off Thunder Cape in 31 fathoms, after having been set two nights, took 70 Leucichthys, or 70 fish per night per 1,000 feet of net, of which half were *zenithicus* (record 21). A net lifted north of the Welcome Islands on September 17, 1923, in 11 fathoms, after having been set two nights, took a single *zenithicus* among the 16 Leucichthys (record 22). Two nets lifted on September 17, 1923, south of the Welcome Islands in 23 fathoms, after having been set two nights, took 121 fish, or 60 fish per night per 1,000 feet of net, of which but 6 per cent were *zenithicus* (record 23). Two nets lifted on September 19, 1923, off Sawyer Bay, from 49 fathoms, two nights out, had 50 fish, or 25 fish per 1,000 feet of net per night, 62 per cent of which were *zenithicus* (record 24). On September 25, 1923, two 2½-inch nets (1,000 feet of netting) set for one night in Simpson Channel in 74 fathoms took only 4 fish, all of them *zenithicus* (record 26). On September 29, 1923, two nets lifted after four nights from 42 fathoms off Salter Island took 25 fish, or 6 fish per night per 1,000 feet of net, of which 92 per cent were *zenithicus* (record 27). One thousand feet of net set out of Rossport, Ontario, off Bread Rock in 80 to 90 fathoms, and lifted on October 4, 1921, after having been set for four nights, took about 210 fish, or 52 fish per night per 1,000 feet (record 25). All but 11 per cent of these were *zenithicus*. Two thousand five hundred feet of netting lifted on June 22, 1922, 3 miles SE. ½ E. of the Quebec Harbor Light on Michipicoten Island in 80 fathoms, three nights out, took 75 fish, or 10 fish per night per 1,000 feet (record 30), of which 60, or 79 per cent, were *zenithicus*. One thousand eight hundred feet of netting lifted off Alona Bay on the east shore of the lake on June 26, 1922, in 60 fathoms, after having been set for five nights, took about 200 fish, or 22 fish per night per 1,000 feet (record 32), of which 87 per cent were *zenithicus*. The fish taken in the 4½-inch nets in Michigan waters, out of Grand Marais (record 2), Marquette (records 3 and 6), and Ontonagon (record 10); in Wisconsin waters off South Twin Island (records 14, 15, and 16); in Minnesota waters off Grand Marais (record 19); and in Ontario waters off Port Coldwell (record 28), Michipicoten Island (record 29), and Coppermine Point (records 31 and 32), were only casual inclusions and can show little concerning the abundance of these fish.

These data indicate that *zenithicus* occurs more or less abundantly at depths of 11 to 100 fathoms, but they do not mark the zone of maximum abundance for the species because the various observations have been made at different seasons and at different places and make no allowance for seasonal migrations nor for differences of habit induced by different physical conditions. It is clear, however, that the gangs set exclusively in depths of 60 to 100 fathoms average only 17 *zenithicus* per night per 1,000 feet (records 5, 25, 26, 30, and 32), while those set wholly or in part at depths of 15 to 45 fathoms average 41 *zenithicus* (records 1, 4, 11, 12, 13, 18, 21, 23, 24, and 27). In shallower water the species has been found rare. The data indicate further that *zenithicus* comprises 79 to 99 per cent of all the Leucichthys taken by the special nets, except in Thunder Bay and vicinity (records 20 to 24), where *reighardi* is commonest. *Zenithicus* does not now support, nor is it certain that it ever has maintained, a fishing industry, although at Marquette and Duluth lifts of the species are made occasionally at certain seasons. In abundance it now ranks only second to *artedi*, *nigripinnis cyanopterus* having ceased long since to occur in commercial quantities.

BREEDING HABITS

No specimens were taken in the spawning season, and the time of breeding and the location of spawning grounds are known only from the testimony of fishermen and from specimens taken out of Marquette, Mich., in December, 1922. Mr. Parker informs me that by setting 10 miles N. by W. ¼ W. in 20 to 40 fathoms during the last week in November, from 3 to 6,000 pounds of spawning chubs usually are taken in a gang of 2¾-inch nets 5 miles long lifted after four nights (record 9). The run is said to last about a week. The bottom on the spawning grounds is clay. Of the five species of "chubs" that are known from Superior, *kiyi* and *hoyi* never attain sufficient size to gill in 2¾-inch nets, *reighardi* is not known to occur east of Keweenaw Point, Mich., and *cyanopterus* spawns in September; therefore these fish can only be *zenithicus*. James Scott, of Grand Marais, Minn., gives information that indicates that the species may spawn during November along the shores near Grand Marais. He says that when the herring nets, which are floated to take *artedi*, fall by accident to the bottom, *zenithicus* are taken in them in unusual abundance. The fish are distinguished from the herring by the Grand Marais fishermen and are known locally as ciscoes.

Observations made on the state of development of the ovaries tend to confirm the above-mentioned statements. Of the specimens taken at all ports during June, July, August, and September, only a few specimens (and these were less than 200 millimeters long) collected in Whitefish Bay on June 14, 1922 (record 1), showed spawn in a state approaching ripeness. Those taken at Grand Marais, Minn., on September 14, 1921, in Thunder Bay on September 19, 1923, and at Rossport, Ontario, on October 4, 1921, had well-developed eggs, and an occasional male taken on the last two dates showed traces of pearls. The female fish taken at Marquette, Mich., in early December, 1922, were either spawning or ready to spawn.

Late November and early December is probably the spawning time for the species throughout the lake. It is likely that the small fish with ripe ova taken in June were spawning for the first time and may have retained their eggs beyond the normal time of spawning. At any rate, the proportion of specimens with such abnormal ovaries was insignificant, and there is no reason to believe that the species spawns more than once a year. The known spawning grounds at Marquette are at depths of 20 to 40 fathoms on clay, and probably it will be found that spawning grounds in other areas of the lake are similarly situated.

Leucichthys zenithicus of Lake Nipigon

Zenithicus of Lake Nipigon is compared in the chief characters with the typical race below:

Gill rakers on the first branchial arch:
- Superior, (34) 39–43 (46).[37]
- Nipigon, (33) 36–39 (42).[38]

Scales in lateral line:
- Superior, (69) 74–84 (90).
- Nipigon, (66) 70–77 (83).

L/H:
- Superior, (3.6) 3.8–4.1 (4.4).
- Nipigon, (3.5) 3.7–4 (4.2).

H/E:
- Superior, (3.9) 4.2–4.6 (5.1).
- Nipigon, (3.6) 4–4.4 (4.6).

H/M:
- Superior, (2.1) 2.3–2.5 (2.7).
- Nipigon, (2.2) 2.3–2.5 (2.8).

H/S:
- Superior, (3.1) 3.3–3.6 (4).
- Nipigon, (3) 3.2–3.5 (3.8).

Pv/P:
- Superior, (1.3) 1.6–2 (2.4).
- Nipigon, (1.5) 1.6–1.9 (2.1).

Av/V:
- Superior, (1) 1.3–1.6 (1.9).
- Nipigon, (1.1) 1.3–1.5 (1.7).

L/D:
- Superior, (3.6) 4–4.7 (5.1).
- Nipigon, (3.5) 3.7–4.5 (5).

The comparisons show that the Nipigon race differs from the typical race in having fewer gill rakers and lateral-line scales and possibly a relatively larger head, eye, and snout, and a slightly deeper body. It has also fewer scale rows.

The color in life is much paler than in the typical race. The pea green of the back is very pale, and the green cranial patches are often wanting. Pigmentation also is reduced, especially on the dorsal surface and on the maxillary, which usually is pigmented over not more than one-fourth its area, and on the abdominal fins, which are usually immaculate.

No pearled individuals have been seen, but pearl organs doubtless are developed during the breeding season.

VARIATIONS

Racial variations.—The examination of my specimens shows no indication of the occurrence of well-marked races in the lake. There are not enough specimens available for extensive comparison, however.

Size variations.—In Table 27, 10 specimens more than 200 millimeters long and 10 less than 200 millimeters long are compared extensively. The differences between the two groups are of proportion. Small specimens have a relatively larger head and eye, longer paired fins, a relatively somewhat shorter snout and maxillary, and less body depth.

Of the 14 small specimens examined, none were found sexually mature at less than 170 millimeters.

COMPARISONS [39]

Zenithicus is separable from all the species of Leucichthys of the lake except *reighardi* and *hoyi* by the number of gill rakers on the first branchial arch, which in none of the other forms number less than 44 and in *zenithicus* not more than 42.

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[37] These and succeeding figures, except those for lateral-line scales, are based on an examination of 787 specimens ranging in length from 200 to 332 millimeters. Those for scales are given for 956 specimens.

[38] Figures for gill rakers and lateral-line scales are based on an examination of 160 and 147 specimens, respectively. All others are given from an examination of 141 specimens ranging in length between 200 and 308 millimeters.

[39] The specimens compared for proportions are those 200 millimeters or more in length or, in the case of *artedi*, 225 millimeters or more. The counts are given for specimens of all sizes.

Zenithicus may be separated from *reighardi* by its greater number of gill rakers and lateral-line scales, longer snout, and less depth of head and body. These characters are compared for the two species below:

Gill rakers:
- *zenithicus*, (33) 36–39 (42), with 78 per cent more than 36.
- *reighardi*, (32) 33–36 (38), with 9 per cent more than 36.

Lateral-line scales:
- *zenithicus*, (66) 70–77 (83), with 55 per cent more than 73.
- *reighardi*, (64) 66–73 (77), with 15 per cent more than 73.

H/S:
- *zenithicus*, (3) 3.2–3.4 (3.8), with 19 per cent more than 3.4.
- *reighardi*, (3.3) 3.5–3.6 (4), with 85 per cent more than 3.4.

L/HD:
- *zenithicus*, (5.8) 6.1–6.8 (7.4), with 84 per cent more than 6.2.
- *reighardi*, (5.5) 5.7–6.2 (6.6), with 10 per cent more than 6.2.

HD/S:
- *zenithicus*, (1.8) 1.9–2.1 (2.3), with 6 per cent more than 2.1.
- *reighardi*, (2) 2.2–2.3 (2.7), with 83 per cent more than 2.1.

L/D:
- *zenithicus*, (3.5) 3.7–4.5 (5), with 55 per cent more than 4.
- *reighardi*, (3.5) 3.6–4.1 (4.4), with 14 per cent more than 4.

Zenithicus has also a somewhat smaller head, a more compressed body, and shows less pigment throughout. The maxillary is usually pigmented over only one-fourth or less in *zenithicus* and at least one-third its extent in *reighardi;* and all the abdominal fins are immaculate in over two-thirds of the individuals of *zenithicus*, while two-thirds of the specimens of *reighardi* examined have some pigment.

From *nigripinnis regalis*, *zenithicus* differs, in addition to the lower gill-raker number, in having less body depth and a much more elliptical body outline as seen from the side; in having much less pigmentation on body and fins, a smaller eye, longer snout, and shorter pectorals. Certain of these characters are compared below:

L/D:
- *zenithicus*, (3.5) 3.7–4.5 (5), with 55 per cent more than 4.
- *nigripinnis*, (3.1) 3.5–4 (4.5), with 16 per cent more than 4.

H/E:
- *zenithicus*, (3.6) 4–4.4 (4.6), with 60 per cent more than 4.1.
- *nigripinnis*, (3.5) 3.7–4.1 (4.3), with 4 per cent more than 4.1.

H/S:
- *zenithicus*, (3) 3.2–3.5 (3.8), with 9 per cent more than 3.5.
- *nigripinnis*, (3.4) 3.6–3.8 (4.3), with 94 per cent more than 3.5.

Pv/P:
- *zenithicus*, (1.5) 1.6–1.9 (2.1), with 69 per cent more than 1.6.
- *nigripinnis*, (1.2) 1.4–1.6 (1.9), with 7 per cent more than 1.6.

The mandible, in relation to the upper jaw, is shorter in *zenithicus*, and the head, seen from the side, is much more elongate and less distinctly triangular.

Only small individuals can be confused with *hoyi*, as the latter does not often grow larger than 200 millimeters; and almost always they can be separated from *hoyi* by their shorter mandible (which in *hoyi*, in addition to being longer, usually has a distinct symphysial knob), less depth of head and body, and fewer gill rakers, which in *zenithicus* number (33) 36–39 (42), with 10 per cent more than 39, as compared with (40) 42–46 (48) for *hoyi*. From the few small specimens of *zenithicus* at hand, it appears also that they have relatively smaller eyes and relatively shorter paired fins, especially ventrals.

Zenithicus is distinguishable from *artedi* and *nipigon* by having many fewer gill rakers and a longer snout and maxillary. Comparative figures follow:

Gill rakers:
- *zenithicus*, (33) 36–39 (42), with 4 per cent more than 40.
- *artedi*, (41) 46–49 (53).
- *nipigon*, (54) 56–59 (66).

H/S:
- *zenithicus*, (3) 3.2–3.4 (3.8), with 1 per cent more than 3.6.
- *artedi*, (3.5) 3.7–3.9 (4.2), with 91 per cent more than 3.6.
- *nipigon*, (3.3) 3.5–3.8 (4), with 55 per cent more than 3.6.

H/M:
- *zenithicus*, (2.2) 2.3–2.5 (2.8), with 17 per cent more than 2.5.
- *artedi*, (2.5) 2.7–2.8 (3), with 98 per cent more than 2.5.
- *nipigon*, 2.5–2.7 (3.1), with 78 per cent more than 2.5.

Zenithicus is less pigmented on body and fins and has, as a rule, a shorter and more included mandible. It is distinguished further from *nipigon* by its less depth of body and by the fact that it seldom grows longer than 300 millimeters, while specimens of *nipigon* commonly exceed that limit.

GEOGRAPHICAL DISTRIBUTION

In Table 26 are collected my data and those of the specimens examined from the University of Toronto collection on the distribution of *zenithicus* in Lake Nipigon. They are platted on the chart of the lake in Figure 2. All are derived from the use of special small-meshed nets set during the course of a survey of the fishes of the lake. The records are distributed widely enough to warrant the conclusion that *zenithicus* occurs throughout the lake where there are suitable conditions.

BATHYMETRIC DISTRIBUTION

Zenithicus was present in two of the three sets made by me in Lake Nipigon. On July 25, 1922, off the source of the Nipigon River, in 10 to 15 fathoms, *zenithicus* made up 13 per cent of the catch; and on the following day, off Macdiarmid, in 30 fathoms, 43 per cent of the take was of this species (records 16 and 1). (For a statement of the comparative abundance of the coregonids in these lifts, see p. 409.) No *zenithicus* occurred in the lift made on July 28, 1922, off Livingston Point, in 56 fathoms. The specimens from the University of Toronto collection, so far as is known, were taken at depths of 6 to 54 fathoms, but chiefly in less than 30 fathoms. The species probably prefers water of moderate depth.

BREEDING HABITS

Of five specimens collected on October 26, 1922 (record 19), one female was spent and the other individuals were nearly ripe, so that it may be assumed the spawning season falls around the first of November. Nothing else is known of the breeding behavior of the species in Lake Nipigon.

Leucichthys zenithicus of Lake Michigan

The *zenithicus* of Lake Michigan resembles closely the typical form in respect to body shape, adult size, and most systematic characters. The chief characters are compared below:

Gill rakers on the first branchial arch:
- Superior, (32) 39–43 (46).[40]
- Michigan, (35) 38–42 (44).[41]

Scales in lateral line:
- Superior, (69) 74–84 (90).[42]
- Michigan, (70) 75–85 (91).[43]

L/H:
- Superior, (3.6) 3.8–4.1 (4.4).[44]
- Michigan, (3.9) 4–4.3 (4.5).

H/E:
- Superior, (3.9) 4.2–4.6 (5.1).
- Michigan, (4) 4.2–4.5 (5).

H/M:
- Superior, (2.1) 2.3–2.5 (2.7).
- Michigan, (2.2) 2.4–2.6 (2.8).

H/S:
- Superior, (3.1) 3.3–3.6 (4).
- Michigan, (3.2) 3.4–3.7 (4).

Pv/P:
- Superior, (1.3) 1.6–2 (2.4).
- Michigan, (1.7) 2–2.2 (2.6).

Av/V:
- Superior, (1) 1.3–1.6 (1.9).
- Michigan, (1.2) 1.4–1.6 (2).

These data indicate that the Michigan form has a shorter head and pectorals than the typical form. The snout, maxillary, and ventrals may also be somewhat shorter, and the body, on the average, is somewhat wider. It is noteworthy, also, that while in Lake Superior *zenithicus* almost invariably has pigment on the maxillary, 176 out of 487, or about one-third, of the individuals examined of the form in Lake Michigan have no pigment except occasionally on the jugal. The premaxillaries in the latter class are also immaculate or but lightly pigmented, and the mandible more often is included within the upper jaw.

The color in life is not strikingly different from that of the typical form except for the reduced pigmentation. The dorsal surface and the fins are conspicuously less pigmented than in the Superior form, and of the fins the anal and ventrals are often immaculate.

Males, at least, develop pearl organs during the breeding season. The breeding dress is not known to be different from that described for *johannæ*, on page 350.

VARIATIONS

There are too few specimens from any locality to indicate whether there is local variation in this species. Small individuals of the species, however, as is usual, differ in certain characters from larger ones. In Table 29 are presented a series of counts and proportions for 7 specimens smaller than 200 millimeters, and for 10 larger than 200 millimeters. It appears from this table that the head, eye, and paired fins are somewhat larger in the small specimens and the maxillary relatively somewhat shorter.

Only one of these small specimens (a male, 192 millimeters) shows sex organs approaching maturity. Of two other small fish collected, but not recorded in the table, one male (165 millimeters) is mature.

[40] Eight hundred and eighty-three specimens

[41] These and other figures for Lake Michigan, unless otherwise marked, are based on an examination of 123 specimens, ranging in length from 200 to 312 millimeters.

[42] Nine hundred and fifty-six specimens.

[43] One hundred and forty specimens.

[44] These and other figures for Lake Superior, unless otherwise marked, are based on an examination of 787 specimens, ranging in length from 200 to 332 millimeters.

COMPARISONS [45]

Zenithicus approaches closely only *reighardi* and *alpenæ*. It is distinguishable from typical *reighardi* by the longer snout and maxillary, smaller eye, somewhat longer head, and more gill rakers on the first branchial arch. Fish of the northern race of *reighardi*, however, usually show nearly as long a snout, and the maxillary and head differences are not so pronounced as between *zenithicus* and typical *reighardi*. A numerical expression of these characters for these fish follows:

Gill rakers on the first branchial arch:
- *zenithicus*, (35) 38–42 (44), with 74 per cent more than 38.
- *reighardi*, north, (30) 34–37 (43), with 15 per cent more than 38.
- *reighardi*, south, (31) 35–38 (43), with 13 per cent more than 38.

H/E:
- *zenithicus*, (4) 4.2–4.5 (5), with 74 per cent more than 4.2.
- *reighardi*, north, (3.7) 4–4.3 (4.6), with 16 per cent more than 4.2.
- *reighardi*, south, (3.6) 3.9–4.2 (4.4), with 5 per cent more than 4.2.

H/M:
- *zenithicus*, (2.2) 2.4–2.6 (2.8), with 23 per cent more than 2.5.
- *reighardi*, north, (2.3) 2.5–2.7 (3), with 73 per cent more than 2.5.
- *reighardi*, south, (2.5) 2.6–2.8 (2.9), with 97 per cent more than 2.5.

H/S:
- *zenithicus*, (3.2) 3.4–3.7 (4), with 30 per cent more than 3.6.
- *reighardi*, north, (3.2) 3.4–3.8 (4.3), with 40 per cent more than 3.6.
- *reighardi*, south, (3.5) 3.6–4 (4.4), with 83 per cent more than 3.6.

MS/E:
- *zenithicus*, (2.6) 2.8–3.1 (3.2), with 97 per cent more than 2.6.
- *reighardi*, north, (2.2) 2.5–2.7 (3.1), with 46 per cent more than 2.6.
- *reighardi*, south, (2.2) 2.4–2.6 (2.8), with 5 per cent more than 2.6.

L/H:
- *zenithicus*, (3.9) 4–4.3 (4.5), with 7 per cent more than 4.3.
- *reighardi*, north, (3.9) 4.1–4.4 (4.7), with 26 per cent more than 4.3.
- *reighardi*, south, (4) 4.2–4.5 (4.8), with 48 per cent more than 4.3.

Reighardi has a wider body, deeper head, shorter pectorals, and more heavily pigmented premaxillaries, maxillary, and mandible, and there is often more pigment on the body and abdominal fins. (See also fig. 11.)

Discussion of the differences between *zenithicus* and *johannæ* and *alpenæ* are given on pages 351 and 364.

Zenithicus is easily distinguished from *nigripinnis* by the fewer gill rakers, which in the former are not more than 44 and in the latter seldom less; by its shallower and more elongated head in side view, as contrasted with the deep, blunt one of *nigripinnis*; by its less body depth, which in side view is usually elliptical in the first and ovate in the other; by the mandible, which in *zenithicus* is not conspicuously pigmented and is included in the upper jaw and in *nigripinnis* is usually heavily pigmented and equal to or longer than the upper jaw; and by the much paler and shorter paired fins. The comparative figures for fin length follow:

Pv/P:
- *zenithicus*, (1.7) 2–2.2 (2.6), with 90 per cent more than 1.8.
- *nigripinnis*, (1.5) 1.6–1.8 (2.2), with 18 per cent more than 1.8.

Av/V:
- *zenithicus*, (1.2) 1.4–1.6 (2), with 64 per cent more than 1.4.
- *nigripinnis*, 1.2–1.5 (1.6), with 28 per cent more than 1.4.

[45] Figures given under this section for proportions are based on specimens 200 millimeters or more in length, except *artedi* where the limit is 225 millimeters. Counts are given for specimens of all sizes.

Zenithicus spawns in November and *nigripinnis* spawns in late December and early January, so that the state of ripeness of the sex products may aid also in separating certain specimens.

Zenithicus differs from *kiyi* chiefly in the length of the mandible and paired fins, size of the eye, and body shape. In *zenithicus* the mandible is heavy, never with a symphysial knob, and usually shorter than the upper jaw; in *kiyi* the mandible is frail, usually with a symphysial knob, and equals or exceeds in length the upper jaw.

Zenithicus has a smaller eye and much shorter paired fins than *kiyi* and, moreover, attains greater size. Extreme examples of the former measure 312 millimeters; of the latter, 245 millimeters. The eye, of course, changes in proportion to the head with growth, and while the specimens of *zenithicus* average larger than the kiyis, they were all taken in the same nets, and the differences thus are those that would be exhibited by specimens in the same catch. The figures are given:

H/E:
zenithicus, (4) 4.2–4.5 (5), with 93 per cent more than 4.1.
kiyi, (3.6) 3.8–4.2 (4.3), with 19 per cent more than 4.1.

Pv/P:
zenithicus, (1.7) 2–2.2 (2.6), with 97 per cent more than 1.7.
kiyi, (1.1) 1.4–1.7 (2.1), with 18 per cent more than 1.7.

Av/V:
zenithicus, (1.2) 1.4–1.6 (2), with 90 per cent more than 1.3.
kiyi, (0.96) 1–1.3 (1.4), with 2 per cent more than 1.3.

The body of *zenithicus* is much wider and less deep, and the slope of the body contours as seen from the side is more gradual than in *kiyi*. The shape of the head, seen from the side, is also different because of the difference in position of the premaxillaries in the two forms. *Zenithicus* shows, on the average, less pigment on the head, back, and fins. Female *kiyi* will show ova in a more advanced state of development than females of *zenithicus* taken at the same time, as *kiyi* probably spawns a month earlier.

Zenithicus may be distinguished readily from *hoyi* by its shorter and heavier mandible and shallower and more elongate head and body. The snout, also, is more truncate, due to the more vertical position of the premaxillaries. In *hoyi* the mandible is frail, usually with a symphysial knob, and equals or exceeds in length the upper jaw.

The head is distinctly triangular in side view, and the body is always conspicuously deep, the depth often due to bloating. *Hoyi*, moreover, is a decidedly small species. Few individuals grow larger than 230 millimeters, while *zenithicus* attains a length of 300 millimeters. Numerous small specimens of *hoyi* usually are found ensnarled in the twine of all the commercial nets of whatever mesh, while small *zenithicus* seldom are taken in this manner. *Zenithicus* has fewer gill rakers on the first branchial arch, more lateral-line scales, a smaller eye, longer snout, and shorter paired fins. Those characters that can be expressed numerically are compared below. The specimens of the two species, however, are not comparable for those characters that deal with proportions, inasmuch as the *hoyi* are smaller than the others, so that these differences probably are greater than they would be in specimens of like size.

Gill rakers on the first branchial arch:
zenithicus, (35) 38–42 (44), with 19 per cent more than 41.
hoyi, (37) 41–44 (48), with 71 per cent more than 41.
Lateral-line scales:
zenithicus, (70) 75–85 (91), with 73 per cent more than 76.
hoyi, (60) 67–77 (84), with 11 per cent more than 76.
H/E:
zenithicus, (4) 4.2–4.5 (5), with 74 per cent more than 4.2.
hoyi, (3.8) 3.9–4.2 (4.5), with 8 per cent more than 4.2.
H/S:
zenithicus, (3.2) 3.4–3.7 (4), with 30 per cent more than 3.6.
hoyi, (3.5) 3.7–3.8 (4.1), with 76 per cent more than 3.6.
Pv/P:
zenithicus, (1.7) 2–2.2 (2.6), with 55 per cent more than 2.
hoyi, (1.6) 1.8–2 (2.3), with 21 per cent more than 2.
Av/V:
zenithicus, (1.2) 1.4–1.6 (2), with 41 per cent more than 1.5.
hoyi, (1.1) 1.3–1.5 (1.7), with 9 per cent more than 1.5.

Females of the species may be distinguished further by the difference exhibited in the state of development of ova. *Zenithicus* spawns in November and *hoyi* in March.

Zenithicus differs from *artedi* chiefly in having fewer gill rakers on the first branchial arch, longer ventral fins, head, snout, and maxillary. The figures for these characters for the two species are given below:

Gill rakers on the first branchial arch:
zenithicus, (35) 38–42 (44), with 3 per cent more than 43.
artedi, (41) 46–50 (55), with 97 per cent more than 43.
Av/V:
zenithicus, (1.2) 1.4–1.6 (2), with 12 per cent more than 1.6.
artedi, (1.4) 1.6–1.8 (2.3), with 76 per cent more than 1.6.
L/H:
zenithicus, (3.9) 4–4.3 (4.5), with 7 per cent more than 4.3.
artedi, (4.1) 4.3–4.5 (5), with 71 per cent more than 4.3.
H/M:
zenithicus, (2.2) 2.4–2.6 (2.8), with 9 per cent more than 2.6.
artedi, (2.5) 2.7–3 (3.3), with 91 per cent more than 2.6.
H/S:
zenithicus, (3.2) 3.4–3.7 (4), with 30 per cent more than 3.6.
artedi, (3.3) 3.7–4 (4.4), with 84 per cent more than 3.6.

Zenithicus is less pigmented and paler in color on the back and cranium and on the abdominal fins than *artedi*; and the mandible, while not much shorter than in the latter, is heavier and less pigmented. Both species spawn at about the same time, so the state of development of the sex organs is of no systematic importance.

GEOGRAPHICAL DISTRIBUTION

My data on the occurrence of *zenithicus* in Lake Michigan are given in Table 28 and are platted on the chart in Figure 4. There are 27 records, all but 2 of them made from an examination of the catches of the commercial chub nets set out of 12 ports on the lake. The records show that the species is found along the shores of the lake, except in Green Bay, and in the strip of the Michigan shore between Frankfort and

Grand Haven. However, no satisfactory investigations have been made in the latter area, and it is not unlikely that *zenithicus* occurs there also. It may be stated, then, that *zenithicus* may be found in suitable conditions throughout Lake Michigan.

BATHYMETRIC DISTRIBUTION

The records in Table 28 are made chiefly from the 2½ to 2¾ inch chub nets, which were set during the fishing season in between 12 and 90 fathoms. All the lifts of these nets took at least a few short-jawed chubs, except three lifts in Green Bay (two on August 16, 1920, off Little Sturgeon and 8 miles south of Green Island in 11 and 16 fathoms, respectively, and the other on August 18, 1920, 4 miles west of Boyer Bluff in 18 to 24 fathoms), the lift made 5 miles northwest of Cathead Light, Mich., on June 22, 1920, in 40 to 60 fathoms, and the three lifts made off Charlevoix, Mich., on August 10, 11, and 21, 1923, in 35 to 60 fathoms. It is to be noted that the observations out of Milwaukee, Wis., and Michigan City, Ind., which show the fish in the shallowest water, were made on or near the spawning grounds of the species and during the breeding season.

No specimens have been seen among the small fish casually taken by the 4 to 4½ inch trout and whitefish nets; and in the catches of the 1½-inch bait nets set in 26 to 40 fathoms, examined at seven ports (see p. 354), only a few individuals were seen at Sheboygan, Wis., on September 28, 1920, and at Port Washington, Wis., on September 25, 1920.

The data at hand from the commercial chub nets warrant the conclusion that *zenithicus* in Lake Michigan during the year ranges between the depths of 12 and 90 fathoms. It probably does not come into shallower water, at least not during the summer, as none ever have been reported from the herring pound nets that are set out of several ports at depths of less than 10 fathoms. The juvenile individuals, it appears, are not common during the summer at 26 to 40 fathoms, as they were seen seldom in the 1½-inch bait nets.

RELATIVE ABUNDANCE

Only the seven lifts of the commercial small-meshed nets mentioned in the preceding paragraph took no *zenithicus*. Lifts of the chub nets in which only an occasional specimen occurred were made out of Washington Harbor, Wis., on August 19, 1920, 20 miles E. ½ N. of Rock Island, in 71 to 90 fathoms (record 1); off Sturgeon Bay, Wis., on August 23, 1920, 12 miles E. by S. of the ship-channel mouth, in 60 to 70 fathoms (record 2); on September 25, 1920, 18 miles E. ½ S. of Port Washington, Wis., in 65 to 48 fathoms (record 6); on March 2 and 4, 1921, 21 miles NNW. and 15 miles NW. by N. ½ N. of Michigan City, Ind., in 28 to 30 fathoms (records 20 and 21); on October 4, 1920, 9 miles north of Point Betsie, Mich., in 60 to 70 fathoms (record 24); on July 31, 1923, 5 miles northwest of Cathead Light in 40 to 60 fathoms (record 25); and on June 29, 1920, 5 miles N. by E. of Charlevoix, Mich., in 40 to 55 fathoms (record 26). All these lifts were made outside the spawning season of the species. Only four other lifts were examined previous to October 11, and in these the percentage of *zenithicus* ranged from 20 to 40. A lift of 310 pounds, made on August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms (record 3), had 20 per cent *zenithicus;* a lift of 250 pounds, made on September 23, 1920, 27 miles ESE. of Milwaukee, Wis., in 60 fathoms (record 10), had 35 per cent; a lift of unknown size, made on September 3, 1920, 22 miles NW. by N. ½ N. of Michigan City, Ind., in 30 to 40 fathoms, had 29 per cent (record 14); and a lift of 200 pounds, made on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms, had 40 per cent (record 27).

The remaining records were made out of Milwaukee, Wis., and Michigan City, Ind., during October and November, either near or on the spawning grounds of the species and in or approximately in the breeding season. On November 15, 1920, a lift of 700 pounds, made 20 miles ESE. of Milwaukee, Wis., in 28 to 35 fathoms, was composed almost exclusively of *zenithicus* (record 12). Off Michigan City, Ind., a lift of 535 pounds, made on October 11, 1920, 20 miles N. by W. ¾ W., in 30 to 40 fathoms, had 44 per cent *zenithicus;* a lift of 1,000 pounds, made on November 8, 1920, 18 miles NNW., in 30 to 38 fathoms, had 54 per cent; a lift of 700 pounds, made on November 19, 1920, 17 miles NNW., in 28 to 32 fathoms, had 15 per cent; a lift of undetermined size, made on November 19, 1920, 10 miles NNW., in 18 fathoms, had 93 per cent; and a lift made on November 19, 1920, 17½ miles NW. by N. ¾ N., in 32 fathoms, had 70 per cent (records 15 to 19).

The records show nothing clearly about the zone of maximum density for the species. Previous to the spawning season it has been found rare in three lifts at 60 fathoms and deeper (records 1, 2, and 24) and to comprise 35 and 40 per cent of two lifts at similar depths (records 10 and 27). In seven lifts at 40 to 65 fathoms it was rare or absent (records 6, 25, and 26, Northport and Charlevoix), and in two others at 30 to 50 fathoms made up 20 and 29 per cent of the lifts (records 3 and 14). (Green Bay records that show chiefly or exclusively *artedi* and records 20 and 21, made on March 2 and 4, 1921, in 28 to 30 fathoms on the spawning grounds of *hoyi*, are excepted.) In this connection, it should be pointed out that the records of few short-jawed chubs were made (excepting record 6) in the northern part of the lake, and it is possible that the species is not widely distributed in that section. In the breeding season lifts made between 18 and 40 fathoms in the southern part of the lake had 15 to 99 per cent of *zenithicus*, the density varying, it is supposed, with the proximity of the nets to the spawning grounds (records 12, 15 to 19.) As the fishermen have learned from experience to conduct their fishing operations for deep-water Leucichthys largely in 60 fathoms or less, it is probable that *zenithicus* finds its maximum density when not spawning outside the 60-fathom contour.

BREEDING HABITS

Fish have been taken on their spawning grounds off Milwaukee, Wis., and Michigan City, Ind. Fishermen report a chub spawning off Port Washington, Wis., and Grand Haven, Mich., which from their description appears to be of this species. Doubtless there are breeding grounds in the entire area between Port Washington and Grand Haven and possibly off other ports on the lake. A chub of some sort is said to spawn out of Algoma and Sheboygan, Wis., and Ludington, Mich., but it is not certain from the description of these fish that they are *zenithicus*. On all grounds spawning takes place on sand and clay at depths of 10 to 30 fathoms, according to the fishermen, the depth varying with the weather. When the lake is calm the fish come shallowest, and the fishermen move their nets in and out to follow them. The time of spawning is said also to be affected by climatic conditions and regularly varies about two weeks. The fish, as a rule, congregate between the middle of October and the first of November and remain on the grounds about a month. In 1920 spawning was later than usual. Out of Milwaukee, on November 15 in 28 to 35 fathoms (record 12), and out of Michigan City, Ind., on November 19 in 18 and 28 to 32 fathoms (records 18 and 19), virtually all the females were still hard. The males were pearled and exuded milt on pressure. It is noteworthy that the lift on November 19 in 18 fathoms had 93 per cent *zenithicus*, while the lift made in 28 to 32 fathoms 7 miles farther out on the same course had only 15 per cent. Furthermore, 87 per cent of the fish recorded under record 18 were males, and about the same percentage of the fish recorded under record 12 were females. These observations may indicate that the males may move first to the spawning grounds in shallow water, as is known to be the case in some other coregonids.

Leucichthys zenithicus of Lake Huron

Zenithicus in Lake Huron likewise seldom grows larger than 300 millimeters, and as nets of 2¾-inch mesh are the smallest used for chubs it is one of the smallest of the chubs commonly taken. In body shape and most other systematic characters the form of Lake Huron closely resembles the typical form. The body, however, is wider on the average. The chief systematic characters are compared in detail in Tables 6 to 11, and are summarized below:

Gill rakers on the first branchial arch:
- Superior, (32) 39–43 (46).[46]
- Huron, (34) 37–40 (44).[47]

Lateral-line scales:
- Superior, (69) 74–84 (90).
- Huron, (70) 72–82 (88).

L/H:
- Superior, (3.6) 3.8–4.1 (4.4).
- Huron, (3.9) 4.1–4.3 (4.5).

H/E:
- Superior, (3.9) 4.2–4.6 (5.1).
- Huron, (3.9) 4.2–4.6 (5.2).

H/M:
- Superior, (2.1) 2.3–2.5 (2.7).
- Huron, (2.3) 2.4–2.6 (2.7).

H/S:
- Superior, (3.1) 3.3–3.6 (4).
- Huron, (3.2) 3.4–3.7 (4).

Pv/P:
- Superior, (1.3) 1.6–2 (2.4).
- Huron, (1.6) 1.9–2.1 (2.3).

Av/V:
- Superior, (1) 1.3–1.6 (1.9).
- Huron, (1.2) 1.5–1.6 (1.8).

These data indicate that the Huron form has, on the average, slightly fewer gill rakers on the first branchial arch, a shorter head, and perhaps a somewhat shorter snout, maxillary, and paired fins than the typical form. Furthermore, while in Lake Superior *zenithicus* almost always has pigment on the maxillary, 19 out of 116 individuals examined have no pigment on the maxillary but a little on the jugal. The mandible also is less often equal to or longer than the upper jaw. The Michigan form differs from the typical form in virtually the same characters, and the variation is in the same direction.

The color of living specimens is not different from that of the typical form. Preserved specimens from which all color has vanished show less pigment on the pec-

[46] Figures for Lake Superior for gill rakers are given for 883 specimens, those for scales for 956. All others are given for 787 specimens, ranging in length from 200 to 332 millimeters.

[47] These and other figures for Lake Huron, except those for lateral-line scales, which are given for 166 specimens, are based on an examination of 91 specimens 200 to 318 millimeters in length.

torals and anal, and the ventrals are usually immaculate. The maxillary is also sometimes unpigmented.

Males taken on the breeding grounds off Cheboygan and Rogers, Mich., during the last half of September and the first half of October show pearl organs, which are distributed on the scales as in the Lake Michigan specimens and differ from them in their development only in being smaller. It is possible, however, that the individuals examined have not attained their full nuptial dress.

VARIATIONS

Virtually all specimens of the species obtained have come from the same locality so that there are no data on local variation. Small individuals, however, differ in certain respects from large ones. In Table 31, 10 specimens of less than 200 millimeters and 10 specimens larger are compared extensively, and in Tables 8 to 11 are given the variations of some of the principal characters for all collected specimens of either class. A résumé is given below:

Gill rakers on the first branchial arch:
- Large specimens, (34) 37–40 (44).
- Small specimens, (32) 35–38 (41).

L/H:
- Large specimens, (3.9) 4.1–4.3 (4.5).
- Small specimens, (3.7) 4–4.2 (4.4).

H/E:
- Large specimens, (3.9) 4.2–4.6 (5.2).
- Small specimens, (3.5) 3.7–4.1 (4.3).

H/M:
- Large specimens, (2.3) 2.4–2.6 (2.7).
- Small specimens, (2.2) 2.5–2.7 (2.9).

H/S:
- Large specimens, (3.2) 3.4–3.7 (4).
- Small specimens, (3.2) 3.5–3.8 (4.3).

Pv/P:
- Large specimens, (1.6) 1.9–2.1 (2.3).
- Small specimens, (1.7) 2–2.2 (2.6).

Av/V:
- Large specimens, (1.2) 1.5–1.6 (1.8).
- Small specimens, (1.1) 1.3–1.6 (1.7).

The data indicate that smaller individuals have fewer gill rakers, a somewhat longer head, a larger eye, a somewhat shorter snout, maxillary, and pectorals, but somewhat longer ventrals. The small fish, however, are chiefly from a locality different from that which yielded the larger ones and may belong to another race. The body depth is also less, of course.

The smallest collected specimens (139 millimeters) were sexually mature, but some immature individuals were found as long as 215 millimeters.

COMPARISONS

Zenithicus resembles most closely *alpenæ*. A discussion of the differences between these two species may be found on page 371. *Zenithicus* is compared with *johannæ* on page 357.

Zenithicus is distinguished from *nigripinnis* by its paler fins (which in *nigripinnis* are often very black), more fusiform and shallower body, more elongate and narrower head, more included mandible, and by the fewer gill rakers, which number (34) 37–40 (44),[48] with 2 per cent more than 41, as compared with (40) 46–50 (52), with 97 per cent more than 41 in *nigripinnis*. Females of the two species can be distinguished, likewise, by the degree of development of their ova, for *zenithicus* spawns prior to the middle of October and *nigripinnis* after November.

[48] Figures in this paragraph are given for specimens 200 millimeters or more in length.

Only small *zenithicus* can be confused with *kiyi* as examples of the latter of greater size than 249 millimeters have not been seen. Small *zenithicus* may be distinguished from *kiyi* by their included mandible, which is usually longer than the upper jaw and with a symphysial knob in *kiyi*; by their more fusiform body, their smaller, less triangular head, which in *zenithicus* of less than 200 millimeters in length is contained (3.7) 4–4.2 (4.4) times in the head length, with 85 per cent more than 3.9, as compared with (3.5) 3.6–3.9 (4.1) times, with 6 per cent more than 3.9 for *kiyi;* and their shorter paired fins, especially the pectorals. The value of Pv/P for small *zenithicus* is (1.7) 2–2.2 (2.6), with 97 per cent more than 1.7, and for *kiyi* (1.1) 1.4–1.7 (1.9), with 5 per cent more than 1.7. The eye, compared with the head length, is also smaller in *zenithicus*.

For a discussion of the distinctions between *zenithicus* and *hoyi*, see page 461.

From *artedi*, *zenithicus* may be separated by its fewer gill rakers, longer head, snout, and maxillary. These characters for the two species are compared below:[49]

Gill rakers:
- *zenithicus,* (34) 37–40 (44), with 49 per cent more than 39.
- *artedi,* (40) 45–50 (53).

L/H:
- *zenithicus,* (3.9) 4.1–4.3 (4.5), with 1 per cent more than 4.4.
- *artedi,* (4) 4.3–4.6 (5), with 57 per cent more than 4.4.

H/M:
- *zenithicus,* (2.3) 2.4–2.6 (2.7), with 3 per cent more than 2.6.
- *artedi,* (2.6) 2.8–3 (3.3), with 96 per cent more than 2.6.

H/S:
- *zenithicus,* (3.2) 3.4–3.7 (4), with 29 per cent more than 3.6.
- *artedi,* (3.5) 3.7–4 (4.3), with 82 per cent more than 3.6.

Zenithicus averages also fewer scales in the lateral line and longer paired fins, and the mandible is better developed and more decidedly included within the upper jaw. *Zenithicus* spawns in late September and *artedi* spawns in November, so that the state of development of the sex organs, especially in females, also serves as a character to separate the two species.

GEOGRAPHICAL DISTRIBUTION

All my data on the occurrence of this species in Lake Huron are assembled in Table 30 and are platted in Figure 5. It is noteworthy that there are fewer records for the short-jawed chub from the 2¾-inch nets than for the longjaw or chub, but that, on the other hand, there are many more records for it from the 4½-inch nets.

Lake Huron proper.—Though the short-jawed chub has not always been found in the lifts of the 2¾-inch chub nets, the locations from which it has been taken in general are not different from those that have yielded longjaws and chubs, and thus the same conclusions on distribution are warranted for this form as for these other fish. It may be stated, then, at least provisionally, that the species ranges throughout Lake Huron in water of 14 to 100 fathoms.

North Channel.—No specimens have been seen from the North Channel. Chubs of some sort, however, are known to occur in the region (see p. 373). The chart shows

[49] Figures for *zenithicus* are based on fish 200 millimeters or more in length; for *artedi* on specimens 225 millimeters or more in length, except in the case of gill rakers, which are given for all the specimens collected. The figures of the *manitoulinus* race are not included.

a maximum depth of 28 fathoms for the channel, and as this species has been taken in water as shallow it is possible that it may be present here.

Georgian Bay.—From Georgian Bay a gilled specimen was found among the chubs taken on November 6, 1917, off Wiarton, Ontario, in 45 to 60 fathoms; and on July 30, 1919, out of Lions Head, Ontario, in 60 fathoms two small individuals were found ensnarled in the netting. Though no specimens have been seen among the samples taken from five other lifts, not including those made on the spawning grounds of the longjaw, it is possible, nevertheless, that *zenithicus* occurs throughout the bay and that the nets are not set in the proper locations or possibly are of too large mesh to capture it.

From these data it appears that *zenithicus* probably is found throughout Lake Huron proper and possibly throughout Georgian Bay at depths of 14 to 100 fathoms, but that it has not yet been recorded from the North Channel.

BATHYMETRIC DISTRIBUTION

The table shows *zenithicus* to have been taken in the 2¾ and 3 inch chub nets at depths of 35 to 100 fathoms. In less than 35 fathoms its occurrence has been established only by means of the 4½-inch trout nets, the 2¾-inch chub nets that were set under my direction with the trout gangs, and the 1½-inch bait nets. The 4½-inch nets brought in specimens in 1917 on September 7, 10 (two boats), 12, 14, and 22, and on July 10, 1923 (records 9, 11, 12, 13, 14, 22, and 35). The box of 2¾-inch nets set with the 4½-inch gangs off Alpena, Mich., on September 17, 1917, 13½ miles SE. by S. of the can buoy in 15 fathoms (record 16); on September 19, 1917, 23 miles SE. by E. ½ E. of the can buoy in 30 fathoms (record 19); and on September 26, 1917, 13 miles SE. by S. of the city in 17 fathoms (record 23) brought in *zenithicus*. However, none were caught in the box of nets lifted on November 2, 1917, 7 miles ENE. of the can buoy in 15 fathoms. The 1½-inch bait nets in about 30 fathoms took specimens at Cheboygan, Mich., on October 15, 1919 (record 4), at Alpena, Mich., on September 8, 1917, and September 16, 1919 (records 10 and 29), and at Harbor Beach, Mich., on March 15, 1919 (record 37). From these data it appears that at least during late summer and early fall *zenithicus* ranges at depths of 14 to 100 fathoms in Lake Huron.

RELATIVE ABUNDANCE

The short-jawed chub has been seen in large quantities in the chub nets only on its spawning grounds in 35 to 50 fathoms northward from Forty Mile Point from the middle of September to the middle of October (records 2, 3, and 6). On or near the same grounds it occurs in some numbers outside the spawning season (records 1 and 5), but how abundant it is then is not known.

Out of Alpena, Mich., *zenithicus* always has been rare or absent in the 11 lifts examined, made in September and October, 1917, in the center of the lake northeast or east of the city in 60 to 80 fathoms (records 7, 8, 15, 17, 24, and 25), and in the five examined lifts made nearer shore in 60 to 100 fathoms on August 7, 1920, 19 miles NE. ½ N. of Thunder Bay Island, June 28, 1923, 19 miles northeast of Thunder Bay Island, June 30, 1923, 17 miles NE. by N. ¾ N. of Thunder Bay Island, July

2, 1923, 20 miles E. by N. of the can buoy, and July 5, 1923, 18 miles NE. ¾ E. of Thunder Bay Island (records 30 to 33). On October 27, 1917, 35 miles NE. by N. ¾ N. of Harbor Beach, Mich., in 50 fathoms (record 36), it was also rare. In three lifts made in 60 to 64 fathoms on August 30, 1919, 18 miles N. by E. ½ E. of Thunder Bay Island, September 3, 1919, 28 miles E. ¼ S. of the can buoy, and July 7, 1923, 13 miles NE. ½ N. of Thunder Bay Island, *zenithicus* comprised 14 to 17 per cent of the catches. In Georgian Bay it has been found absent or rare among the fish seen in seven lifts of the 3-inch nets, the number not including the sets on the spawning grounds of the longjaw (records 38 and 39.)

In less than 35 fathoms the 4½-inch trout nets, the 1½-inch bait nets, and the 2¾-inch chub nets set under my direction with the 4½-inch gangs have taken the species. While it never was abundant or even common in the 4½-inch nets off Alpena, Mich., in September, 1917, and in July, 1923, there are more records for it in these nets than for any other species of chubs. (Records 9, 11, 12, 13, 14, 22, and 35.) The 2¾-inch nets set with the trout nets brought in only one fish on September 17, 1917, from 15 fathoms (record 16), and September 26, 1917, from 17 fathoms (record 23); six on September 19, 1917, from 30 fathoms (record 19); and none on November 2, 1917, from 15 fathoms. Thus the fish were not shown more abundant by these nets than by the 4½-inch nets. In the 1½-inch bait nets at 30 fathoms occasional specimens were taken off Cheboygan, Mich., on October 15, 1919 (record 4), and off Alpena, Mich., on September 8, 1917, and September 16, 1919 (records 10 and 29). Off Harbor Beach, Mich., on March 15, 1919, 12 per cent of the small fish examined from a catch of the bait nets were *zenithicus* (record 37). A single specimen was taken in the special 1½-inch net set off Presque Isle Light in 60 fathoms on September 13, 1919 (record 28). In view of the fact that the fish spawn in 35 to 50 fathoms, it would be expected that immature fish would be more common in these nets than the records show. However, the evidence from this source is scant and is by no means conclusive.

All the records thus indicate that during the summer and early fall *zenithicus* is not common in nets of any class except in the 2¾-inch nets set on its spawning grounds in the north end of the lake. It should be noted, however, that most of the records indicating relative abundance have been made during, shortly before, or after the spawning period, which falls between the middle of September and the middle of October. If *zenithicus*, like most other fish, seeks spawning grounds in water shallower than that in which it feeds, then the maximum density of its population may be looked for at depths greater than 35 to 50 fathoms.

BREEDING HABITS

Only in 35 to 50 fathoms northward from Forty Mile Point were *zenithicus* found abundantly. On September 28 and 29 and October 14, 1917, lifts from these grounds examined by me contained this species almost exclusively. At this period the fish were spawning. Males were taken with pearls, and females were full of ripe eggs, except on the latest date, when many were nearly spent or spent. The fishermen say that the fish begin to move onto the clay bottom between Spectacle Reef and Forty Mile Point in 30 to 50 fathoms toward the middle of September. At first they run into 30 fathoms but move out later to 40 to 50 fathoms to spawn. Records of the fishing tugs show that the movement began about September 13 in 1915. From this date until October 8 from 2,100 to 4,400 pounds of fish were taken daily from 5 miles of nets lifted after having been set two and three nights. Previous to this run 1,000 to 1,500 pounds in nets five nights out were considered good lifts. After October 8 the weight of the lifts dropped rapidly. On the 8th, 2,450 pounds were taken; on the 9th, 1,555 pounds; on the 19th, 595 pounds; on the 20th, 520 pounds. What becomes of the fish after they leave the spawning grounds is unknown. Certainly they do not return in any numbers before June, because few chubs of any kind are caught here from the opening of navigation until June.

These are the only spawning grounds known. The occurrence of small individuals in the 1½-inch nets at Harbor Beach, Mich., in March, 1919, indicates that the species also spawns somewhere in the southern part of the lake. An occasional female among these individuals shows large but not ripe eggs, and an occasional male has well-developed testes and a trace of nuptial pearls. Most of the specimens, however, exhibit sex organs apparently normal for the species. It is possible that specimens spawning for the first time mature irregularly, an assumption that is strengthened by the finding of small specimens of this species in Lake Superior with ripe eggs in June (see p. 384).

FOOD

Only seven stomachs were examined from specimens collected in September, 1917, off Cheboygan, Mich. Mysis and Pontoporeia comprised 95 per cent of the food. Pisidium, pebbles, wood fragments, larval chironomids, and unidentifiable bottom material constituted the rest.

LEUCICHTHYS REIGHARDI Koelz

REIGHARD'S CHUB (FIGS. 17 AND 18)

Leucichthys reighardi Koelz, 1924, pp. 5–8, Lake Michigan; Dymond, 1926, pp. 65–66, Pl. VII, Lake Nipigon.

Leucichthys reighardi has been described from southern Lake Michigan. Races of the species also occur, so far as is known, in the northern part of that lake and in Lakes Ontario, Superior, and Nipigon. In all four lakes it is represented by relatively small decidedly terete fishes with included mandible, relatively few gill rakers on the branchial arches, few scales in the lateral line, short paired fins (except in Nipigon), and short snout. Each race, however, has its own peculiarities, but it seems desirable to name only the two extremes of development. The race in Lake Ontario is nearly like the typical one, differing chiefly in the relatively somewhat smaller size of head and eye. In both lakes the forms appear to prefer the shallower waters and to spawn in May or June. The race of northern Lake Michigan tends to have a longer snout and maxillary. The Superior and Nipigon forms show more differences, and the Nipigon form, which shows the extreme development, has been named *dymondi*. These two forms differ from the typical one chiefly in the relatively longer head, maxillary, and pectoral fins, fewer scales in the lateral line, greater number of dorsal and anal rays, in the reduction of the pigmentation of the head, and in the less vertical position of the premaxillaries. The Nipigon race also differs slightly in a few other proportions. Both races likewise prefer shallow water but spawn probably in November.

Type

The type is a female specimen (catalogue No. 87351, U. S. National Museum), 210 millimeters in length, collected in Lake Michigan on April 1, 1921, off Michigan City, Ind., in 30 fathoms of water. Counts of certain multiple parts and proportional lengths for this specimen are shown in Table 33. Certain numerical expressions of type characters are repeated in the description.

Leucichthys reighardi reighardi of Lake Michigan

Reighardi is one of the smaller chubs, ranking in respect to size with *kiyi* and *hoyi*. The largest specimen collected measures only 278 millimeters in length, and most of the fish seen have been smaller than 240 millimeters. The body is little compressed, much less than in any other member of the genus excepting *artedi*, and, as seen from the side, tapers smoothly and regularly to the head and tail from the deepest portion of the body, which is through a point at the front of the dorsal. In most of the specimens at hand the depth at this point is 22 to 26 per cent of the total length. Occasionally an individual is taken in which this figure rises to 29 per cent, and in such specimens the predorsal profile is steeper over its anterior half.

The head is of medium size, moderate depth, bluntly triangular in side view, its dorsal contour (not including the premaxillaries) straight or faintly curved. It is contained 4.4 [(3.9) 4.1–4.5 (4.8)][50] times in the total length.

The snout is relatively short and is contained 3.8 [(3.2) 3.4–4 (4.4)] times into the head length. In side view it is usually truncate on account of the nearly vertical position of the premaxillaries. The premaxillaries are always heavily pigmented and usually make an angle of 60° to 70° with the horizontal axis of the head, so that their tip is usually at or below the lower edge of the pupil. The maxillary is always more or less pigmented, the cutting edge usually rimmed with black halfway to its distal end. It is contained 2.7 [(2.3) 2.5–2.8 (3)] times in the head length. The lower jaw is always shorter than the upper and is usually heavily tipped with black. The maxillary plus snout divided by eye equals 2.3 [(2.2) 2.4–2.6 (2.8)][51] in south; in north [(2.2) 2.5–2.7 (3.1)].[52] The eye is relatively large and is contained 3.8 [(3.6) 3.9–4.2 (4.6)] times in the head length. It is situated in the second quarter of the head's length, encroaching more or less on the third. The gill rakers on the first branchial arch number 14 + 23 [(11) 12–14 (16) + (19) 21–24 (27) = (30) 34–38 (43)].[53] The lateral line is nearly straight; its scales number 74 [(66) 72–81 (96)].[53] Rows of scales around the body in front of the dorsal and ventrals number 41 [(38) 40–43 (46)];[54] in front of the adipose and anus 31 [(30) 32–35 (39)];[54] around the caudal peduncle at its commencement 22 [22–24 (26)].[54]

The dorsal fin is relatively low and has 9 [(8) 9–10 (11)][55] rays. The anal rays number 10 [(9) 10–11 (12)];[56] the ventral rays 11 [10–12];[56] the pectoral rays 16

[50] The ratios given in brackets (except where otherwise noted) are based on an examination of 314 specimens, among them 145 paratypes, ranging in length from 200 to 278 millimeters.
[51] One hundred and thirty-three specimens 200 millimeters or more in length.
[52] One hundred and fifty-eight specimens 200 millimeters or more in length.
[53] Four hundred and six specimens of all sizes.
[54] Thirty-one specimens.
[55] One hundred and seventy-nine specimens.
[56] Forty-four specimens.

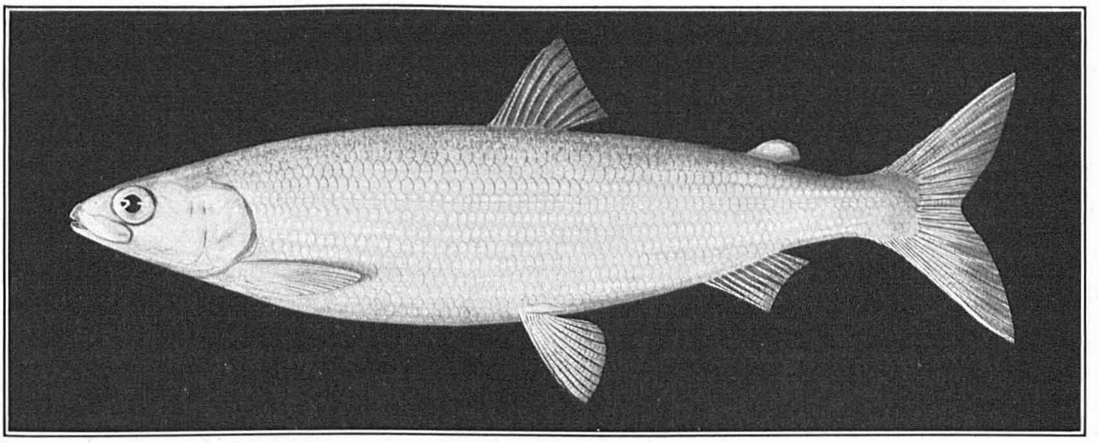

FIG. 17.—*Leucichthys reighardi* Koelz, Reighard's chub. Female (type), 210 millimeters long, taken in Lake Michigan off Michigan City, Ind., in 30 fathoms on April 1, 1921

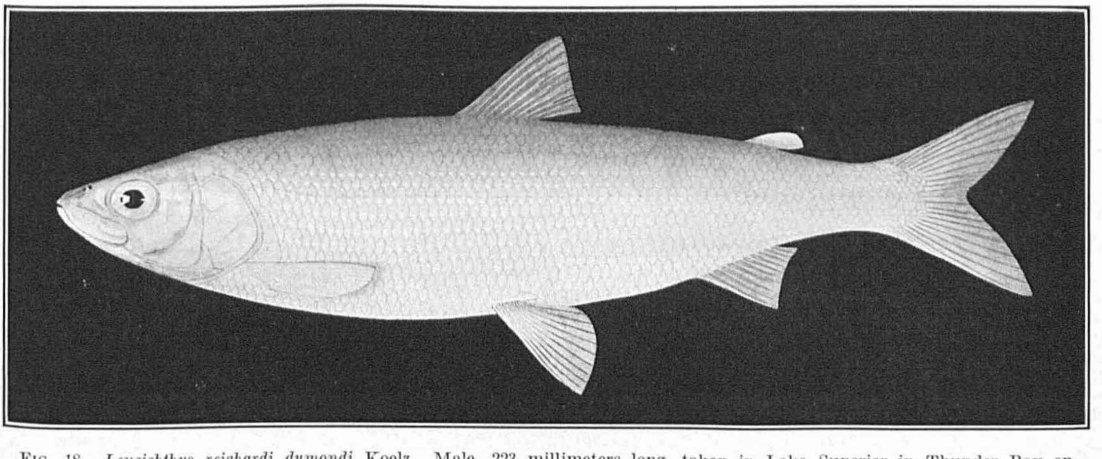

FIG. 18.—*Leucichthys reighardi dymondi* Koelz. Male, 223 millimeters long, taken in Lake Superior in Thunder Bay on November 25, 1922

[15–17].[56] The paired fins are short. The pectoral length divided into the distance from its insertion to that of the ventral equals 2.1 [(1.7) 2.0–2.5 (2.8)]. The length of the ventral is contained 1.4 [(1.2) 1.4–1.7 (1.9)] times in the distance from its origin to the anal.

The color of living specimens differs in only minor details from that of other chubs. After preservation, as in all species, pigmentation becomes more conspicuous. The entire dorsal surface is pigmented more or less heavily and evenly. The pigment becomes denser in the prenarial area and usually shows very dark on the premaxillaries and on the tip of the mandible. It continues often in a black rim along the cutting edge of the maxillaries. The preorbital area, the postoculars, and at least half of the maxillary are pigmented abundantly. On the cheeks and on the sides of the body pigment diminishes rather gradually as the ventral surface is approached. It is absent on the belly. Often the dorsal border of the pectoral and sometimes the inner surface of its longest rays are lined with pigment. The cranial margin and a wide distal band of the dorsal and the lateral borders, the distal third of the longest and half of the shortest rays of the caudal are smoky to black in hue. A few dots of pigment are often evident on the membrane of the anal. The ventrals are usually immaculate but may show more or less pigment, especially in the north.

Males and at least some females acquire pearl organs during the breeding season. There are no specimens available from which to prepare a description of the pearls at the height of their development, but one male taken on August 18, 1920, off Washington Harbor, Wis., exhibits nuptial adornment about like that described for *johannæ* on page 350.

VARIATIONS

Racial variations.—Specimens taken in the northern waters are, on the average, different from those of the southern half of the lake. Northern fish tend to have a longer snout and maxillary and, as has been stated previously, average more pigmented on the fins. Some specimens have these parts developed to so great a degree that they resemble closely specimens of *zenithicus*. The values of these two characters in northern and southern specimens 200 millimeters or more in length are given below. The specimens have been divided according as their origin is north or south of a line drawn south of Washington Island, Wis., and Frankfort, Mich.

H/S:	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4
Northern fish	1	3	28	27	41	30	17	13	4	2	0	1	--
Southern fish	--	--	--	4	18	35	22	22	22	8	1	0	1

H/M:	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3
Northern fish	1	8	35	46	44	24	4	2
Southern fish	--	--	3	38	50	37	7	--

MS/E:	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1
Northern fish	2	5	12	20	46	39	17	12	4	1
Southern fish	2	15	41	36	32	5	2	--	--	--

Size variations.—In Table 33, 20 specimens are compared extensively, half of them less than 200 millimeters in length and half of them more than 200 millimeters. In Tables 8 to 11 values for several characters are given for all the specimens of the

[56] Forty-four specimens.

collection, similarly separated according to size. From these tables it may be seen that the only differences recognizable in the two classes are differences of proportion. It appears that the head and eye are proportionally but slightly larger in the smaller specimens, while the snout is shorter and the body depth is less, of course.

The smallest specimens that were collected at Sheboygan, Wis., on September 28, 1920 (144 to 150 millimeters), showed developing sex glands and probably would spawn at the succeeding spawning season. Occasional specimens under 170 millimeters have been found to be immature, however.

COMPARISONS[57]

Reighardi is most like *zenithicus* in appearance. A discussion of the differences between the two forms is given on page 389. *Reighardi* is compared with *johannæ* and *alpenæ* on pages 351 and 365.

Reighardi differs from *nigripinnis* in its more elliptical body shape as seen from the side, its shorter and more included mandible, paler body and fins, wider body, fewer gill rakers on the first branchial arch and lateral-line scales, and much shorter paired fins. Certain of these characters are compared below:

Gill rakers on the first branchial arch:
- *reighardi*, (30) 34–38 (43), with 3 per cent more than 40.
- *nigripinnis*, (41) 46–50 (52).

Lateral-line scales:
- *reighardi*, (66) 72–81 (96), with 26 per cent more than 79.
- *nigripinnis*, (74) 80–87 (89), with 84 per cent more than 79.

Pv/P:
- *reighardi*, (1.7) 2–2.5 (2.8), with 97 per cent more than 1.8.
- *nigripinnis*, (1.5) 1.6–1.8 (2.2), with 18 per cent more than 1.8.

Av/V:
- *reighardi*, (1.2) 1.4–1.7 (1.9), with 42 per cent more than 1.5.
- *nigripinnis*, 1.2–1.5 (1.6), with 8 per cent more than 1.5.

As *reighardi* spawns in the spring and *nigripinnis* in the winter, the state of ripeness of the sex products also may serve as a distinguishing character.

Reighardi is distinguishable from *kiyi* by the body shape, which is subterete in the former and subfusiform in the latter; by the length of the mandible, which in *reighardi* is always included in the upper jaw while in *kiyi* it is equal to or usually longer than the upper jaw; and by the smaller, less sharply triangular head and shorter paired fins. Comparative figures for certain of these characters follow:

L/H:
- *reighardi*, (3.9) 4.1–4.5 (4.8), with 85 per cent more than 4.1.
- *kiyi*, (3.7) 3.8–4.1 (4.3), with 8 per cent more than 4.1.

Pv/P:
- *reighardi*, (1.7) 2–2.5 (2.8), with 96 per cent more than 1.9.
- *kiyi*, (1.1) 1.4–1.7 (2.1), with 4 per cent more than 1.9.

Av/V:
- *reighardi*, (1.2) 1.4–1.7 (1.9), with 91 per cent more than 1.3.
- *kiyi*, (0.96) 1–1.3 (1.4), with 2 per cent more than 1.3.

As *reighardi* spawns in spring and *kiyi* in fall, females usually are distinguishable by the condition of the ovaries.

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[57] Figures given in this section for proportions are based on specimens 200 millimeters or more in length. Counts are given for specimens of all sizes.

Reighardi differs from *hoyi* in having the lower jaw shorter while in *hoyi* it is usually equal to or longer than the upper; in having fewer gill rakers on the first branchial arch and shorter paired fins, as will appear from the comparisons:

Gill rakers on the first branchial arch:
reighardi, (30) 34–38 (43), with 3 per cent more than 40.
hoyi, (37) 41–44 (48), with 86 per cent more than 40.

Pv/P:
reighardi, (1.7) 2–2.5 (2.8), with 83 per cent more than 2.
hoyi, (1.6) 1.8–2 (2.3), with 21 per cent more than 2.

Av/V:
reighardi, (1.2) 1.4–1.7 (1.9), with 91 per cent more than 1.3.
hoyi, (1.1) 1.3–1.5 (1.7), with 60 per cent more than 1.3.

In addition, *reighardi* has, on the average, a proportionately shorter head and maxillary and more lateral-line scales. *Reighardi* spawns in May or June and *hoyi* in March, so that at times the state of development of the sex organs also may be of aid in separating the species.

Reighardi is distinguishable from *artedi* by the fewer gill rakers on the first branchial arch, which seldom are more than 41 in the former and not less than 41 in the latter, and a less triangular head, as seen from the side. The snout of *reighardi* is sharply truncated in front by the nearly vertical position of the premaxillaries. *Reighardi* has, on the average, shorter pectorals, a somewhat longer maxillary, the mandible is more conspicuously tipped with black, and the back is usually paler in color. *Reighardi* spawns in the spring and *artedi* in the fall, so that the state of development of the sex organs may serve as a differentiating character at times.

GEOGRAPHICAL DISTRIBUTION

Table 32 shows my data on the occurrence of *reighardi* in Lake Michigan. They are shown platted on a chart of the lake in Figure 4. There are 43 records, all but 14 of them made from the commercial chub nets. While the species seldom has been found in numbers, a few individuals have been present in most lifts examined, even in that one made on the Sheboygan reef (record 8); and it may be stated safely that the species is distributed along the shores of the lake and probably on some of the reefs.

BATHYMETRIC DISTRIBUTION

Data on the depth range of *reighardi* have been collected principally from an examination of the lifts of the 2⅜ to 2¾ inch chub nets set at depths of 12 to 90 fathoms. All the chub lifts examined have yielded at least a few examples of this species, except those made off Milwaukee, Wis., on September 24, 1920, 9 miles NNE. in 22 to 25 fathoms and on November 15, 1920, 20 miles ESE. in 28 to 35 fathoms, and that made on November 19, 1920, 10 miles northwest of Michigan City, Ind., in 18 fathoms. The two last were made on the spawning grounds of *zenithicus*, and it is not surprising that no *reighardi* occurred there, while the former was made on grounds unfrequented by chubs of any species. In Green Bay, where 2⅜ to 2¾ inch nets are set for herring, *reighardi* was seen only in those nets set in the deepest water. A few individuals were taken in a gang of nets on August 18, 1920, off Boyer Bluff, Washington Island, Wis., in 18 to 24 fathoms (record 1).

In the catches of the 1½-inch bait nets examined from seven ports (see p. 354) small *reighardi* were found always. Lifts were examined from depths of 26 to 40 fathoms from off Sheboygan, Port Washington, and Racine in Wisconsin, Michigan City, Ind., and Manistee, Northport, and Traverse City in Michigan (records 9, 12, 16, 23, 28, 33, and 35). They were present, also, in a lift of special nets made from 8 to 12 fathoms in Platte Bay, Mich., on July 21, 1923, and in a lift from 6 to 16 fathoms off Traverse City, Mich., on July 25, 1923 (records 31 and 36).

In the 4 to 4½ inch trout nets examples of the species were brought in at Washington Harbor, Wis., on August 18, 1920, from 20 to 24 fathoms; at Ludington, Mich., on August 30, 1920, from 14 to 26 fathoms; and at Manistee, Mich., on August 28, 1920, from 28 to 32 fathoms (records 3, 4, 27, and 29). At Sheboygan, Wis., on September 28, 1920, 3½-inch nets lifted from 35 to 40 fathoms had specimens also (record 8).

From these observations it appears that *reighardi*, when not spawning, ranges between 6 and 90 fathoms. These data do not give the outside limits of the range, however.

RELATIVE ABUNDANCE

I have stated elsewhere, in discussing the relative abundance of other species of chubs, that conditions were decidedly unfavorable during the collecting season of 1920 for the accumulating of data necessary for conclusive statements on this head. In those lifts of the chub nets mentioned in the preceding section no *reighardi* were seen. In most of the other chub lifts examined there were found only a few fish of this species. Examples of the species were rare or found only occasionally among the catches of other Leucichthys in lifts made on August 18, 1920, 4 miles west of Boyer Bluff in 18 to 24 fathoms (record 1); August 19, 1920, 20 miles E. ½ N. of Rock Island in 71 to 90 fathoms (record 5); August 23, 1920, 12 miles E. by S. of the Sturgeon Bay ship-channel mouth in 60 to 70 fathoms (record 6); August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms (record 7); September 25, 1920, 18 miles E. ½ S. of Port Washington, Wis., in 65 to 48 fathoms (record 11); September 23, 1920, 27 miles ESE. of Milwaukee, Wis., in 60 fathoms (record 15); September 3, 1920, 22 miles NW. by N. ½ N. of Michigan City, Ind., in 30 to 40 fathoms, October 11, 1920, 20 miles N. by W. ¾ W. in 30 to 40 fathoms, November 8, 1920, 18 miles NNW. in 30 to 38 fathoms, November 19, 1920, 17 miles NNW. and 17½ miles NW. by N. ¾ N. in 28 to 32 fathoms, and on March 4, 1921, 15 miles NW. by N. ½ N. in 28 fathoms (records 17, 18, 19, 20, 21, and 24); on October 4, 1920, 9 miles north of Point Betsie in 60 to 70 fathoms (record 30); August 10, 1923, 8 miles off Big Rock Point; June 29, 1920, 5 miles N. by E. of Charlevoix, Mich., in 40 to 55 fathoms; from an unknown locality on August 21, 1923 (records 37, 39, 41); on June 22, 1920, 5 miles northwest of Cathead Light, Mich., in 40 to 60 fathoms (record 32); and on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms (record 43). In one lift examined at Michigan City on March 2, 1921, made 21 miles NNW. in 30 fathoms; in a lift made July 31, 1923, 5 miles northwest of Cathead Light in 40 to 60 fathoms; and in a lift made August 11, 1923, 3 miles NW. ½ W. of Charlevoix in 35 to 60 fathoms (records 22, 34, and 40), from 16 to 41 per cent of the catch was made up of *reighardi*. In a letter of April 25, 1921, referring to 47 specimens of *reighardi* sent me for examination, taken on April 1, 1921, off Michigan City in 30 fathoms (record 25), Robert Ludwig writes that about 30 per cent of the entire lift on that date were fish belonging to the species sent. A sample of chubs caught on May 26, 1921, 8 miles northeast of Port Washington, Wis., in 20 to 35 fathoms, by D. H. Smith & Sons (record 13), was found on examination to be chiefly *reighardi*.

In the 1½-inch bait nets, lifts made from 28 to 40 fathoms on September 28, 1920, 5 miles SE. by E. of Sheboygan, Wis.; on June 23, 1920, off Northport Point; and on July 18, 1923, in West Traverse Bay, from 20 to 30 per cent of the small fish gilled were *reighardi* (records 9, 33, and 35). They were rare in similar lifts made off Port Washington, Wis., on September 25, 1920, and on March 2, 1921, off Michigan City, Ind., in 26 to 30 fathoms (records 12 and 23). The special 1½-inch nets set in Platte Bay on the Michigan shore, in West Traverse Bay, and off the South Manitou Island in July, 1923, in 4 to 25 fathoms (see Table 68) took few or no specimens of this species (records 31 and 36).

It appears from these data that for unknown reasons few *reighardi* were taken in the chub nets during the summer and fall of 1920. On several occasions in later years it has been found common in the chub hauls. The records of maximum abundance are from lifts made between 30 and 60 fathoms. Inasmuch as juvenile specimens have been taken commonly in the bait nets, and occasional specimens have been found ensnarled in the trout nets, both of which are set regularly at less than 40 fathoms, it seems probable that the species prefers the shallower waters and that, therefore, the above-mentioned limits indicate more or less closely the zone of maximum density for the species.

BREEDING HABITS

The time and places of spawning are not definitely known. There are, however, data bearing on both, which are worthy of consideration. Of the fish examined at Michigan City, Ind., on March 2, 1921, at Grand Haven, Mich., on March 20, 1919, and Milwaukee, Wis., on March 24, 1919, most of the males showed pearl organs and emitted milt on pressure and the females exhibited ova nearly fully developed. The specimens received from Michigan City on April 1, 1921, had sex organs in about the same stage of development, except that 2 of the 26 females were spent. Of 39 females received from Charlevoix, Mich., taken on May 3, 1924, 7 were spent, 1 was spawning, and most of the rest had eggs nearly ripe. Males received from Port Washington, Wis., on May 26, 1921, had no pearls (these structures are very frail and are removed easily by friction), but milt was exuded, and the females had ova nearly mature. It should be pointed out, in this connection, that if the nets were not actually set on the spawning grounds only spent or unripe fish would be taken, and the data just reviewed do not indicate more than that the specimens were taken at a period not remote from the spawning season. At Northport, Mich., on June 22, 1920, and at Charlevoix on June 29, 1920, females were collected that were spent or still had some eggs in the body cavity. Female specimens taken thereafter exhibited ovaries in which the eggs of a new season were appearing, but an occasional pearled male or a female with retained ripe eggs was taken at Washington Harbor, Wis., on August 18, 1920; at Sturgeon Bay, Wis., on August 23, 1920; at Algoma, Wis., on August 24, 1920; at Michigan City, Ind., on September 3, 1920; and at Port Washington, Wis., on September 25, 1920. Whether these abnormal individuals matured their sex products with the rest and were not relieved of them normally or whether the germ cells ripened at abnormal periods is uncertain. The examination of the sexual condition of collected specimens thus indicates that spawning must occur sometime between the last of March or first of April and the last of June.

There is circumstantial evidence offered in the testimony of D. H. Smith & Sons, of Port Washington, Wis., who on May 26, 1921, sent the samples of chubs of which *reighardi* comprised the majority, which indicates that spawning grounds for the species are found near Port Washington. Mr. Smith states that a heavy run of chubs began during the last week of April and continued until the middle of June on grounds 3 to 4 miles E. to NE. by N. of Port Washington. The nets were run along the beach at depths of 14 to 35 fathoms on bottom of "dirty sand with some showing of mud." As heavy runs of chubs examined from other ports have been found to consist of spawning fish of some species, it is likely that this run consisted of spawning *reighardi*. *Hoyi*, the only other spring spawner, spawns in March. The finding of a majority of *reighardi* approaching the spawning condition in the sample of fish taken on these grounds on May 26, 1921, and the coincidence of the dates of this run with the period during which the species must spawn (according to an examination of the sexual condition of specimens collected at various times and places) confirm the assumption. Mr. Smith states that to his knowledge the fishermen of no neighboring ports found the run, but he is of the opinion that a trial on suitable grounds probably would have been fruitful.

Evidence of two kinds thus indicates that *reighardi* spawns probably in May and early June at depths of 14 to 35 fathoms on a muddy sand bottom.

Leucichthys reighardi dymondi (new subspecies) of Lake Nipigon

The Nipigon race (fig. 18) differs more markedly from the typical form than any of the other races but is much like the Superior race. The characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (31) 35–38 (43).[58]
- Nipigon, (32) 33–36 (38).[59]

Lateral-line scales:
- Michigan, (67) 72–81 (96).[58]
- Nipigon, (64) 66–73 (77).[59]

L/H:
- Michigan, (4) 4.2–4.5 (4.8).
- Nipigon, (3.5) 3.7–3.9 (4.1).

H/E:
- Michigan, (3.6) 3.9–4.2 (4.4).
- Nipigon, (3.6) 4–4.4 (4.8).

H/M:
- Michigan, (2.5) 2.6–2.8 (3).
- Nipigon, (2.2) 2.3–2.5 (2.7).

H/S:
- Michigan, (3.5) 3.7–4 (4.4).
- Nipigon, (3.3) 3.5–3.6 (4).

Pv/P:
- Michigan, (1.8) 2.1–2.4 (2.8).
- Nipigon, (1.4) 1.6–1.8 (2).

Av/V:
- Michigan, (1.2) 1.4–1.7 (1.8).
- Nipigon, (1.1) 1.3–1.6 (1.7).

L/D:
- Michigan, (3.5) 3.8–4.3 (5).[60]
- Nipigon, (3.5) 3.6–4.1 (4.4).

Scale rows:
1. Michigan, (38) 40–43 (46).[61]
   Nipigon, (37) 39–41 (43).[62]
2. Michigan, (30) 32–35 (39).[61]
   Nipigon, (30) 31–33 (34).[62]
3. Michigan, 22–24 (26).[61]
   Nipigon, 22–24.[62]

Dorsal rays:
- Michigan, (8) 9–10 (11).[63]
- Nipigon, (9) 10–11.[62]

[58] These figures for Lake Michigan are based on an examination of 192 specimens of all sizes from the southern sector of the lake. Most of them are paratypes. All unmarked figures are given for 146 specimens ranging in length between 200 and 243 millimeters.

[59] These figures for Lake Nipigon are based on an examination of 98 individuals ranging in length between 145 and 304 millimeters. Unmarked figures are given for 83 specimens 200 millimeters or more in length.

[60] One hundred and eleven specimens over 200 millimeters.

[61] Thirty-one specimens.

[62] Eighteen specimens.

[63] One hundred and seventy-nine specimens.

It appears, thus, that the Nipigon race has fewer scales in the lateral line and fewer scale rows and somewhat fewer rakers, more dorsal rays, a proportionally longer head, snout, maxillary, and paired fins, and a proportionally smaller eye, and a deeper body. The premaxillaries also are less vertical in position. The two forms are alike as concerns body shape, as seen from the side, in having an included lower jaw (though in *dymondi* the mandible is proportionally longer and not so invariably included), and in the small size attained. (Extreme examples obtained after extensive collecting in virgin waters measure only 304 millimeters.)

This form appears sufficiently distinct to merit a name and is here designated as *dymondi*. The type is specimen No. 57467, described in detail in Table 35. It is catalogued as No. 88353, U. S. National Museum.

Living specimens are paler in color than those from Lake Michigan, and preserved specimens show reduced pigment. The prenarial area is not conspicuously darker, and the mandible tip is never black. The maxillary may be immaculate occasionally and frequently is pigmented over only one-fourth its surface; the paired fins and the anal are frequently immaculate. Usually, however, there is at least a rim of pigment on the dorsal edge of the pectorals, and sometimes there is pigment on them all.

One male specimen collected on July 26, 1922, showed traces of pearl organs, and it is likely that at least all males develop them in the breeding season.

VARIATIONS

Racial variations.—There are not sufficient specimens available for examination to determine whether there are intraspecific variations.

Size variations.—In Table 35 are compared extensively 10 specimens more than 200 millimeters in length and 9 specimens 200 millimeters in length or smaller. A few small fish are compared with larger ones for several characters only in Tables 8 to 11. Small fish seem to have a proportionally larger eye, shorter snout, and less body depth. The base of the dorsal and of the anal and the gill rakers also appear to be somewhat longer, and the dorsal and anal rays are less in the small fish, though the lower number of rays no doubt is due to the exclusion from the individual counts of one of the first rays, which are apt to be shorter in small specimens.

The few specimens examined indicate that individuals that have attained a length of 170 millimeters by the middle of the summer are sexually mature.

COMPARISONS [64]

The low gill-raker count will distinguish *reighardi* from any of the Nipigon Leucichthys except *zenithicus*. A discussion of the differences between *reighardi* and *zenithicus* is given on page 386.

Reighardi differs from *nigripinnis regalis* in having a much more elliptical body shape (seen from the side), a shorter, more included mandible, a much paler body and fins, and a smaller eye. The comparative figures for gill rakers and eye size follow:

Gill rakers on the first branchial arch:
- *reighardi*, (32) 33–36 (38).
- *nigripinnis*, (44) 48–51 (54).

H/E:
- *reighardi*, (3.6) 4–4.4 (4.8), with 44 per cent more than 4.1.
- *nigripinnis*, (3.5) 3.7–4.1 (4.3), with 5 per cent more than 4.1.

[64] The specimens in this section compared for proportions are those 200 millimeters or more in length, except in the case of *artedi*, where they are 225 millimeters or more. The counts are given for specimens of all sizes.

Reighardi has on the average fewer lateral-line scales, a somewhat longer head and snout, and shorter paired fins.

Reighardi differs from *hoyi* in having a shorter, more included, and less hooked mandible, less sharply triangular head (as seen from the side), fewer gill rakers on the first branchial arch, and fewer lateral-line scales. The comparative figures for the last-named characters follow:

Gill rakers on the first branchial arch:
reighardi, (32) 33–36 (38).
hoyi, (40) 42–46 (48).
Lateral-line scales:
reighardi, (64) 66–73 (77), with 23 per cent more than 72.
hoyi, (66) 73–80 (85), with 82 per cent more than 72.

Reighardi has also on the average a somewhat smaller eye and shorter ventrals.

Reighardi has many fewer gill rakers on the first branchial arch than *artedi* or *nipigon*; also fewer lateral-line scales and a longer snout and maxillary. These characters are compared below:

Gill rakers on the first branchial arch:
reighardi, (32) 33–36 (38).
artedi, (41) 46–49 (53).
nipigon, (54) 56–59 (66).
Lateral-line scales:
reighardi, (64) 66–73 (77), with 23 per cent more than 72.
artedi, (65) 71–76 (81), with 59 per cent more than 72.
nipigon, (68) 72–77 (82), with 80 per cent more than 72.
H/S:
reighardi, (3.3) 3.5–3.6 (4), with 24 per cent more than 3.6.
artedi, (3.5) 3.7–3.9 (4.2), with 92 per cent more than 3.6.
nipigon, (3.3) 3.5–3.8 (4), with 55 per cent more than 3.6.
H/M:
reighardi, (2.2) 2.3–2.5 (2.7), with 10 per cent more than 2.5.
artedi, (2.5) 2.7–2.8 (3), with 98 per cent more than 2.5.
nipigon, 2.5–2.7 (3.1), with 78 per cent more than 2.5.

Reighardi is also less pigmented throughout and has a proportionally longer head.

GEOGRAPHICAL DISTRIBUTION

In Table 34 are given the data of specimens collected by me with 2½ and 2¾ inch gill nets in 1922 and of specimens examined from the University of Toronto collection. These data are platted on the map of the lake in Figure 2. The records are distributed sufficiently widely over the lake to warrant the conclusion that *reighardi* occurs throughout the lake where it can find suitable conditions.

BATHYMETRIC DISTRIBUTION

There are few data to indicate the depth preferences of this species. Only three sets of the special 2½ and 2¾ inch gill nets were made by me in the lake, and *reighardi* occurred in two. Twenty per cent of the fish taken on July 25, 1922, off the source of Nipigon River in 10 to 15 fathoms (record 16), belonged to this species, while on the next day the catch off Macdiarmid in 30 fathoms had only 14 per cent of this species (record 2). It is interesting here to give the relative abundance of the other species of the lake in these lifts for a comparison with the depth relations of these species as they are known in the Great Lakes. *Zenithicus* comprised 13 and 43 per cent of the catches, respectively; *nigripinnis* 30 and 38 per cent (both in others of the Great Lakes found in deeper waters); while the combined percentage of *artedi*, *nipigon*, and *clupeaformis* (shallow-water forms) was 35 and 3 per cent. Thus, in the set at 10 to 15 fathoms the deep-water *zenithicus* and *nigripinnis* had a combined percentage of 43, and in the 30-fathom lift 81; while the rest, including *reighardi*, which in other lakes show a preference for shallower water, had a combined percentage of 55 and 17. A set made off Livingston Point on July 28, 1922, in 56 fathoms took no *reighardi*. The specimens in the University of Toronto collection, so far as is known, also were taken in shallow water, but it is not possible to state what proportion of the catch they comprised.

All the data thus indicate that *reighardi* occurs regularly on the shoals of the lake, more abundantly in 10 to 15 fathoms than at 30, and is absent at 56 fathoms. These conclusions that the species prefers the shallower waters are quite in accord with the known habits of the species in the Great Lakes.

BREEDING HABITS

The specimens collected on October 26, 1922 (record 21), were not yet ripe but were near maturity. It is likely, then, that the spawning time falls in November, as in the case of the related form in Lake Superior. Nothing is known about the location or the character of the grounds selected for spawning.

Leucichthys reighardi dymondi (new subspecies) of Lake Superior

The Superior form (fig. 18) is most like that of Lake Nipigon but in severa particulars is rather intermediate between the Nipigon and Michigan forms. The principal systematic characters of the three forms that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (31) 35–38 (43).[65]
- Nipigon, (32) 33–36 (38).[66]
- Superior, (32) 34–38 (42).[67]

Lateral-line scales:
- Michigan, (67) 72–81 (96).[65]
- Nipigon, (64) 66–73 (77).[66]
- Superior, (65) 71–77 (83).

L/H:
- Michigan, (4) 4.2–4.5 (4.8).
- Nipigon, (3.5) 3.7–3.9 (4.1).
- Superior, (3.7) 3.9–4.2 (4.4).

H/E:
- Michigan, (3.6) 3.9–4.2 (4.4).
- Nipigon, (3.6) 4–4.4 (4.8).
- Superior, (3.6) 3.9–4.2 (5).

H/M:
- Michigan, (2.5) 2.6–2.8 (3).
- Nipigon, (2.2) 2.3–2.5 (2.7).
- Superior, (2.3) 2.4–2.6 (2.7).

H/S:
- Michigan, (3.5) 3.7–4 (4.4).
- Nipigon, (3.3) 3.5–3.6 (4).
- Superior, (3.4) 3.6–3.9 (4.1).

Pv/P:
- Michigan, (1.8) 2.1–2.4 (2.8).
- Nipigon, (1.4) 1.6–1.8 (2).
- Superior, (1.5) 1.8–2 (2.4).

Av/V:
- Michigan, (1.2) 1.4–1.7 (1.8).
- Nipigon, (1.1) 1.3–1.6 (1.7).
- Superior, (1.2) 1.4–1.7 (1.9).

[65] These figures for Lake Michigan are given for 192 specimens of all sizes from the southern sector of the lake; most of them are paratypes. Unmarked figures are given for 146 specimens ranging from 200 to 243 millimeters in length.

[66] These figures for Lake Nipigon are based on an examination of 98 individuals ranging in length between 145 and 304 millimeters. Unmarked figures are given for 83 specimens 200 millimeters or more in length.

[67] These and unmarked figures for Lake Superior are based on an examination of 234 specimens ranging in length from 199 to 320 millimeters.

Dorsal rays:
- Michigan, (8) 9–10 (11).[68]
- Nipigon, (9) 10–11.[69]
- Superior, 10–11 (12).[70]

Anal rays:
- Michigan, (9) 10–11 (12).[71]
- Nipigon, (10) 11–12.[72]
- Superior, (10) 11–12 (13).[73]

The mandible usually is included within the upper jaw, but it is not infrequently equal to it or longer. The premaxillaries are not usually vertical but make an angle of 55° to 65° with the horizontal axis of the head. The mandible seldom is pigmented, and the pigmentation of the prenarial area is much reduced, though the area is conspicuously darker still. The body is rather compressed, so that the body form is not subterete. The average size attained seems to be about the same for the Superior race as for the others, except that in virgin waters there are more fish larger than 250 millimeters. Only a single specimen longer than 290 millimeters has been seen, however.

Thus, it appears that in the matter of number of gill rakers, size of eye, and length of the ventral fins, the Superior form is very like the typical one. In respect to the number of dorsal and anal rays, the length of the mandible, position of the premaxillaries, and body width it is like the *dymondi* form. In the matter of number of lateral-line scales, length of head, maxillary, snout, and pectorals, and pigmentation of the head parts it seems to be more or less intermediate between the two. As the characters in which Superior specimens are predominantly like *dymondi* are more numerous and influence most their general appearance, I have called this form *dymondi* also.

The color of living specimens is much like that described for the Ontario race, except that the green of the back is paler, seldom being conspicuous beneath the overlying pigmentation. Specimens in spirits are pigmented on the ventral and anal more often than those of the typical form.

No specimens in full nuptial adornment have been collected. None of the males taken out of Port Arthur on November 25, 1922, showed pearl organs, but these fish were transported on ice, and friction had removed the epidermal structures. An occasional male taken in Thunder Bay in September, 1923, showed incipient pearl organs, and it is certain that in the breeding season, at least, the males are pearled.

VARIATIONS

Racial variations.—Virtually all my specimens are from Thunder Bay or the vicinity, so that nothing can be said about variations with locality.

Size variations.—Most of the specimens in the collection were taken in 2½-inch gill nets, so that they are too equal in size to furnish data on changes with growth.

COMPARISONS [74]

Reighardi resembles *zenithicus* most closely. The differences between these two species are discussed on page 380.

There is a close superficial resemblance to *artedi*, but there are sharp differences between the two species. *Reighardi* is not known to have more that 42 gill rakers on

[68] One hundred and seventy-nine specimens.
[69] Eighteen specimens.
[70] Thirty-five specimens.
[71] Forty-four specimens.
[72] Eighteen specimens.
[73] Fifty specimens.
[74] Figures of proportions for *reighardi* and *nigripinnis* are based on specimens 200 millimeters or more in length; those for *artedi* on specimens 225 millimeters or more. Proportions for *kiyi* and *hoyi* and all counts are based on specimens of all sizes.

the first branchial arch, while *artedi* is not known to have less. *Reighardi* also has a longer head, a longer maxillary, longer paired fins, and fewer scales in the lateral line. A comparison of these characters for the two species follows:

L/H:
reighardi, (3.7) 3.9–4.2 (4.4), with 3 per cent more than 4.2.
artedi, (4) 4.3–4.6 (4.9), with 88 per cent more than 4.2.
H/M:
reighardi, (2.3) 2.4–2.6 (2.7), with 4 per cent more than 2.6.
artedi, (2.6) 2.7–3 (3.2), with 91 per cent more than 2.6.
Pv/P:
reighardi, (1.5) 1.8–2 (2.4), with 14 per cent more than 2.
artedi, (1.6) 2–2.3 (2.6), with 63 per cent more than 2.
Av/V:
reighardi, (1.2) 1.4–1.7 (1.9), with 3 per cent more than 1.7.
artedi, (1.3) 1.6–1.9 (2), with 36 per cent more than 1.7.
Lateral-line scales:
reighardi, (65) 71–77 (83), with 2 per cent more than 80.
artedi, (72) 84–93 (105), with 85 per cent more than 80.

Reighardi differs from *nigripinnis cyanopterus* in having fewer gill rakers, fewer scales in the lateral line, a larger eye, and a much more terete body. The comparative figures for certain of these characters follow:

Gill rakers on the first branchial arch:
reighardi, (32) 34–38 (42), with 10 per cent more than 38.
nigripinnis, (36) 38–42 (48) with 84 per cent more than 38.
Lateral-line scales:
reighardi, (65) 71–77 (83), with 2 per cent more than 80.
nigripinnis, (73) 79–86 (91), with 72 per cent more than 80.
H/E:
reighardi, (3.6) 3.9–4.2 (5), with 9 per cent more than 4.2.
nigripinnis, (4) 4.3–4.6 (5.2), with 85 per cent more than 4.2.

The paired fins also average shorter in *reighardi*, the dorsal contour of the pectoral usually is straight rather than decurved, and the body and fins are paler.

Reighardi is distinguishable from *kiyi* and *hoyi* by its more terete shape, its included mandible, greater adult size, fewer gill rakers on the first branchial arch, and shorter paired fins. *Reighardi* is further separable from *kiyi* by the fewer scales in the lateral line. The comparative figures for such of these characters as can be expressed accurately numerically are given below:

Gill rakers on the first branchial arch:
reighardi, (32) 34–38 (42), with 10 per cent more than 38.
kiyi, (36) 37–42 (45), with 71 per cent more than 38.
hoyi, (37) 40–45 (49), with 96 per cent more than 38.
Pv/P:
reighardi, (1.5) 1.8–2 (2.4), with 62 per cent more than 1.8
kiyi, (1.1) 1.3–1.5 (1.7).
hoyi, (1.4) 1.5–1.8 (2.2), with 11 per cent more than 1.8.
Av/V:
reighardi, (1.2) 1.4–1.7 (1.9), with 94 per cent more than 1.3.
kiyi, (0.9) 1–1.2 (1.4), with 1 per cent more than 1.3.
hoyi, (0.9) 1.1–1.3 (1.6), with 11 per cent more than 1.3.
Lateral-line scales:
reighardi, (65) 71–77 (83), with 2 per cent more than 80.
kiyi, (72) 76–84 (87), with 29 per cent more than 80.
hoyi, (65) 69–78 (84), with 2 per cent more than 80.

GEOGRAPHICAL DISTRIBUTION

Data in Table 36 and Figure 3 show *reighardi* in Superior to be confined to the western sector of the lake from Ontonagon, Mich., to Grand Marais, Minn., and to the islands blocking Nipigon Bay. The numerous sets of the special 2½ and 2¾ inch nets made in other parts of the lake (see Table 24) have not revealed it, but there is a bare possibility that it may occur elsewhere in habitats not explored.

BATHYMETRIC DISTRIBUTION

Pound nets were inspected only out of two ports on the north and west shores of the lake, and at each inspection some examples of this species were taken. Those gill-net sets in the area of distribution that were made near shore, so that part, at least, of the gang fished at moderate depths, have recorded the species. It has been absent from the special 2½ and 2¾ inch nets set within its distribution area only on October 4, 1921, off Bread Rock, Ontario, in 80 to 90 fathoms and on September 25, 1923, in Simpson Channel in 74 fathoms. It may be stated then, that in the summer, at least, *reighardi* runs onto the shoals and is known to range out to depths of 49 and possibly 65 fathoms, probably where such depths are attained in the proximity of shore.

RELATIVE ABUNDANCE

Reighardi has been taken commonly only in the bays and channels along the north shore of the lake.

Specimens of *reighardi* were rare among the Leucichthys taken in the 2½ and 2¾ inch nets lifted on August 24 and 25, 1921, 21 miles west and 6 miles NNW. of Ontonagon, Mich., in 15 to 45 and 20 to 38 fathoms (records 1 and 2); July 11, 1922, between Cat and South Twin Islands in 15 to 20 fathoms (record 3); July 17, 1922, 20 miles NE. by E. of Duluth in 30 to 40 fathoms (record 4); and on September 14, 1921, off Terrace Point, Minn., in 30 to 65 fathoms (record 5). In the northern bays it has been found common only in the shallower waters. Thus, in Thunder Bay and vicinity, in the lift of special 2½-inch nets made on September 15, 1923, between Silver Island and the mainland in 14 fathoms and inside Thunder Cape in 31 fathoms (records 8 and 9), and on September 17, 1923, inside the Welcome Islands in 11 fathoms and outside the Welcome Islands in 23 fathoms (records 10 and 11), and on September 19, 1923, in Thunder Bay off Sawyer Bay in 49 fathoms (record 12), *reighardi* constituted 32 to 92 per cent of the coregonids taken. Farther eastward, in the vicinity of Rossport, Ontario, in the lift made on September 25, 1923, in Moffat Strait in 13 to 14 fathoms, 17 per cent of the catch of coregonids was of *reighardi* (record 18.) It was rare in the lift made on September 29, 1923, off Salter Island in 42 fathoms (record 19). It was absent in the lift made on September 25, 1923, in Simpson Channel in 74 fathoms and on October 4, 1921, off Bread Rock in the main lake in 80 to 90 fathoms.

The species occurred in unknown numbers in the herring lifts made in Thunder Bay on November 25, 1922 (record 7.) These specimens were collected by H. Walmsley, of Booth Fisheries, from the herring fishermen. Testimony of these fishermen establishes that when the November herring run is on not infrequently 100 pounds or so of these fish are taken in a lift of several thousand pounds of herring, especially at the beginning and close of the herring season. The herring nets are set in Thunder Bay in November at depths of 6 to 30 fathoms.

A number of specimens have been taken in the pound nets in Black Bay and the vicinity of Nipigon Bay. The pounds were of such large mesh that only the largest examples of the species were captured, and it is probable that the species was numerous even in the environs of the nets. Oscar Anderson, of Rossport, Ontario, in whose pounds most of the specimens were taken, stated that the large *reighardi* had been present in the Moffat Strait net for most of the summer of 1922, and that in early August, 1923, they were very common there.

From the data just reviewed it appears that *reighardi* occurs most abundantly along the shores of the bays and in the channels of the north shore. It has not been found common in water deeper than 49 fathoms, and no specimens have been taken from nets in water deeper than 65 fathoms. The temperature data in Table 13 show that the warmest waters in the lake are found within this zone of abundance.

BREEDING HABITS

An occasional male showing incipient pearl organs and exuding a little milt on pressure was taken in the lifts made in Thunder Bay on September 15 and 17, 1923 (records 9, 10, and 11), but most of the fish showed green gonads. None of the fish taken at Rossport, Ontario, on September 25 and 29, 1923 (records 18 and 19), showed indications of sexual ripeness. The majority of females taken at Port Arthur, Ontario, on November 25, 1922 (record 7), were spent, but the eggs of an occasional individual were still hard in the ovary. The males also were spent, though most of them yielded a little milt on pressure. The condition of the sex organs of these Port Arthur fish indicates that they had spawned recently. No spawning grounds of the species are known, but certainly some are to be found in Thunder Bay.

Leucichthys reighardi reighardi of Lake Ontario

The Lake Ontario form of *reighardi* resembles very closely the typical form. The principal characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (31) 35–38 (43).[75]
- Ontario, (33) 35–38 (42).[76]

Lateral-line scales:
- Michigan, (67) 72–81 (96).[75]
- Ontario, (66) 73–81 (86).

L/H:
- Michigan, (4) 4.2–4.5 (4.8).
- Ontario, (4) 4.4–4.7 (5).

H/E:
- Michigan, (3.6) 3.9–4.2 (4.4).
- Ontario, (4) 4.2–4.5 (5).

H/S:
- Michigan, (3.5) 3.7–4 (4.4).
- Ontario, (3.3) 3.6–3.9 (4.2).

H/M:
- Michigan, (2.5) 2.6–2.8 (2.9).
- Ontario, (2.6) 2.7–2.9 (3).

Pv/P:
- Michigan, (1.8) 2.1–2.5 (2.8).
- Ontario, (1.7) 2.2–2.5 (2.9).

Av/V:
- Michigan, (1.2) 1.4–1.7 (1.8).
- Ontario, (1.3) 1.5–1.7 (2.1).

From the figures it appears that Ontario specimens tend to have a proportionally shorter head and smaller eye than the typical Lake Michigan form. These

[75] These figures are based on an examination of 192 specimens of all sizes. All other figures are given for 146 specimens ranging in length between 200 and 243 millimeters. Only fish taken in the southern sector of the lake are included in these tabulations. Most of them are cotypes.

[76] These and succeeding figures for Lake Ontario are based on 76 collected specimens ranging in length from 203 to 295 millimeters.

differences concern proportions that usually are affected by growth, and as of the two groups that of Lake Ontario contains the largest individuals, it would appear that the differences must lose in significance. The removal of the larger fish from the Ontario group reduces the disparity between the H/E figures for the two groups but alters little the L/H relations. (See section on "Size variations.")

While most of the individuals of the species taken in Lake Ontario have been of about the same size as those taken in Lake Michigan, a few exceptionally large examples have been taken. The largest of these measures 295 millimeters. These larger fish are usually conspicuously deeper than the smaller ones, and the anterior dorsal profile is not gradual, but the line rises rather rapidly for half the distance from the occiput to the dorsal and continues to the dorsal with only a slight upward trend.

The color of living specimens is like that of the chub and other Great Lakes Leucichthys. The underlying color of the back is usually pale pea green to blue green, though occasional individuals show bright tones. The iridescence is usually pinkish. In spirits specimens show, on the average, less pigmentation than the paratypes. The anal and ventrals are always immaculate, and the black of the snout and mandible is somewhat reduced.

The males and at least some females develop pearl organs during the breeding season. Among the specimens preserved, however, there are none that have retained more than traces here and there of the breeding adornment.

VARIATIONS

Racial variations.—Too few specimens have been obtained from any locality to permit extensive comparisons to ascertain whether there are racial differences within the species.

Size variations.—Only two specimens smaller than 200 millimeters have been seen, hence it is not possible to make the usual comparisons between small and large fish. The collected specimens may be divided, however, according as they are more or less than 250 millimeters in length, and some indication may be derived of the effect of growth on the systematic characters usually employed. Such a division leaves for comparison a group of 32 specimens 250 millimeters or more in length and a group of 44 smaller ones. The only marked difference between the characters of the two groups is in the H/E ratio—the larger fish have a proportionally smaller eye. The range of H/E for the small fish is 4–4.4 (4.5); for the larger ones (4) 4.2–4.6 (5).

COMPARISONS [77]

Reighardi is easily distinguishable from the other species in the lake on account of the fewer gill rakers on the first branchial arch and the shorter paired fins. A comparison of these characters follows:

Gill rakers on the first branchial arch:
- *reighardi*, (33) 35–38 (42), with 4 per cent more than 40.
- *hoyi*, (39) 42–47 (50), with 98 per cent more than 40.
- *kiyi*, (41) 43–46 (48).
- *artedi*, (41) 46–50 (54).

[77] Figures in this section are given for all collected specimens.

Pv/P:

reighardi, (1.7) 2.2–2.5 (2.9), with 89 per cent more than 2.1.
hoyi, (1.4) 1.7–2 (2.2), with 1 per cent more than 2.1.
kiyi, (1.5) 1.7–2 (2.2), with 3 per cent more than 2.1.
artedi, (1.7) 1.9–2.1 (2.5), with 15 per cent more than 2.1.

Av/V:

reighardi, (1.3) 1.5–1.7 (2.1), with 90 per cent more than 1.4.
hoyi, (1.1) 1.3–1.5 (1.6), with 38 per cent more than 1.4.
kiyi, (1) 1.2–1.4 (1.6), with 7 per cent more than 1.4.
artedi, (1.3) 1.5–1.8 (2), with 89 per cent more than 1.4.

Reighardi also has a less triangular head, seen from the side, a wider, more terete body, and the mandible is almost always shorter than the upper jaw, while in the other species, excepting *artedi* the reverse is true. In *artedi* the lower jaw has been found shorter than the upper in less than half the specimens examined. The body outline, as seen from the side, is more elliptical than in *kiyi;* and *reighardi* has also a shorter head, larger eye, and longer maxillary and snout than this species. It has a shorter head and maxillary than *hoyi*. As *reighardi* spawns in spring (probably in April or May) and *kiyi* spawns in August and *artedi* in November, the state of development of the sex organs may, at certain seasons, at least, aid in separating individuals of the several species.

GEOGRAPHICAL DISTRIBUTION

Data on the occurrence of *reighardi* given in Table 38 and shown platted on the chart in Figure 7 show that specimens of the species have been taken in the special 2½ and 2¾-inch nets out of every port visited on the New York shore and out of Brighton on the Canadian shore. Specimens have been seen also from other collections taken from off Port Credit, Ontario. It is probable, then, that the species is distributed along the shores of the entire lake.

BATHYMETRIC DISTRIBUTION

The only data available on the depth distribution of the species are derived from the use of special nets of 2½ and 2¾-inch mesh, which were set only between the depths of 20 and 75 fathoms at some time during the summers of 1921 and 1923, and from the examination of a few sets of 3-inch nets that are in commercial use for herring. Individuals occurred in the catches of these nets at depths of 20 to 65 fathoms. They were absent in the lift off Oswego, N. Y., made on September 4, 1923, in 70 to 75 fathoms, but occurred in lifts from off that port made in shallower water.

RELATIVE ABUNDANCE

The data from any of the nets show nothing conclusive about the relative abundance of the species, inasmuch as all the special sets were made with only the element of depth as a guiding factor, and it is well known that other factors influence the distribution of fishes. The data, however, seem to point to certain conclusions, which may be given more weight in that they agree with what is known about the habits of the species elsewhere.

No *reighardi* were taken in a special lift made off Bronte, Ontario, on June 29, 1921, in 40 to 50 fathoms; off Wilson, N. Y., on June 25, 1921, and July 16, 1921, in 50 fathoms, and off Oswego, N. Y., on September, 4, 1923, in 70 to 75 fathoms. Specimens of the species were rare in a lift made 8½ miles NNW. of Sodus Point,

N. Y., on July 12, 1921, in 60 fathoms (record 7); July 4, 1921, 7 miles off Braddock Point Light, N. Y., in 65 fathoms (record 8); June 23, 1921, 3 miles north of Wilson, N. Y., in 30 fathoms, and on July 19, 1921, 6½ miles N. by W. ½ W. of that port in 65 fathoms (records 9 and 10). Occasional specimens were taken in the special lift made on August 30, 1923, 14 miles west of Sandy Pond, N. Y., in 60 fathoms (record 4), and in the lifts of the commercial nets of 3-inch mesh made on July 11, 1921, 5 miles NNW. of Nine-Mile Point, N. Y., in 25 to 35 fathoms (record 5) and on August 24, 1923, 9 miles west of Sandy Pond, N. Y., in 25 to 30 fathoms (record 3). *Reighardi* occurred commonly in the lifts of the special nets made on June 10 and 16, 1921, 20 miles S. by W. of Presque Isle Light, Ontario, in 40 to 50 fathoms (records 1 and 2), on July 21, 1921, 2 miles north of Wilson, N. Y., in 20 fathoms (record 11), and also in the commercial 3-inch nets lifted on September 1, 1923, off Nine-Mile Point, N. Y., from 30 fathoms (record 6). (The occurrence of numerous examples of the species in the 3-inch nets is of particular significance, as only individuals of extreme size can be gilled in nets of such large mesh.)

The data from these sources thus indicate that the species is found most commonly at depths of 20 to 50 fathoms.

BREEDING HABITS

No breeding grounds of *reighardi* are known, nor can the time of spawning be established definitely. Of 6 female specimens sent me by Andrew Pritchard, of the University of Toronto, taken on February 12, 1926, off Port Credit, Ontario, 3 were spent, 2 were nearly ripe, and 1 was apparently a nonspawner. Mr. Pritchard, in a letter of January 8, 1927, says that in his experience spent fish are not common so early in the year. In April, 1926, most of the fish were nearly ripe, and a few started to spawn toward the end of the month. The main run, however, was in the first two weeks in May, when, according to the fishermen at Port Credit, the decks of their boats often were covered with spawn from the captured fish.

All but one of the fish taken at Brighton, Ontario, on June 10 and 16, 1921 (records 1 and 2), were either spent females or males from which milt could be squeezed. The exception was a female with loose eggs in the body cavity. Males taken at other ports later in that season not infrequently emitted milt or exhibited traces of pearls. The female showed eggs of the next season developing in the ovaries. The fish from Lake Ontario listed under *Leucichthys prognathus* as ripe or nearly ripe in May and June by Evermann and Smith (1896, p. 317) undoubtedly are of this species.

It appears, thus, that the spawning season for the species is probably in early May, certainly before June 10.

LEUCICHTHYS NIGRIPINNIS Gill

THE BLACKFIN (FIGS. 19, 20, AND 21)

Argyrosomus nigripinnis Gill, in Hoy, 1872, p. 99, Lake Michigan off Racine; Evermann and Smith 1896, pp. 317–320, pl. 27, Lake Michigan (probably not "lakes of Wisconsin and Minnesota").

Leucichthys nigripinnis Jordan and Evermann, 1911, pp. 26–27, Pl. IV, Lake Michigan (probably not "lakes of Wisconsin"); Dymond, 1926, pp. 62–63, Pl. III, Lake Nipigon.

Coregonus prognathus Smith, 1894, pp. 4–13, pl. 1, Lake Ontario.

Argyrosomus prognathus Evermann and Smith, 1896, pp. 314–317, pl. 26, Lake Ontario.

Leucichthys prognathus Jordan and Evermann, 1911, pp. 23–24, Lake Ontario.

Leucichthys cyanopterus Jordan and Evermann, 1911, pp. 27–28, fig. 13, Lake Superior off Marquette.

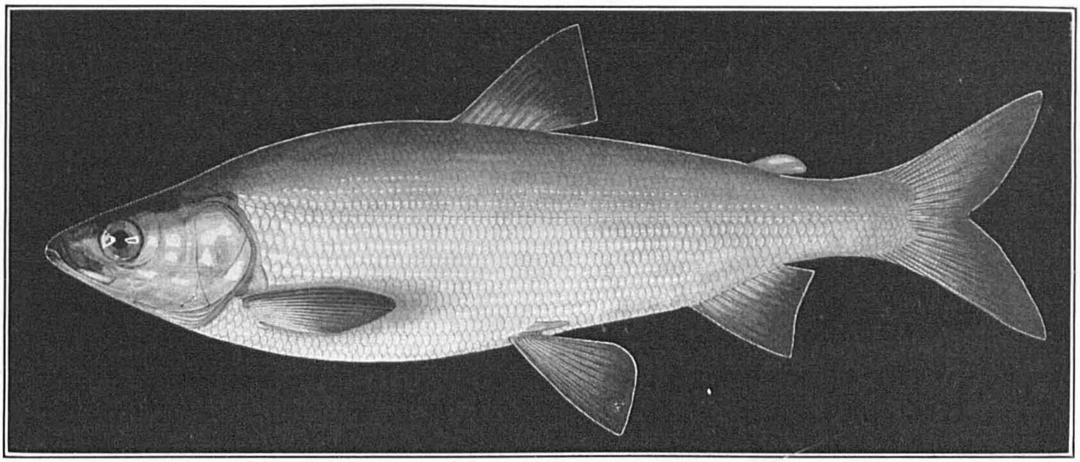

FIG. 19.—*Leucichthys nigripinnis* Gill, the blackfin. Male, 314 millimeters long, taken in Lake Michigan off Port Washington, Wis., in 60 to 80 fathoms on May 26, 1922

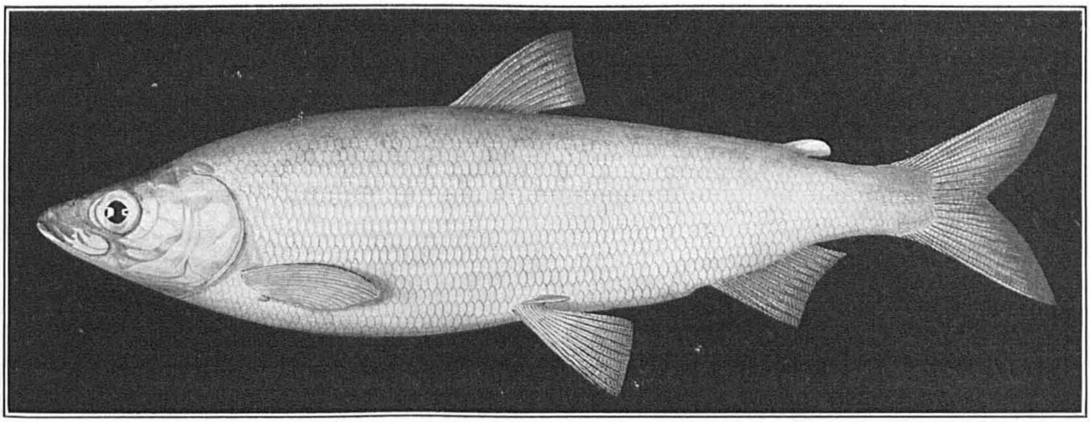

FIG. 20.—*Leucichthys nigripinnis cyanopterus* Jordan and Evermann, the bluefin. Male, 284 millimeters long, taken in Lake Superior off Michipicoten Island in 80 fathoms on June 22, 1922

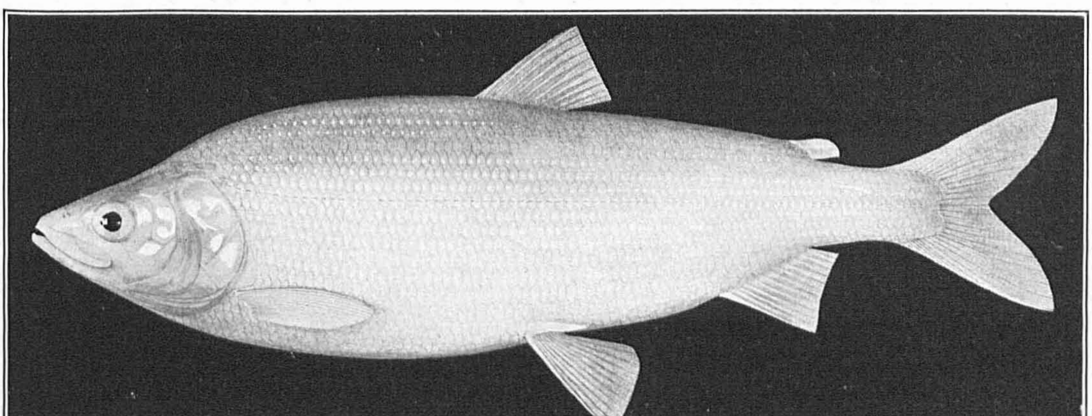

FIG. 21.—*Leucichthys nigripinnis prognathus* Smith, the bloater. Type, 297 millimeters long, taken in Lake Ontario

Leucichthys nigripinnis has been described from Lake Michigan and also has been recorded from Lakes Superior, Huron, Ontario, and Nipigon. In all the lakes it is distinguished by the large size it attains, its deep body (which is ovate in side view), and by its relatively long paired fins. In all but Superior and Ontario the species has conspicuously pigmented fins, and in all but Nipigon it inhabits by preference depths of 60 fathoms and more. The Huron form differs from the type form chiefly in having a larger head and eye, possibly fewer lateral-line scales, and slightly longer paired fins. The Superior form has fewer gill rakers, a longer head and snout, a smaller eye, less body depth, a shorter mandible, and paler fins than the typical form. In addition, it spawns in September as compared with December and January in the other Great Lakes. In Nipigon the form is distinguished chiefly by having slightly more gill rakers than the type, fewer lateral-line scales and scale rows, a larger head and eye, and longer pectorals. The fins are somewhat darker and the body paler. It frequents much shallower water and probably spawns about the same time as the Michigan form. The Ontario form probably was but little different from the typical race except that probably it was less pigmented. The race in Lake Nipigon has been designated *regalis* in this paper. The Lake Superior and Lake Ontario forms have been described as distinct species and called *cyanopterus* and *prognathus*, respectively. They are here regarded as subspecies.

Type

The type is no longer extant. The name is based on a specimen sent by Hoy to Gill, who named but did not describe it. The name is fixed by a cursory account published by Hoy in 1872.

Leucichthys nigripinnis nigripinnis of Lake Michigan

The blackfin is one of the largest of the deep-water Leucichthys. It not infrequently reaches a length of 35 centimeters (13¾ inches), with a weight of a little more than 1½ pounds, and nets of 3½ to 4 inch mesh were used to take it when it supported a fishery. The body is, in general, similar in shape to that of *johannæ*; as a rule, however, it is less elongate and slightly deeper. The depth is usually equal to 25 to 29 per cent of the total length. The width is about 47 to 52 per cent of the depth. At the occiput the dorsal profile rises rapidly to half the distance that separates the occiput from the dorsal. The remaining half of the contour line continues to the dorsal with only a slight upward trend. From the dorsal the contour continues ventrad and caudad in nearly a straight line to the adipose. The ventral profile, from the tip of the mandible to the ventral fins, runs like the opposite dorsal line. For the anterior half of this distance the line curves strongly downward and back ward, while the remaining half runs nearly parallel to the dorsal line and the linea lateralis. The portion of the body from the dorsal and ventrals to the head appears, therefore, to be of nearly uniform depth. As the depth increases the more vertical become the lines proceeding immediately from the occiput and the isthmus. From the ventrals the ventral contour line continues caudad and dorsad in a moderate curve. The head is moderate, broadly triangular as viewed from the side, and is contained (3.8) 4.1–4.4 (4.7)[78] times in the total length of the fish. The premaxil-

[78] These values and those given subsequently, unless indicated otherwise, are based on an examination of 52 specimens, which range in length between 220 and 360 millimeters.

laries usually are half as wide as long and make an angle of 45° to 60° with the horizontal axis of the head. Instead of a smooth curve connecting the tip of the snout with the occiput, as in the longjaw, where the premaxillaries occupy a similar position, the profile in the blackfin runs straight from the tip of the premaxillaries to their articulation with the rostroethmoidal cartilage and then continues in a faint curve to the occiput. The maxillary is pigmented and seldom extends much beyond the anterior edge of the pupil. The snout, viewed from the side, is deep and blunt and is contained 3.5–3.9 (4.1) times in the head length. The eye is large and is contained 4–4.4 (4.6) times in the total length of the head. The lower jaw usually is pigmented conspicuously and equal to or somewhat longer than the upper; occasionally, however, it is somewhat shorter. The gill rakers on the first branchial arch number (15) 16–19 + (26) 29–32 (34) = (41) 46–50 (52). Scales in the lateral line number (74) 80–87 (89). Scale rows around the body just in front of the dorsal and ventrals number (41) 42–44 (45);[79] just in front of the adipose and anus (32) 33–35 (36);[79] around the caudal peduncle (23) 24–26 (27).[79] Dorsal rays are 10–11;[79] anal rays (10) 11–12 (13);[79] ventral rays 11–12;[79] and pectoral rays (15) 16–17 (18).[80] The length of the pectoral fin is contained (1.5) 1.6–1.8 (2.2) times in the distance from the pectorals to the ventrals.

The distal half of the dorsal margin of the pectorals is usually decurved. The ventrals are contained 1.2–1.5 (1.6) times in the distance from their origin to that of the anal.

COLOR IN LIFE

The general tone is silvery, as in other Leucichthys, but in typical specimens the silvery cast is least conspicuous in this species on account of the heavy pigmentation. The entire dorsal surface is blue black, almost obscuring the pea green to blue green beneath. Below the lateral line a pale blue green is evident beneath the silvery layer. The sides and cheeks are suffused with a purplish iridescence, which is strongest above the lateral line. The maxillary and mandible are whitish, both more or less heavily pigmented. The fins also are whitish, all of them usually so heavily pigmented that the effect is also blue black.

In spirits the entire dorsal surface is more or less heavily pigmented, varying from dense pigment, giving an almost black effect in some individuals, to but scattered pigment in others. The top of the head is usually darker than the back, with the pigment here often concentrated in front of the nares. The tip of the mandible is dark, and the pigment of the back usually descends onto the sides of the head and body, sometimes with undiminished intensity on the operculum, postoculars, and in the preorbital area. The cranial margin and distal half of the dorsal fin, dorsal margin and distal half of the pectorals, distal half of the ventrals, distal half of the longer rays of the anal, and the lateral border and a broad band of the caudal are washed more or less with intense black. More or less of the fins may be pigmented, but the usual extent of the pigmentation has been given.

No blackfins were collected during the spawning season, but a male in the Field Museum collection, taken off Chicago, showed traces of pearls; and no doubt the males, at least, develop pearl organs, as do all other members of the genus in the basin.

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[79] Sixteen specimens.

[80] Twenty-six specimens.

VARIATIONS

Too few specimens are available for a study of local variations, and there is no material for a study of variation with growth, as none of the collected specimens are less than 220 millimeters in length. The smallest specimen collected measures 220 millimeters and is mature, but occasional much larger specimens in the collection are immature.

COMPARISONS [81]

Small blackfins bear a superficial resemblance to the kiyi, from which they may be distinguished by their more numerous gill rakers (which in the blackfin are seldom less than 44 and in the kiyi not usually more than 42) and by their more heavily pigmented fins, especially the ventrals, which are always more or less black in the former but usually immaculate in the latter. The blackfin has a wider body and thicker belly walls, a deeper and blunter head, and somewhat shorter paired fins. Females of the two species may be separated by the state of development of the ova. The blackfin spawns in late December and early January and the kiyi in October.

Only small *nigripinnis* could be confused with *hoyi*, as the former grows much larger. *Nigripinnis* is distinguished from *hoyi* by the body shape, which in the former is ovate, seen from the side, and in the latter elliptical; by the more numerous gill rakers on the first branchial arch and scales in the lateral line; and by the much darker coloration, particularly on the abdominal fins, which in the bloater are often immaculate and never conspicuously pigmented, while in the blackfin all of them are usually conspicuously black. The characters that can be expressed in figures are compared below:

Gill rakers on the first branchial arch:
- *nigripinnis*, (41) 46–50 (52), with 81 per cent more than 45.
- *hoyi*, (37) 41–44 (48), with 5 per cent more than 45.

Lateral-line scales:
- *nigripinnis*, (74) 80–87 (89), with 90 per cent more than 77.
- *hoyi*, (60) 67–77 (84), with 7 per cent more than 77.

The pectoral fins probably average a trifle longer in *nigripinnis*. The state of the sex organs also should serve often as a criterion in distinguishing at least questionable females, as *hoyi* spawns in March, *nigripinnis* in January. Individuals of *nigripinnis* under 200 millimeters in length probably would not be found often to be sexually mature, while *hoyi* are regularly mature as small as 140 millimeters.

Nigripinnis differs from *artedi* chiefly in the body shape, which is ovate in side view in the former and elliptical in the latter, and in the longer paired fins and greater body depth. The comparative figures for the last-named characters follow:

Pv/P:
- *nigripinnis*, (1.5) 1.6–1.8 (2.2), with 18 per cent more than 1.8.
- *artedi*, (1.6) 1.9–2.2 (2.6), with 94 per cent more than 1.8.

Av/V:
- *nigripinnis*, 1.2–1.5 (1.6), with 8 per cent more than 1.5.
- *artedi*, (1.4) 1.6–1.8 (2.3), with 89 per cent more than 1.5.

L/D:
- *nigripinnis*, (3.2) 3.4–3.9 (4.3).
- *artedi*, (3.6) 4.0–4.9 (5.3), with 62 per cent more than 4.3.

[81] Figures given in this section for proportions are based on specimens 200 millimeters or more in length, except *artedi*, where he limit is 225 millimeters. Counts are given for specimens of all sizes.

Nigripinnis has also a much longer maxillary, a somewhat longer head relatively, and is more pigmented, especially on the paired fins, than the herring. The ventrals, particularly, are darker in *nigripinnis.*

Discussions of the differences between *nigripinnis* and *johannæ, alpenæ, zenithicus,* and *reighardi* are found on pages 352, 365, 389, and 402.

GEOGRAPHICAL DISTRIBUTION

My data on the occurrence of the blackfin in Lake Michigan are given in Table 40 and are shown platted on the chart in Figure 4. There are 20 records, all but 5 of them from personal observation on the commercial catches of the chub nets. A few individuals have been taken out of most of the ports visited, and the data indicate that the species may be found, at least occasionally, throughout the lake at suitable depths.

BATHYMETRIC DISTRIBUTION

The data in the aforementioned table are derived almost exclusively from an examination of the catches of the 2½ to 2¾ inch chub nets and from the testimony of fishermen. They show the blackfin to have been taken at depths of 30 to 90 fathoms. With the exception of the two lifts out of Michigan City on September 3 and October 11, 1920, in 30 to 40 fathoms (records 10 and 11), no individuals occurred in about 12 catches examined from nets lifted out of less than 40 fathoms, not including the sets on the spawning grounds of *zenithicus* and *hoyi.* None ever have been seen by me from either the 4 or 4½ inch trout and whitefish nets or the 1½-inch bait nets set usually at depths of less than 50 fathoms. (See p. 354.) The testimony of the fishermen, who undoubtedly know the blackfin, establishes its habitat in the deeper waters of the lake, and it is probable that the blackfin does not range outside of the 30-fathom contour. The outer limit of its range is not known.

RELATIVE ABUNDANCE

My observations on the abundance of the blackfin were made during the summer and fall of 1920 and in the summer of 1923 from an examination of the catches of the 2½ to 2¾ inch chub nets. Few chubs of any kind were taken in 1920. (See p. 354.) The fishermen, moreover, are unanimous in the opinion that blackfins are taken commonly only in nets of 3-inch or larger mesh, so that my observations show nothing conclusive on the present abundance of this species. (The small fish apparently do not consort with the largest ones and apparently not even with the other chubs. This does not seem to be true of the species in Lake Huron.) In each of the lifts made out of the following ports a few specimens were taken: Out of Washington Harbor, Wis., on August 19, 1920, 20 miles E. ½ N. of Rock Island in 71 to 90 fathoms (record 1); out of Sturgeon Bay, Wis., on August 23, 1920, 12 miles E. by S. of the ship-channel mouth in 60 to 70 fathoms (record 2); out of Port Washington, Wis., on September 25, 1920, 18 miles E. ½ S. in 65 to 48 fathoms, and on May 26, 1922, 24 miles E. by N. in 60 to 80 fathoms (records 3 and 4); out of Milwaukee, Wis., on March 24, 1919, in 50 fathoms, and on September 23, 1920, 27 miles ESE. in 60 fathoms (records 5 and 6); out of Michigan City, Ind., on September 3, 1920, and on October 11, 1920, 22 miles NW. by N. ½ N. and 20 miles N. by W. ¾ W. in 30 to 40 fathoms (records 10 and 11); out of Grand Haven, Mich., on March 20, 1919, 12 miles west in 50 to 55 fathoms (record 12); out of Ludington, Mich., on August 30, 1920, 17 miles W. ½ S. in 60 to 70 fathoms (record 13); out of Frankfort, Mich., on October 4, 1920, 9 miles north of Point Betsie in 60 to 70 fathoms (record 15); out of Northport, Mich., on June 22, 1920, and on July 31, 1923, 5 miles northwest of Cathead Light in 40 to 60 fathoms (records 16 and 17); out of Charlevoix, Mich., on June 30, 1920, 3 miles northwest in 40 to 65 fathoms and on August 11, 1923, 3 miles NW. ½ W. in 35 to 60 fathoms (records 18 and 19); and out of Manistique, Mich., on August 12, 1920, 15 miles SE. by S. ½ S. in 60 to 70 fathoms (record 20). All but the lifts out of Michigan City (records 10 and 11), it will be noted, were made, at least in part, from depths of 50 fathoms or more. In only one lift made at more than 50 fathoms were no blackfins observed, namely, out of Sheboygan, Wis., on October 1, 1920. It was absent in about 12 other lifts examined from nets set in less than 50 fathoms, the number not including those lifts made out of Milwaukee, Wis., and Michigan City, Ind., on the spawning grounds of *zenithicus* and *hoyi*.

My observations thus show that few blackfins were taken in the lifts examined during 1920 and that these were, for the most part, from nets lifted from depths of 50 fathoms or more. The early writers (Hoy, 1870; Milner, 1872) also had observed, or derived an opinion, that the blackfin was a fish of the deeper waters. If we turn to the testimony of the fishermen, we find that the species was formerly abundant in several localities, always at great depths. William Lahmann, a retired fisherman of Milwaukee, says that they were formerly abundant 40 miles ESE. of Milwaukee, Wis. (off Racine), in 80 to 90 fathoms, where they were caught while spawning in December and January (record 7). Cornelius Tamms, likewise of Milwaukee, states that he fished for blackfins with 3½-inch nets on these grounds from April to June (record 8). Charles Hyttel, sr., of Racine, who furnished the type specimen to Doctor Hoy, says that formerly he fished blackfins in 3½-inch nets off the city at depths of 60 fathoms and more. They spawned there, he says, in January (record 9). Peter and Hans P. Petersen, of Manistee, Mich, formerly fished blackfins 5 to 8 miles west of Manistee in 4⅛-inch nets at depths of 40 to 80 fathoms in December and January when the fish were spawning (record 14). Mr. Lahmann and the Petersens give 1905 as the year of a marked decline in the abundance of the species. Mr. Hyttel's tug records show occasional fair lifts in 1907, especially in January, but the records for succeeding years, including 1911, indicate takes of few blackfins.

BREEDING HABITS

Nothing is known from personal observation of the time or place of spawning. None of the specimens collected as late as October 4, 1920 (record 15), showed ripe eggs, and those taken as early as March 20, 1919, were spent. Thus the spawning season is some time between October and March. Observations of fishermen from several ports fix the time and indicate the location of at least two spawning grounds. Mr. Lahmann, of Milwaukee, and Mr. Hyttel, sr., of Racine, both have claimed to have taken the fish on their spawning grounds, 40 miles ESE. of Milwaukee, in 60 to 90 fathoms during late December and early January. The Petersens say that they have taken them spawning at the same season 5 to 8 miles west of Manistee in 40 to 80 fathoms on clay. There are, or were, probably other spawning grounds in the lake.

Evermann and Smith (1896, p. 319) say that blackfins examined by them from off Sheboygan, Wis., taken about November 12 and 18, were "ripe or nearly ripe with spawn, * * * some were partially spent." These fish may have had prematurely developed gonads, as appears to happen frequently in the Great Lakes Leucichthys.

Leucichthys nigripinnis nigripinnis of Lake Huron

The Huron form resembles very closely the typical form. The chief characters may be compared at a glance:

Gill rakers on the first branchial arch:
- Michigan, (41) 46–50 (52).[82]
- Huron, (40) 46–50 (52).[83]

Lateral-line scales:
- Michigan, (74) 80–87 (89).
- Huron, (72) 77–83 (88).

L/H:
- Michigan, (3.8) 4.1–4.4 (4.7).
- Huron, (3.7) 4–4.2 (4.4).

H/E:
- Michigan, 4–4.4 (4.6).
- Huron, (3.6) 3.9–4.2 (4.6).

H/S:
- Michigan, 3.5–3.9 (4.1).
- Huron, (3.3) 3.4–3.8 (4.2).

Pv/P:
- Michigan, (1.5) 1.6–1.8 (2.2).
- Huron, (1.2) 1.4–1.7 (1.9).

Av/V:
- Michigan, 1.2–1.5 (1.6).
- Huron, (1) 1.1–1.4 (1.6).

It appears from the foregoing that the Huron form has, on the average, a larger head and eye and possibly fewer lateral-line scales and slightly longer paired fins.

The color of living fish is like that of the typical specimens. Specimens in spirits are also like those from Lake Michigan. The most noteworthy variation among individuals of the same school (and this has been observed most frequently in Georgian Bay) is the absence in some few examples of the characteristic bright blue body color and the reduction of the usual pigmentation of the fins, especially of the ventrals. These individuals differ from the rest in no other characters.

Males, at least, are known to develop pearl organs during the breeding season, but no examples in full breeding dress have been seen.

VARIATIONS

Racial variations.—The 71 specimens from Georgian Bay, compared in their principal characters with the 63 specimens from Lake Huron, virtually all taken off Alpena, Mich., do not show any differences to exist between the individuals of the two groups, except that the former may have a somewhat smaller eye.

Size variations.—All the collected specimens are over 200 millimeters in length, and most of them are over 250 millimeters in length, so that it is not possible to separate two groups of specimens for comparison according to size.

No specimen of blackfin smaller than 208 millimeters has been seen by me, and very few have been seen smaller than 230 millimeters. Specimens have not been found to be sexually mature under 220 millimeters.

[82] All figures for Lake Michigan are based on an examination of 52 specimens, which range in length from 220 to 360 millimeters.
[83] All figures for Lake Huron are based on an examination of 134 specimens ranging in length from 208 to 371 millimeters.

COMPARISONS[84]

Nigripinnis resembles small *kiyi* and *artedi* most closely.

Small *nigripinnis* can be distinguished from *kiyi* probably only by the usual absence of black on the ventrals and the lighter pigmentation of the other ventral fins and by the fewer gill rakers, which in the former are (40) 46–50 (52) and in the latter (34) 36–40 (44), with 24 per cent more than 39. The state of development of ova in females might also serve to aid in separating the species at certain seasons, as *nigripinnis* spawns probably at least a month later than *kiyi*.

From *artedi*, *nigripinnis* is distinguished always by the body shape, as seen from the side, and the softer, more oily flesh. The body of the blackfin typically is deepest anteriorly, so as to be somewhat ovate in side view, and in the herring is more nearly elliptical. The common form of *artedi* has a smaller head and maxillary and shorter paired fins, but none of these differences hold for the Cutler race. A comparison of these characters follows:

L/H:
- *nigripinnis*, (3.7) 4–4.2 (4.4).
- *artedi*, (4) 4.3–4.6 (5), with 57 per cent more than 4.4.

H/M:
- *nigripinnis*, (2.4) 2.5–2.6 (2.7), with 16 per cent more than 2.6.
- *artedi*, (2.6) 2.8–3 (3.3), with 96 per cent more than 2.6.

Pv/P:
- *nigripinnis*, (1.2) 1.4–1.7 (1.9), with 1 per cent more than 1.8.
- *artedi*, (1.7) 2–2.2 (2.6), with 92 per cent more than 1.8.

Av/V:
- *nigripinnis*, (1) 1.1–1.4 (1.6), with 1 per cent more than 1.5.
- *artedi*, (1.4) 1.6–1.8 (2.1), with 90 per cent more than 1.5.

The fins of *nigripinnis* are, as a rule, much darker than of any *artedi* except those around Cutler. However, there is little occasion for confusing the two species in the field, as only stragglers of *artedi* are found off the shoals and *nigripinnis* is found rarely at depths of less than 60 fathoms.

Nigripinnis is compared with the other species of Leucichthys occurring in Lake Huron under the heading "Comparisons" in the accounts of these species.

GEOGRAPHICAL DISTRIBUTION

Table 42 contains all my data on the occurrence of the blackfin in Lake Huron. Figure 5 shows these data plotted on the chart of Lake Huron.

Lake Huron proper.—The records from the chub nets show the blackfin to occur in the same localities in the lake as do the other species of chubs. The same conclusion regarding distribution is warranted for this form, therefore, namely, that it ranges throughout the deeper waters of Lake Huron.

North Channel.—No specimens have been seen from the North Channel. The fishermen report chubs from this region (see p. 373), but they are not blackfins, according to these reports. Most fishermen are able to distinguish the blackfin from the other three species of chubs, and it is reasonably sure, therefore, that these reports are correct.

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[84] Figures given in this section are for all collected specimens except those of *artedi*, which are given for those specimens 225 millimeters or more in length, not including specimens of *manitoulinus*.

Georgian Bay.—Records 23 to 28 show the blackfin to occur with the other chubs in Georgian Bay at depths similar to those in which it occurs in Lake Huron.

From these data the conclusion may be reached that the blackfin occurs in the deeper waters of Lake Huron and Georgian Bay.

BATHYMETRIC DISTRIBUTION

There are no records of the occurrence of the blackfin in any of the net lifts examined by me from less than 35 fathoms. (See p. 374.) At depths of 35 to 100 fathoms it has been found by the chub nets. No catches were seen from more than 100 fathoms, but it is likely that the blackfin does occur beyond this limit, inasmuch as record 20 shows a huge haul of chubs from 80 to 100 fathoms, most of which were blackfins.

RELATIVE ABUNDANCE

At Cheboygan, Mich., on July 21, 1917, at Rogers, Mich., on July 24, 1917, and at Harbor Beach, Mich., on October 27, 1917 (records 1, 2, and 22), the specimens collected were the only ones seen. At all these ports the fishermen distinguish the blackfins from the other chubs, and all agree that the species is met rarely in their waters. On September 28 and 29, 1917, at Cheboygan, and on October 14, 1917, at Rogers, on the spawning grounds of *zenithicus* no blackfins were seen. Off Alpena, Mich., the tugs brought in blackfins more or less abundantly. From the center of the lake northeast of the can buoy, in 60 to 80 fathoms, on September 10, 1917 (record 5), September 14, 1917 (record 7), and September 17, 1917 (record 8); August 30, 1919, 18 miles N. by E. ½ E. from Thunder Bay Island (record 14); September 3, 1919, 28 miles E. ¼ S. from the can buoy in 60 to 64 fathoms (record 15); in 60 to 70 fathoms on August 7, 1920, 19 miles NE. ½ N., on June 30, 1923, 17 miles NE. by N. ¾ N., and on July 7, 1923, 13 miles NE. ½ N. of Thunder Bay Island (records 16, 18, and 21), blackfins comprised 5 to 24 per cent of the catches. From the center of the lake east of the can buoy in 65 to 80 fathoms on September 7, 1917 (record 4), September 12, 1917 (record 6), September 21, 1917 (record 9), September 24, 1917 (record 10), September 26, 1917 (record 11), October 17, 1917 (record 12), and October 20, 1917 (record 13), blackfins comprised 30 to 63 per cent of the catches. Three lifts made in 1923—on June 28, 19 miles northeast of Thunder Bay Island in 60 to 70 fathoms; July 2, 20 miles E. by N. of the can buoy in 60 to 70 fathoms; and on July 5, 18 miles NE. ¾ E. of Thunder Bay Island in 80 to 100 fathoms (records 17, 19, and 20), all lifts of over a ton—contained 75 to 90 per cent of blackfins. In Georgian Bay at Lions Head, Ontario, on July 30, 1919, only a straggler appeared in the haul made 21 miles east of Surprise Shoal in 60 fathoms (record 23). On October 6, 1919, off White Bluff in 70 fathoms most of the fish in a lift of 425 pounds were blackfins (record 24). On July 28, 1919, in a gang lifted off Cape Croker from 52 fathoms four blackfins were taken (record 26).

From all these data it appears that the blackfin is found in varying numbers in the chub lifts made at depths of 35 to 100 fathoms. Neither the 4½-inch, 1½-inch, nor the special 2¾-inch nets (see p. 374) have revealed it in less than 35 fathoms. From 35 to 50 fathoms few are taken in the chub lifts. The greatest proportion occurs in lifts from 60 to 100 fathoms. The proportion is highest in those lifts from Lake Huron that were made in 1917 in the center of the lake east of Alpena and in 1923, 17 to 20 miles northeasterly from Thunder Bay Island, and in these lifts it may be as high as 90 per cent. In Georgian Bay the only lift in which blackfins were abundant was made from 70 fathoms. The blackfin thus seems to reach its maximum density at depths of 60 fathoms and more. This conclusion agrees with accounts of its habits in Lake Michigan.

BREEDING HABITS

It is not known that anyone has taken the fish on their spawning grounds in Lake Huron or Georgian Bay. From the condition of the ovaries of females examined as late as the middle of October, and from the occurrence of faint pearls on the row of scales below the lateral line in a single male taken at Lions Head, Ontario, on October 6, 1919, and one at Alpena on October 17, 1917, it appears that spawning does not take place before November. It may be deferred even until the last of December, as in the Lake Michigan form.

As in *johannæ*, some females often are taken which show undeveloped ovaries while the ova in the majority of the females of the species are approaching maturity. On September 21, 1917, out of 37 females examined 13 were nonspawning. (See p. 361.) These nonspawners ranged from 26 to 29 centimeters in length, the 24 spawners from 23 to 33 centimeters. On October 17, 1917, out of 43 females 12 were nonspawning and ranged from 25 to 29 centimeters in length; the remainder from 21.5 to 34 centimeters in length. On October 20, 1917, out of 41 females 11 were nonspawners of 26 to 31 centimeters and 30 were spawners 22.5 to 35 centimeters. The percentage of such sexually immature fish is too high to class the phenomenon as an abnormality, but an understanding of its significance must wait on knowledge of the rate of growth and age at maturity of the species.

FOOD

Stomachs have been examined from 56 individuals collected off Alpena, Mich., in September and October, 1917, and from two taken in Georgian Bay off Lions Head on October 6, 1919, all from depths of more than 60 fathoms. Mysis comprised almost the sole food of all specimens. In one or two stomachs a trace of plant fragments and of adult insects or a fish scale was found.

Leucichthys nigripinnis cyanopterus Jordan and Evermann, of Lake Superior

THE BLUEFIN (FIG. 20)

The *nigripinnis* of Superior differs in many tehnical characters from the typical form, but the description of the body and its parts given for the type is applicable except as noted hereafter. The numerical expressions of the chief characters of the two forms are summarized for comparison chiefly from the data given in Tables 6 to 11.

Gill rakers on the first branchial arch:
- Michigan, (41) 46–50 (52).[85]
- Superior, (36) 38–42 (48).[86]

Lateral-line scales:
- Michigan, (74) 80–87 (89).
- Superior, (73) 79–86 (91).

L/H:
- Michigan, (3.8) 4.1–4.4 (4.7).
- Superior, (3.7) 3.9–4.2 (4.4).

H/E:
- Michigan, 4–4.4 (4.6).
- Superior, (4) 4.3–4.6 (5.2).

H/S:
- Michigan, 3.5–3.9 (4.1).
- Superior, (3.2) 3.4–3.7 (3.9).

Pv/P:
- Michigan, (1.5) 1.6–1.8 (2.2).
- Superior, (1.4) 1.6–1.8 (2.2).

Av/V:
- Michigan, 1.2–1.5 (1.6).
- Superior, (1.1) 1.3–1.5 (1.7).

$\frac{HD+AB}{M+S}$
- Michigan, (1.55) 1.75–1.85 (2).
- Superior, (1.45) 1.65–1.75 (1.85).

L/D:
- Michigan, (3.2) 3.4–3.9 (4.3).
- Superior, (3.2) 3.6–4.3 (4.6).

The most striking differences shown by these figures are the reduction in the number of gill rakers on the first branchial arch, the longer head and snout, the smaller eye, and less body depth in the Lake Superior specimens. In addition, the mandible, which is usually equal to or longer than the upper jaw in the typical form, is as often shorter as equal to the upper jaw and is but seldom decidedly longer.

This form was described by Jordan and Evermann (1909) as a new species. Their type is a specimen taken off Marquette, Mich. (No. 64672, U. S. National Museum). It is described in most of its characters in Table 45. The reasons for regarding it as a subspecies are discussed on page 331.

The color in life is less pronounced than in the Lake Michigan form, the coloration in general being not very different from that recorded for *zenithicus* of Superior. Preserved specimens of this race show less pigment, especially on the fins, than preserved specimens from Lake Michigan. The distal ends of the pectoral rays are paler, and the ventrals are immaculate in over 60 per cent of the specimens collected. Concentration of pigment in front of the nares is less frequent in the Lake Superior specimens.

Males and at least some females develop pearl organs in the breeding season. Pearled individuals were collected off Grand Marais, Mich., on October 3, 1917, and off Rossport, Ontario, on October 4, 1921. The development of nuptial excrescences is much like that described for *johannæ* on page 350.

VARIATIONS

Racial variations.—There are too few specimens from any locality for a study of local variations. The specimens at hand, however, grouped according to locality, do not indicate any marked difference between the groups.

Size variations.—There is only one specimen smaller than 200 millimeters, so that juveniles can not be compared with adults. Sixty-six specimens 30 centimeters and more in length, when compared with 102 smaller individuals, showed only a somewhat shorter head, smaller eye, greater depth, and shorter paired fins.

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[85] These and other figures for Lake Michigan are based on an examination of 52 specimens ranging in length from 220 to 360 millimeters.

[86] These and succeeding figures for Lake Superior are based on an examination of 168 specimens ranging in length from 198 to 375 millimeters.

COMPARISONS [87]

The bluefin can be confused only with *zenithicus*. A discussion of the differences between these species may be found on page 380. An account of the differences between *nigripinnis* and *reighardi* is given on page 411.

Only small examples can be confused with *hoyi* and *kiyi*, as the latter do not grow large. There are too few *nigripinnis* of a size comparable with these species for contrasting of characters affected by growth. Small *nigripinnis* may be distinguished from both by the shorter mandible (which seldom is distinctly superior in this form), the thicker belly walls, and the more decurved dorsal margin of the pectorals. They may be separated further from *hoyi* by the more numerous lateral-line scales, which in *nigripinnis* number (73) 79–86 (91), with 87 per cent more than 78, and in *hoyi* (65) 69–78 (84), with 7 per cent more than 78; by the smaller average number of gill rakers on the first branchial arch; the greater average number of scale rows; and by the less elliptical body outline, as viewed from the side. The paired fins of small *nigripinnis* probably will be found to average considerably shorter than those of *kiyi*.

From *artedi*, *nigripinnis* usually is separable by its softer, more oily flesh; the body shape, which is ovate, as seen from the side, as compared with the elongate elliptical form in *artedi*; its fewer gill rakers on the first branchial arch; and by its longer paired fins, head, and maxillary. Some of these characters are compared fully below:

Gill rakers on the first branchial arch:
- *artedi*, (41) 45–48 (53), with 87 per cent more than 44.
- *nigripinnis*, (36) 38–42 (48), with 2 per cent more than 44.

L/H:
- *artedi*, (4.1) 4.3–4.6 (5.1), with 80 per cent more than 4.3.
- *nigripinnis*, (3.7) 3.9–4.2 (4.4), with 2 per cent more than 4.3.

H/M:
- *artedi*, (2.5) 2.7–3 (3.1), with 70 per cent more than 2.7.
- *nigripinnis*, (2.3) 2.5–2.7 (2.8), with 3 per cent more than 2.7.

Pv/P:
- *artedi*, (1.7) 2–2.2 (2.8), with 84 per cent more than 1.9.
- *nigripinnis*, (1.4) 1.6–1.8 (2.2), with 5 per cent more than 1.9.

Av/V:
- *artedi*, (1.3) 1.6–1.8 (2.3), with 91 per cent more than 1.5.
- *nigripinnis*, (1.1) 1.3–1.5 (1.7), with 6 per cent more than 1.5.

L/D:
- *artedi*, (3.7) 4.3–5 (5.9), with 80 per cent more than 4.3.
- *nigripinnis*, (3.2) 3.6–4.3 (4.6), with 5 per cent more than 4.3.

In addition, *nigripinnis* has, on the average, the margin of the pectoral more decurved, a longer snout, and fewer lateral-line scales. It spawns in September, while *artedi* spawns in late November, so that the state of development of the sex organs also may aid in separating specimens of the two forms.

GEOGRAPHICAL DISTRIBUTION

Data on the occurrence of the bluefin in Lake Superior, which are presented in Table 44 and shown platted on the chart in Figure 3, have been derived, for the most

[87] Figures given in this section for proportions are for specimens chiefly over 225 millimeters in length. Counts are given for specimens of all sizes.

part, from the use of special 2½ and 2¾ inch nets set out of various ports on the lake and are supplemented by the testimony of various fishermen. These records, 26 in number, show that the bluefin formerly was taken in commercial quantities out of many ports on the lake and that they still occur, if only sparingly, in suitable areas of the lake.

BATHYMETRIC DISTRIBUTION

The special nets used in the survey of the lake, which were set at depths of 15 to 100 fathoms (see p. 382), took at least one specimen of *nigripinnis* at every set excepting one set off Ontonagon, Mich., and those sets made in 1923 in the bays and straits along the north shore. A few specimens also have been found in the 4½-inch nets set along the shore banks (records 10, 15, 18, 22, and 25). It is certain, therefore, that a few individuals, at least, stray into the shallower waters. The records do not indicate the maximum depths at which the species occurs, but the testimony of the commercial fishermen who at one time fished for the species establishes 100 and 110 fathoms as the greatest depths at which nets were set. The general chart of Lake Superior shows that much of its area is overlaid by more than 100 fathoms of water (a depth of 196 fathoms is known), but the fishermen do not set nets at greater depths on account of the strain on them in lifting and on account of the effect of the extreme pressure on their floats. It is safe, however, to predict that if fish were abundant in the deepest water, the nets would be placed there, and it is certain, therefore, that the center of abundance of the bluefin is or was in less than 100 fathoms. There are various conjectures as to what may inhabit the deepest waters, but there are few data on that point. Mr. Parker, of Marquette, informs me that once, northwest of Stannard Rock, his gang of 4½-inch trout nets fell into a hole that flattened the corks on half a mile of his netting and that these nets caught no other fish than the lawyer (*Lota maculosa*), but that the lawyer was abundant. (The chart shows a maximum sounding of 115 fathoms for this area, though a greater depression of small extent might occur easily.)

One may conclude from the foregoing that the bluefin ranges from 15 fathoms into more than 100 fathoms, but that the maximum density is to be looked for nearer the upper limit.

RELATIVE ABUNDANCE

In none of the lifts did the bluefin occur more than casually, but it is possible that the nets employed were of too small mesh to take the fish. The fishermen in Superior found that nets could not take bluefins in commercial quantities if they were of smaller mesh than 3¼ inches, and the experience of Michigan and Ontario fishermen has been the same for the *nigripinnis* of these lakes. It would appear that the smaller individuals of the species did not school with the largest examples or kept farther above the bottom. In lifts made from gangs extending into less than 60 fathoms, off Iroquois Light on June 14, 1922, in 38 fathoms (record 1), off Marquette, Mich., on August 8, 1921, in 42 to 65 fathoms (record 5), off Ontonagon, Mich., on August 25, 1921, in 20 to 38 fathoms (record 11), among the Apostle Islands on July 11, 1922, in 15 to 20 fathoms (record 13), off Duluth, Minn., on July 17, 1922, in 30 to 40 fathoms (record 16), and off Grand Marais, Minn., on September 14, 1921, in 30 to 65 fathoms (record 17), bluefins made up not more than 3 per cent of the catches, and the sets showed a maximum of 0.5 fish per night per thousand feet of net. When the gangs extended from 60 fathoms to greater depths bluefins were less rare. Lifts made off Marquette, Mich., on August 11, 1921, in 100 to 80 fathoms (record 6), off Rossport, Ontario, on October 4, 1921, in 80 to 90 fathoms (record 20), off Michipicoten Island, Ontario, on June 22, 1922, in 80 fathoms (record 23), and off Alona Bay, Ontario, on June 26, 1922, in 60 fathoms (record 26), showed from10 to 21 per cent of bluefins and from 1 to 6 fish per night per thousand feet of net. The records from the 4½-inch trout nets in 60 fathoms and deeper (records 2 and 4) show 25 and 10 specimens per gang, while those in or bordering on shallow water (records 10, 14, 15, 18, 22, and 25) took from 1 to 6 specimens per gang.

My findings that the bluefin prefers depths of more than 60 fathoms are corroborated by the statements of fishermen who over a period of years fished bluefins exclusively out of Grand Marais, Marquette, and Ontonagon in Michigan, Grand Marais in Minnesota, and off Michipicoten Island in Ontario (records 3, 9, 12, 19, and 24). These men all agree that the species occurred most abundantly throughout the fishing season, which extended from April to November, between 60 and 100 or 110 fathoms.

Whatever factors determine the vertical distribution of the bluefin, it is clear that temperature is not the only one, unless it be that the species prefers to inhabit a zone of practically constant temperature, such as probably obtains along the bottom in the deeper waters. The data in Table 13 indicate that in mid-June and up to July the bottom waters to a depth of at least 25 fathoms are not warmer than 4°, the temperature of the maximum density of water, and may be even colder. During August, though the thermocline appears to be relatively near the surface, there is evident a slight effect of warming down to 54 fathoms. In 60 fathoms and deeper there is probably no warming above 4°. The bluefins seldom are taken shallower than 60 fathoms and may spend their lives in water of nearly constant temperature, little influenced, at least directly, by the seasonal temperature fluctuations that affect the upper layers of the water.

It has been intimated in the preceding discussion that the bluefins are no longer of commercial significance in Lake Superior, but it once occurred there abundantly. It has been possible to record some facts of their history, which the various fishermen who were at one time engaged in fishing them have been able to supply from memory. Definite dates given in the testimony have been fixed by association with significant events in the life of the narrator and have been accepted without further research. The first bluefins on the American shore, so far as I can learn definitely, were taken out of Ontonagon, Mich., about 1897. They are recorded in the statistics of the Bureau of Fisheries for that year. The Booth Fisheries Co., according to two of its pilots (McArthur and McMillan), began to take the fish out of Michipicoten Island about 1900. Out of Marquette, Mich., a fishery was started by W. J. Parker in 1901. At Grand Marais, Minn., James Scott first fished them in 1903. They were produced out of other ports at about the same time, but no definite dates are available.

For several years the bluefins supported a lucrative fishery. The tugs, in a gang of the 3¼ to 3¾ inch nets, which were used exclusively, often made hauls of 2 or 3 tons; but, strange enough, the fish ceased to be economically important at about the same time out of all the ports. The Booth Co. discontinued its small-meshed nets in 1903; but the fish were not gone then, because they are said to have been taken abundantly in the 4½-inch ciscowet nets for a few succeeding years. Mr. Scott says that in 1906 they were noticeably scarcer than in the preceding years, but that they could still be taken in paying quantities. Mr. Parker states that in the fall previous to their disappearance they were still fairly numerous, but that there were none in the following spring. They seem to have been taken last out of Ontonagon and Grand Marais, Mich., but since about 1907 no industry has depended on the bluefin alone.

It is not certain what factors contributed to bring about the decline of the species. Unless most of the individuals of the species do not become sexually mature until they attain a length of 10 inches, it is strange that intensive fishing should have affected their abundance so soon. The nets employed would hardly take a fish of smaller size, and in theory it appears judicious to permit the use of a mesh that will take only the largest examples of the species. Furthermore, there were vast areas, especially along the Canadian shore, in which the bluefins were not exploited, and it would be expected that the lake would be restocked from the surplus of these areas if overfishing alone were responsible for their decrease. Latterly no bluefin nets have been tried, and it would be interesting to know if the bluefins are becoming more abundant on the American side and if they occur in their original abundance on the Canadian shore. I have pointed out already in various connections that the nets I used in the survey of the Leucichthys fauna of the lake were too few, probably of unsuitable mesh, and necessarily were employed too much at random to give conclusive results on the present status of the species.

BREEDING HABITS

Pearled males and females spent, spawning, or nearly ripe were collected out of Grand Marais, Mich., on October 3, 1917, in 65 fathoms and deeper (record 2) and out of Rossport, Ontario, on October 4, 1921, in 80 to 90 fathoms (record 20). It is not possible to state, of course, that the nets in either case were lifted from the spawning grounds of the species, but the state of development of the sex organs of the individuals taken indicates, at least approximately, the time of spawning and furnishes corroboration of the statements of the fishermen who once fished for the species. Mr. Parker and Mr. McLean, of Marquette, Mich., and Mr. Scott, of Grand Marais, Minn., state that the bluefins spawned during September on the grounds they frequented during most of the year at depths of 60 to 100 fathoms. Mr. Desjardins and Mr. Macdonald, of Grand Marais, say that the bluefins were most abundant out of that place in September, which would indicate that there was also a spawning run at that time out of that port.

Leucichthys nigripinnis regalis (new subspecies) of Lake Nipigon

The Nipigon blackfin is like the typical form in respect to body shape and general appearance. The main differences are numerical, and the values for certain characters are summarized below for comparison:

Gill rakers on the first branchial arch:
- Michigan, (41) 46–50 (52).[88]
- Nipigon, (44) 48–51 (54).[89]

Lateral-line scales:
- Michigan, (74) 80–87 (89).
- Nipigon, (66) 70–77 (81).

L/H:
- Michigan, (3.8) 4.1–4.4 (4.7).
- Nipigon, (3.6) 3.8–4.1 (4.4).

H/E:
- Michigan, 4–4.4 (4.6).
- Nipigon, (3.5) 3.7–4.1 (4.3).

H/S:
- Michigan, 3.5–3.9 (4.1).
- Nipigon, (3.4) 3.6–3.8 (4.3).

Pv/P:
- Michigan, (1.5) 1.6–1.8 (2.2).
- Nipigon, (1.2) 1.4–1.6 (1.9).

Av/V:
- Michigan, 1.2–1.5 (1.6).
- Nipigon, (1.1) 1.2–1.5 (1.7).

L/D:
- Michigan, (3.2) 3.4–3.9 (4.3).
- Nipigon, (3.1) 3.5–4 (4.5).

The figures indicate that the Nipigon form has, on the average, somewhat more gill rakers on the first branchial arch, many less scales in the lateral line, a larger head and eye, and longer pectorals. In addition to fewer scales, there are also, on the average, two less scale rows, so that around the body in front of the dorsal and ventrals there are usually 40 to 42 [90] rows, in front of the adipose and anus 31 to 33,[90] and around the caudal peduncle at its commencement 22 to 23.[90] The dorsal margin of the pectoral is usually straight instead of decurved. Comparison of specimens in Tables 41 and 47 shows a greater value in Nipigon specimens for the height of the anal fin divided by its base length (AC).

The race appears to be sufficiently distinct to merit designation, and I propose to name it *regalis*. Specimen No. 57416 of Table 47 is designated as the type. It is catalogued in the United States National Museum as No. 88354.

The color in life is similar to that of the typical race, except that the back is not pigmented so heavily and the underlying color is therefore less obscured. All the fins are invariably conspicuously black; the membranes have a trace of sepia, strongest at the bases and becoming pinkish at the bases of the abdominal fins. In spirits specimens seem to average blacker on the fins than the Lake Michigan specimens.

Pearl organs probably are developed by the breeding males, but no specimens taken in the breeding season have been examined.

VARIATIONS

No specimens are available for the study of local variations. Only six specimens smaller than 200 millimeters have been examined, and most of these are so imperfect that their proportions have not been tabulated. The two of this class that have been included in Table 47 show the same kind of differences when compared with longer specimens, as the group of 151 specimens 200 to 290 millimeters in length compared with 69 over 290 millimeters long. The first group showed, on the average, a slightly larger head and eye, slightly longer paired fins, and less body depth than the longest fish.

Specimens smaller than 230 millimeters in length have been found to be sexually immature, and often specimens 250 millimeters long were immature.

[88] These and other values given for Lake Michigan are based on an examination of 52 specimens ranging in length between 220 and 360 millimeters.

[89] These and succeeding figures for Lake Nipigon, unless marked otherwise, are based on an examination of about 230 specimens ranging in length from 204 to 355 millimeters.

[90] Twenty-six specimens.

COMPARISONS [91]

Nigripinnis regalis approaches most closely *nipigon*. The chief differences are in the number of gill rakers on the first branchial arch, which in the former are not known to number more than 54 and in the latter not less; in the body shape, which is usually strongly ovate in side view in the former and elliptical in the latter; and in the relative size of the eye as compared with the head. The value of H/E for *nigripinnis* is (3.5) 3.7–4.1 (4.3) and for *nipigon* (3.8) 4.4–4.6 (5.2), with 71 per cent more than 4.3. The blackfin is pigmented much more heavily as a rule, especially on the abdominal fins.

A discussion of the difference between *nigripinnis* and *zenithicus* and *reighardi* is given on pages 386 and 407.

Only small *nigripinnis regalis* are comparable with *hoyi*, as *hoyi* does not attain great size. The two species are always distinguishable by the more ovate body shape of the former, by the much heavier pigmentation of body and fins and by the greater number of gill rakers on the first branchial arch, which in *nigripinnis* number (44) 48–51 (54), with 68 per cent more than 48, and in *hoyi* (40) 42–46 (48).

Nigripinnis regalis differs from *artedi* in body shape, which is ovate in side view in the former and elliptical in the latter; in the longer paired fins and maxillary, and the deeper body, as is indicated by the following figures:

Pv/P:
- *nigripinnis*, (1.2) 1.4–1.6 (1.9), with 33 per cent more than 1.5.
- *artedi*, (1.5) 1.6–1.8 (2), with 96 per cent more than 1.5.

Av/V:
- *nigripinnis*, (1.1) 1.2–1.5 (1.7), with 7 per cent more than 1.5.
- *artedi*, (1.3) 1.5–1.6 (1.7), with 47 per cent more than 1.5.

H/M:
- *nigripinnis*, (2.4) 2.5–2.6 (3), with 14 per cent more than 2.6.
- *artedi*, (2.5) 2.7–2.8 (3), with 87 per cent more than 2.6.

L/D:
- *nigripinnis*, (3.1) 3.5–4.0 (4.5), with 10 per cent more than 4.
- *artedi*, (3.8) 4.1–4.6 (5), with 88 per cent more than 4.

Artedi is also less pigmented, especially on the paired fins, which are never conspicuously black as in *nigripinnis*.

GEOGRAPHICAL DISTRIBUTION

All the records of specimens taken by me and of those examined from the University of Toronto collection are given in Table 46 and are shown platted on the lake chart in Plate 2. They show that the species has been taken in each of the three lifts of the 2½ and 2¾ inch nets made by me and that individuals also have been obtained from numerous other localities, even in the commercial whitefish nets. It is probable, then, that the species occurs throughout the lake where suitable conditions obtain.

BATHYMETRIC DISTRIBUTION

My records show that the species was taken commonly on July 25, 1922, in 10 to 15 fathoms off the source of the Nipigon River, but more abundantly July 26,

[91] The specimens compared in this section for proportions are those 200 millimeters or more in length, except *artedi*, which are 225 millimeters or more. Counts are given for specimens of all sizes.

1923, in 30 fathoms off Macdiarmid (records 19 and 2). The relative abundance of this and other species of Leucichthys in these two lifts is given on page 409. In the lift made on July 28, 1922, in 56 fathoms, 2½ miles south of Livingston Point, only three specimens were taken, though the same kind and about half the quantity of netting was used as on the other two dates (record 6).

John McIver, Mr. Walsh, and Mr. McKay, who have fished on the lake for several years, state that the species is taken in their 4½-inch whitefish nets most commonly in 20 to 40 fathoms throughout the fishing season. The moon-eye, as the fishermen term the fish, evidently is common in Lake Nipigon, but no nets designed to take it for commercial purposes are employed.

BREEDING HABITS

It is not known when or where the species spawns. None of the specimens obtained on October 26, 1922, at the close of the commercial fishing season on the lake (record 24) showed mature sex organs. The spawning time is probably in winter.

Leucichthys nigripinnis prognathus Smith, of Lake Ontario

I have been able to find no other specimen, either by search in museums or by exploration in Lake Ontario, than the type specimen of Smith 297 millimeters long (No. 45568, U. S. National Museum). The catalogue gives no date or locality other than "Lake Ontario."

The specimen is figured in Figure 21, and certain proportions and counts of multiple parts are given in Table 45. In body shape it agrees closely with the typical blackfin. It is much less pigmented throughout than any known race of blackfin. The abdominal fins are immaculate, or nearly so, and the caudal has only an indication of black on the tips of the rays. The maxillary is pigmented. The mandible is about equal in length to the upper jaw.

GEOGRAPHICAL DISTRIBUTION

Only the statements of the fishermen give any clue to the former distribution of the species in the waters of Lake Ontario. It is inferred from their accounts of a fish attaining large size, inhabiting deep water, and spawning in early winter that this fish was *prognathus*. From this testimony it appears that the fish was taken commonly out of various ports on the south and west shores of the lake. The species probably was distributed throughout the deep waters.

BATHYMETRIC DISTRIBUTION

The fishermen say that the best bloater fishing was at depths of 60 fathoms and more, though at times, at least, smaller quantities could be taken near shore.

ABUNDANCE

I quote Koelz (1926, p. 606) on the history of the species:

> The first fishery for bloaters was carried on out of Oswego about 1875. A fisherman operating out of that port found a few individuals in the outer ends of his whitefish gangs and conceived the idea that it might be profitable to fish them. The fish were sold fresh and were so much in demand that at one time there were several boats engaged exclusively in bloater fishing out of that port.

The industry gradually spread to the westward, and by 1890 bloaters were being taken out of Wilson. At first they were extremely abundant, and it was never necessary, in American waters, to use a net of smaller mesh than 3 inches, and usually the mesh employed was 3½ inches, but before 1900 the bloater was commercially exterminated, and efforts to revive the industry since then have met with absolute failure. Repeated efforts to locate these fish, made by me in the summers of 1921 and 1923, failed, and not a single specimen was found, so that it appears likely that the species is extinct. No cause for its extermination suggests itself. At no time were any but the largest examples of the species taken, and so far as known it had no important vertebrate enemies. The case has close parallels in the related blackfin of Lake Michigan and the bluefin in Lake Superior, which suddenly became commercially insignificant, though not extinct, under identical conditions.

BREEDING HABITS

George Jones, of Sodus Point, N. Y., and Paul Methot, of Oswego, N. Y., who claim to have fished bloaters longest, state that the fish moved somewhat shallower, to depths of 40 to 50 fathoms, in the spawning season. They spawned in January.

LEUCICHTHYS KIYI Koelz

THE KIYI (FIG. 22)

Leucichthys kiyi Koelz, 1921, Lakes Michigan, Huron, and Superior.

Leucichthys kiyi has been described from Lake Michigan and is known to occur also in Lakes Superior, Huron, and Ontario. It is characterized everywhere by its relatively small size (the individuals of Superior and Huron appear to be especially dwarfed and seldom have been seen larger than 20 centimeters), thin body (which is ovate in side view), and relatively long paired fins. It everywhere prefers deep water and usually is found at depths of 60 fathoms or more. The Superior form differs from the type form chiefly in attaining less size, in having somewhat fewer scales in the lateral line, longer pectoral fins, and possibly an average larger head and eye. It spawns in late November, also, as compared with October, which is the supposed spawning time for the Michigan form. The Huron race differs from the typical race chiefly in that it appears seldom to grow so large. The spawning time in Huron in unknown, but it seems to be somewhat later than in Michigan. Ontario specimens differ most of all from those of Michigan, and the Ontario race has been designated here *orientalis*. They have many more gill rakers on the first branchial arch, much shorter paired fins, and a somewhat shorter head. The spawning season in Ontario apparently falls in August.

The type is a female specimen (catalogue No. 84100, U. S. National Museum), 191 millimeters in length to the base of the caudal, collected in Lake Michigan on August 23, 1920, 12 miles E. by S. of the mouth of the Sturgeon Bay ship channel in 60 to 70 fathoms of water.

Leucichthys kiyi kiyi of Lake Michigan

The kiyi is one of the smallest chubs. Extreme examples selected from hundreds of specimens in the field measure only 245 millimeters. The fish are thin as well as small and therefore are not esteemed by the fish smokers. The body is fusiform, slightly more compressed than in other members of the genus, and, as in *johannæ* and *nigripinnis*, its only associates of the deeper waters, the depth is distinctly greatest in front of the dorsal fin. This dimension in the type specimen com-

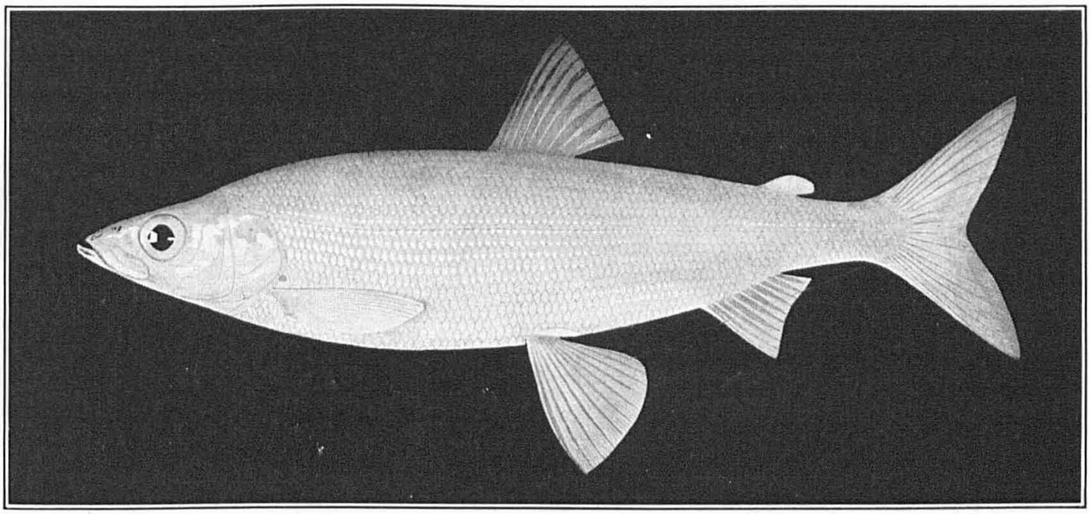

FIG. 22.—*Leucichthys kiyi* Koelz, the kiyi. Female (type), 191 millimeters long, taken in Lake Michigan off the Sturgeon Bay ship channel mouth in 60 to 70 fathoms on August 23, 1920

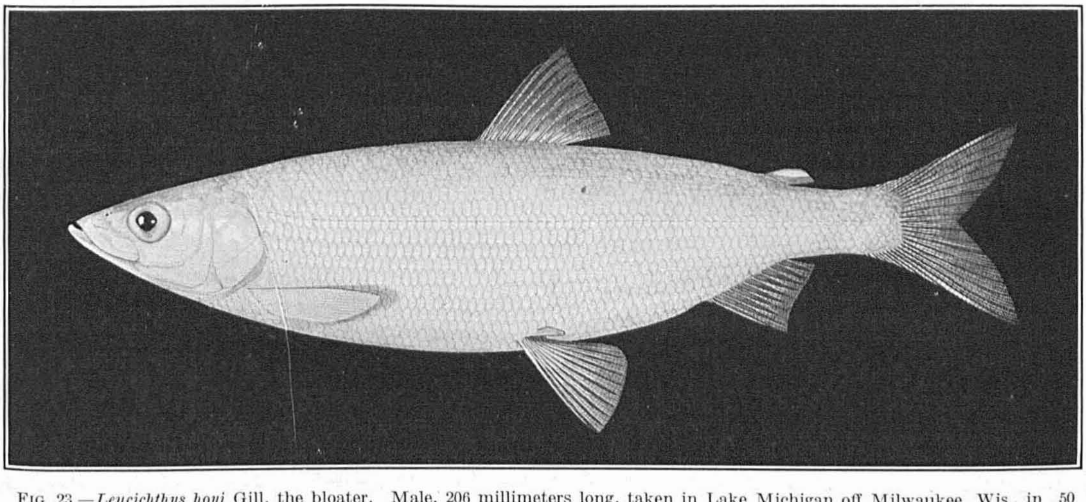

FIG. 23.—*Leucichthys hoyi* Gill, the bloater. Male, 206 millimeters long, taken in Lake Michigan off Milwaukee, Wis., in 50 fathoms on March 24, 1919

prises 24 per cent of the body length. At the occiput the dorsal profile rises in a smooth curve over half the distance to the dorsal and continues to the dorsal with only a slight upward trend. From the dorsal the contour slopes gently to the caudal peduncle. The ventral profile from the tip of the mandible to the ventral fins runs like the opposite dorsal contour, curving strongly downward and backward for two-thirds its extent and extending to the ventrals over its remaining one-third in a line nearly parallel to the lateral line. From the ventrals to the anal the contour converges distinctly toward the lateral line. The head is rather elongated and is contained 4 [(3.7) 3.8–4.1 (4.3)] [92] times in the total length.

Its dorsal profile runs in a faint but distinct convex curve to a point above the center of the orbit and from thence to the occiput is often more or less concave in its course. The premaxillaries are directed forward and make an angle of about 50° with the horizontal axis of the head. The snout is always longer than the large eye, which is contained 3.9 [(3.6) 3.8–4.2 (4.3)] times in the head. The maxillary is pigmented and extends beyond the anterior edge of the pupil but never to its center. The mandible is rather frail and usually projects beyond the upper jaw. Seldom is it shorter. The gill rakers on the first branchial arch are relatively short; they number 15+25 [(11) 13–15 (17)+(21) 23–26 (27)=(34) 36–41 (45)].[93] The scales in the lateral line number 85 [(71) 77–87 (91)]; 82 per cent of all the specimens examined have 79 or more scales. Rows of scales around the body just in front of the dorsal and ventrals number 46 [(39) 41–44 (46)]; [94] just in front of the adipose and anus 37 [(32) 33–35 (37)]; [94] around the caudal peduncle at its commencement 26 [(23) 24–25 (26)].[94] The dorsal rays are 10 [9–10 (11)]; [95] the anal rays 11 [(9) 10–12 (16)]; [96] ventral rays 11 [11–12]; [94] pectoral rays 15 [(15) 16–17 (18)].[94] The dorsal margin of the pectoral is usually straight. The pectorals are contained in the distance from their insertion to that of the ventrals 1.6 [(1.1) 1.4–1.7 (2.1)] times. The ventral length divided into the distance from their origin to the insertion of the anal equals 1.2 [(0.96) 1–1.3 (1.4)].

The color in life is about like that of *johannæ*. The underlying color is obscured in the back by the dense pigmentation, which covers nearly uniformly the entire dorsal surface and which also extends over the entire preorbital area, including all but about the distal one-fourth of the maxillary. The dorsal surface of the head in front of the nostrils, likewise the tip of the mandible, are often very dark. Pigment occurs, too, on the sides, abundantly above but only sparsely below the lateral line. The dorsal and caudal fins are rather widely margined with black, most intensely on the median rays of the caudal. The dorsal margin of the pectorals often is lined with black, and the membranes of the anal are frequently sparingly sprinkled with pigment. The ventrals are usually immaculate. In spirits the color fades, leaving obvious the details of pigmentation.

Pearl organs are developed by at least the breeding males, as evidenced by the taking of specimens showing incipient pearls; but no breeding fish have been examined by me.

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[92] The figures in brackets, unless otherwise marked, are given for 174 examined specimens, 120 of them paratypes, which range in length from 122 to 245 millimeters.

[93] Two hundred and twelve specimens.

[94] Twenty-two specimens.

[95] One hundred and fifty-four specimens.

[96] One hundred and forty-four specimens.

VARIATIONS

There are not enough specimens in my collection for a study of local variation, and the examples in the collection are too nearly uniform in size to yield data on changes with growth.

COMPARISONS [97]

Kiyi resembles *nigripinnis* and *hoyi* more closely than any other Leucichthys of the lake. It is contrasted with the former on page 419. It differs from *hoyi* in body shape (which is rather ovate in side view in *kiyi* and elliptical in *hoyi*), in the fewer gill rakers on the first branchial arch, more lateral-line scales, and longer paired fins. The last-mentioned characters are compared below:

Gill rakers on the first branchial arch:
- *kiyi*, (34) 36–41 (45), with 14 per cent more than 40.
- *hoyi*, (37) 41–44 (48), with 86 per cent more than 40.

Lateral-line scales:
- *kiyi*, (71) 77–87 (91), with 88 per cent more than 77.
- *hoyi*, (60) 67–77 (84) with 7 per cent more than 77.

Pv/P:
- *kiyi*, (1.1) 1.4–1.7 (2.1), with 13 per cent more than 1.7.
- *hoyi*, (1.3) 1.7–2 (2.5), with 74 per cent more than 1.7.

Av/V:
- *kiyi*, (0.9) 1–1.3 (1.4), with 1 per cent more than 1.3.
- *hoyi*, (1) 1.2–1.4 (1.7), with 33 per cent more than 1.3.

In addition, *kiyi* has a relatively longer head, a narrower body, and, on the average, more pigmentation. The state of development of the sex organs, especially in females, may also be of aid in separating the two forms, as *kiyi* probably spawns in October and *hoyi* in March.

Only the smaller specimens of *artedi* can be confused with *kiyi*, as the latter has not been seen to attain a length of more than 245 millimeters. *Kiyi* has fewer gill rakers on the first branchial arch and longer paired fins. These characters are compared below:

Gill rakers on the first branchial arch:
- *kiyi*, (34) 36–41 (45), with 14 per cent more than 40.
- *artedi*, (41) 46–50 (55).

Pv/P:
- *kiyi*, (1.1) 1.4–1.7 (2.1), with 7 per cent more than 1.8.
- *artedi*, (1.6) 1.8–2.1 (2.5), with 80 per cent more than 1.8.

Av/V:
- *kiyi*, (0.9) 1–1.3 (1.4).
- *artedi*, (1.3) 1.5–1.7 (2), with 93 per cent more than 1.4.

The body shape of *kiyi*, as seen from the side, is more or less ovate, as contrasted with the elliptical form of *artedi*; the body is narrower and less pigmented; the head and maxillary are relatively longer; the lower jaw is usually longer than the upper and the mandible is usually hooked, while in *artedi* it is usually shorter than the upper. *Kiyi* probably spawns about a month earlier than *artedi* (in October), and the state

[97] All figures given under this section are based on an examination of all collected specimens, except proportions for *artedi*, which are given for specimens less than 225 millimeters in length.

of development of the sex organs is at times, therefore, a systematic character in differentiating certain specimens.

A discussion of the differences between *kiyi* and *johannæ, alpenæ, zenithicus,* and *reighardi* is given on pages 352, 365, 390, and 402.

GEOGRAPHICAL DISTRIBUTION

All my records on the occurrence of the kiyi are assembled in Table 48 and are platted on the chart in Figure 4. They are 22 in number, and all but two (which were made from the trout nets) are from examinations of the commercial chub hauls. They show that the species has been taken out of all the ports visited, and it may be concluded that it is distributed generally throughout the lake where suitable conditions obtain.

BATHYMETRIC DISTRIBUTION

All the records of the vertical distribution of the kiyi are derived from an examination of the 2½ and 2¾ inch chub nets, which are set at varying depths in the lake, and the 4½-inch trout nets, usually set in less than 40 fathoms. The shallowest gang that took *kiyi* was of chub nets set in 20 to 35 fathoms (record 7) and of 4½-inch nets set in 28 to 32 fathoms (record 16), and the deepest in chub nets from 71 to 90 fathoms (record 2). In the lifts from shallow water the species was rare, but it was distributed throughout the extent of the deepest gang. It is certain, then, that the species comes into water as shallow as 30 fathoms and possibly shallower, though it never has been seen from the 1½-inch nets set in 26 to 40 fathoms (see p. 354), and it descends into depths of 90 fathoms and probably deeper.

RELATIVE ABUNDANCE

The data on relative abundance of the kiyi are only approximate. Fish were very rare in the 2½ and 2¾ inch nets in 1920 (see p. 354); and the kiyi, being a small species, is not taken so abundantly in the 2¾-inch nets as in those of smaller mesh, so that the percentages of abundance are lower necessarily for the lifts of the 2¾-inch nets. The data, however, all bear the same aspect and probably indicate what would be the result of more careful investigation.

No *kiyi* occurred in the lifts of the 2⅜ to 2¾ inch nets made in Green Bay on August 16, 1920, off Little Sturgeon and 8 miles south of Green Island in 11 and 16 fathoms, and on August 18, 1920, 4 miles west of Boyer Bluff in 18 to 24 fathoms; in Lake Michigan proper on June 22, 1920, off Cathead Light in 40 to 60 fathoms; on August 10, 1923, 8 miles NNW. of Big Rock Point, Mich., in 45 to 50 fathoms; on March 24, 1919, in an unknown location off Milwaukee, Wis.; on September 24, 1920, 9 miles NNE., and on November 15, 1920, 20 miles ESE. of Milwaukee, Wis., in 50, 22 to 25, and 28 to 35 fathoms, respectively; on November 19, 1920, 10 miles NNW. of Michigan City, Ind., in 18 fathoms, and 17 miles NNW. in 28 to 32 fathoms, and 17½ miles NW. by N. ¾ N. in 32 fathoms; on March 2, 1921, 21 miles NNW. and on March 4, 1921, 15 miles NW. by N. ½ N. in 28 to 30 fathoms. The November lifts were made on or near the spawning grounds of *zenithicus* and the March lifts on the spawning grounds of *hoyi*, so that the absence of *kiyi* is not so surprising;

but it is obvious from the data that follow that the sets were probably in too shallow water. The species was rare in examined lifts made on August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms (record 4); on September 3, 1920, 22 miles NW. by N. ½ N. of Michigan City, Ind., in 30 to 40 fathoms (record 9); on October 11, 1920, 20 miles N. by W. ¾ W. in 30 to 40 fathoms (record 10); and on November 8, 1920, 18 miles NNW. in 30 to 38 fathoms (record 11); on July 31, 1923, 5 miles northwest of Cathead Light, Mich., in 40 to 60 fathoms (record 18); on June 29, 1920, 5 miles N. by E. of Charlevoix, Mich., in 40 to 55 fathoms, and on August 11, 1923, 3 miles NW. ½ W. in 35 to 60 fathoms (records 19 and 21); on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms (record 22). It made up 35 to 65 per cent of the catches of the nets lifted on September 25, 1920, 18 miles E. ½ S. of Port Washington, Wis., in 65 to 48 fathoms[98] (record 6); on October 4, 1920, 9 miles north of Point Betsie, Mich., in 60 to 70 fathoms (record 17); on September 23, 1920, 27 miles ESE. of Milwaukee, Wis., in 60 fathoms (record 8); on August 23, 1920, 12 miles E. by S. of the mouth of the Sturgeon Bay ship channel, Wis., in 60 to 70 fathoms (record 3); and on August 19, 1920, 20 miles E. ½ N. of Rock Island, Wis., in 71 to 90 fathoms (record 2). It occurred in lifts made on March 20, 1919, 12 miles west of Grand Haven, Mich., in 50 to 55 fathoms (record 13); May 26, 1922, 8 miles northeast of Port Washington, Wis., in 20 to 35 fathoms (record 7); June 30, 1920, 3 miles northwest of Charlevoix, Mich., in 40 to 65 fathoms (record 20); August 18, 1920, 14 miles E. ¾ N. of Rock Island, Wis., in 30 to 50 fathoms (record 1); August 30, 1920, 17 miles and 12 miles W. ½ S. of Ludington, Mich., in 60 to 70 and 40 to 50 fathoms (records 14 and 15); and on October 1, 1920, 11 miles southeast of Sheboygan, Wis., in 60 fathoms (record 5), but in what numbers is not known.

In the seven samples of the catches of the 1½-inch bait nets in 28 to 40 fathoms examined at Sheboygan, Port Washington, and Racine, Wis., at Michigan City, Ind., and at Manistee, Northport, and Traverse City, Mich., no kiyis occurred, and only two specimens were ever seen among the bloaters brought in ensnarled in the lifts of the 4½-inch nets. These were taken on August 28, 1920, 9 miles northwest of Manistee, Mich., in 28 to 32 fathoms (record 16), and on November 19, 1920, 30 miles NNW. of Michigan City, Ind., in 48 to 50 fathoms (record 12).

In summary, *kiyi* was not found in 7 samples from 1½-inch nets at 28 to 40 fathoms, or in 10 catches of chub nets from 11 to 50 fathoms or 3 from 40 to 60 fathoms. It was rare in seven catches of the chub nets from 30 to 60 fathoms and in one from 60 to 70 fathoms. It was common only in five chub catches from 60 to 90 fathoms. It occurred once in unknown numbers in a catch of the chub nets as shallow as 20 to 35 fathoms and once in trout nets at 28 to 30 fathoms and 48 to 50 fathoms. It appears from the foregoing that the species attains its maximum density from 60 to 70 fathoms and probably deeper, and that it ranges occasionally as shallow as 30 fathoms or perhaps less. The fishermen at Grand Haven and Frankfort, Mich., state that a small, thin, large-eyed fish, which undoubtedly is *kiyi*, occurs deeper than 70 fathoms, and it is possible that *kiyi* is distributed throughout the vast central basins of the lake.

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[98] The field notes show that the species was six times more abundant in the 65-fathom end of the gang.

BREEDING HABITS

No spawning grounds of the species are known positively, but W. B. Chapin, of Frankfort, Mich., states that during October spawning kiyis are taken in the 70-fathom end of the chub nets that are set on the "northwest shoal," about 12 miles to the northwest of Frankfort. Males taken at Sheboygan, Wis., on October 1, 1920, showed incipient pearl organs, but none of the females had eggs even approaching the ripe state. At Frankfort on October 4, 1920, a few females were nearly ripe, and many showed well-developed eggs. Two pearled males were taken at Michigan City, Ind., on October 11, 1920, and a spent female was found there on November 8, 1920, among several females that had not yet spawned. If the fish referred to by Mr. Chapin are kiyis on their spawning grounds, then the fish observed by me at Frankfort were those that had not yet ripened sexually; or there may be a variation of a few weeks in the beginning of the spawning season, as in the case of the coregonids of the basin, which spawn in shallower water.

Leucichthys kiyi kiyi of Lake Huron

The *kiyi* of Lake Huron is like the typical form, except that rarely has it been seen so large. In Lake Michigan individuals of 20 to 23 centimeters in length are common, but specimens of such size have been seen rarely in Lake Huron. The principal systematic characters capable of numerical expression are compared below.

Gill rakers on the first branchial arch:
- Michigan, (34) 36–41 (45).[99]
- Huron, (34) 36–40 (44).[1]

Lateral-line scales:
- Michigan, (71) 77–87 (91).
- Huron, (70) 75–83 (89).

L/H:
- Michigan, (3.7) 3.8–4.1 (4.3).
- Huron, (3.5) 3.6–3.9 (4.1).

H/E:
- Michigan, (3.6) 3.8–4.2 (4.3).
- Huron, (3.3) 3.6–3.8 (4.3).

Pv/P:
- Michigan, (1.1) 1.4–1.7 (2.1).
- Huron, (1.1) 1.4–1.7 (1.9).

Av/V:
- Michigan, (0.96) 1–1.3 (1.4).
- Huron, (0.93) 1–1.2 (1.4).

It appears that the scales on the average are less numerous in the lateral line in Huron individuals. The chief difference between the specimens from the two lakes, however, is in the head and eye proportions, but as the Huron specimens are much smaller, on the average, the differences are such as are to be expected and it is likely that in specimens of comparable size they would not exist. (It may be seen in the section on variations that L/H and H/E figures for the few large specimens are very close to the ranges given for these values for the Lake Michigan race, most of which are more than 200 millimeters long.)

The color in life is not different from that of the Michigan form. Alcoholics show about the same degree of pigmentation, and its distribution also is approximately the same.

No pearled fish have been seen, but at least the males probably develop pearl organs in the breeding season.

VARIATIONS

Virtually all the specimens collected have come from the central basin of the lake, and there is no material for studies of local variation. There are only 16 indi-

[99] These figures are based on an examination of 174 specimens, which range in length from 122 to 245 millimeters.

[1] Figures for Lake Huron are based on an examination of 226 specimens, which range in length from 105 to 249 millimeters.

viduals in my collection longer than 200 millimeters, and these have, on the average, a proportionally smaller head and eye than the rest. L/H for these specimens is 3.8–4, as compared with (3.5) 3.6–3.8 (4.1) for the rest; and H/E is (3.7) 3.9–4 (4.3), as compared with (3.3) 3.6–3.8 (4) for the others. See also Table 51, where are compared in detail five specimens longer than 200 millimeters and five smaller.

COMPARISONS [2]

Kiyi usually can be confused only with the juveniles of other Leucichthys, except *hoyi*, as kiyis of greater length than 20 centimeters are rarely found. For the distinguishing characters between *kiyi* and *johannæ*, see page 358; between *kiyi* and *alpenæ*, see page 371; between *kiyi* and *zenithicus*, see page 396; and between *kiyi* and *nigripinnis*, see page 423.

From *hoyi*, *kiyi* is distinguished by its more ovate body shape and more acutely triangular head, as seen from the side; by its fewer gill rakers on the first branchial arch, more lateral-line scales, and longer paired fins. The characters that can be expressed numerically are compared for the two species below:

Gill rakers on the first branchial arch:
- *kiyi*, (34) 36–40 (44), with 12 per cent more than 40.
- *hoyi*, (37) 40–43 (47), with 71 per cent more than 40.

Lateral-line scales:
- *kiyi*, (70) 75–83 (89), with 71 per cent more than 76.
- *hoyi*, (63) 68–76 (84), with 12 per cent more than 76.

Pv/P:
- *kiyi*, (1.1) 1.4–1.7 (1.9), with 15 per cent more than 1.6.
- *hoyi*, (1.4) 1.7–1.9 (2.2), with 85 per cent more than 1.6.

Av/V:
- *kiyi*, (0.9) 1–1.2 (1.4), with 34 per cent more than 1.1.
- *hoyi*, (1) 1.2–1.4 (1.7), with 90 per cent more than 1.1.

Kiyi can be confused only with small *artedi*, as it does not grow large and usually can be distinguished from these at once by the shape of the body, which in *kiyi* is more ovate in outline, as seen from the side; by the many fewer gill rakers on the first branchial arch, much longer paired fins, and larger head and eye. The two species are compared below in those characters that can be expressed numerically:

Gill rakers on the first branchial arch:
- *kiyi*, (34) 36–40 (44), with 12 per cent more than 40.
- *artedi*, (40) 45–50 (53), with 99 per cent more than 40.

L/H:
- *kiyi*, (3.5) 3.6–3.9 (4.1).
- *artedi*, (4) 4.2–4.5 (4.8), with 89 per cent more than 4.1.

H/E:
- *kiyi*, (3.3) 3.6–3.8 (4.3), with 21 per cent more than 3.8.
- *artedi*, (3.6) 3.8–4 (4.4), with 66 per cent more than 3.8.

Pv/P:
- *kiyi*, (1.1) 1.4–1.7 (1.9).
- *artedi*, (1.7) 1.9–2.1 (2.3), with 68 per cent more than 1.9.

Av/V:
- *kiyi*, (0.9) 1–1.2 (1.4).
- *artedi*, (1.3) 1.6–1.7 (1.9), with 97 per cent more than 1.4.

[2] Figures in this section are given for all specimens collected except for the proportions of *artedi*. These involve only those specimens less than 225 millimeters in length.

Kiyi has also a narrower body and a much longer maxillary, snout, and mandible. The latter is usually equal to or shorter than the upper jaw in *artedi* and longer and hooked in *kiyi*. *Artedi* is also more pigmented, especially on the dorsal surface.

GEOGRAPHICAL DISTRIBUTION

All my data on the occurrence of the kiyi in Lake Huron are given in Table 50 and are platted in Figure 5. There are 20 records made during three years and show the species to occur in Georgian Bay and in the central basin of the main lake. At each end of the lake the water becomes shallower, and probably conditions are less suitable there.

BATHYMETRIC DISTRIBUTION

The sources of the data on depth distribution of *kiyi* are, for the most part, the 2¾-inch chub nets that are set at depths of 60 fathoms or more. A few specimens were taken in a special set of 1½-inch net made on September 13, 1919, off Presque Isle Light in 60 fathoms (record 11). Chub nets took specimens in 1917 on September 7, 12, and 21 and on October 17 and 20, and on September 18, 1919, in the center of the lake east of the Alpena can buoy in 65 to 80 fathoms (records 1, 2, 8, 9, 10, and probably 13); on September 14 and 19, 1917, in the center of the lake northeast of the can buoy in 65 to 80 fathoms (records 3 and 5); on September 18, 1917, 17½ miles N. by E., on September 20, 1917, 14 miles NE. by E., on September 21, 1917, 17 miles NE. by N. ¾ N., on September 18, 1919, 14 miles N. by E., on June 30, 1923, 17 miles NE. by N. ¾ N., on July 5, 1923, 18 miles NE. ¾ E., and on July 7, 1923, 13 miles NE. ½ N. of Thunder Bay Island in 60 to 100 fathoms (records 4, 6, 7, 12, 14, 16, and 17); and on July 2, 1923, 20 miles E. by N. of the can buoy in 60 to 70 fathoms (record 15). In Georgian Bay specimens were taken on July 30, 1919, 21 miles east of Surprise Shoal and off Wiarton in about 60 fathoms, and on October 6, 1919, off White Bluff in 70 fathoms (records 18, 19, and 20). A comparison with Tables 18 and 58, which give distribution data for *johannæ* and *hoyi*, shows that not all lifts of the chub nets took *kiyi*. Three lifts off Cheboygan, Mich., at the north end of the lake, and one off Harbor Beach, Mich., at the south end of the lake, in 35 to 50 fathoms, took no *kiyi;* nor were *kiyi* always present in the lifts of the chub nets made off Alpena in more than 60 fathoms. No *kiyi* ever were seen among the small fish taken in the 1½-inch bait nets off Cheboygan (one lift), Alpena (two lifts), and Harbor Beach (two lifts); nor were any included among the small fish taken on eight occasions by the 4½-inch trout and whitefish nets off Alpena set in 30 fathoms or less. (See Table 58.) It appears likely, therefore, that *kiyi* prefers only the deeper waters and occurs, during most of the season at least, only at depths of more than 60 fathoms.

RELATIVE ABUNDANCE

The kiyi has absolutely no commercial significance in Lake Huron, and therefore its relative abundance, as compared with that of the chubs, is of no interest. Inasmuch as virtually all the specimens collected have been found accidentally ensnarled in nets of a mesh too large to gill them, their number in these nets is no satisfactory index of their abundance; there are no data on the absolute abundance of the species, except that a 1½-inch net about 350 feet long, lifted from 60 fathoms off Presque Isle Light on September 13, 1919 (record 11), took only 8 kiyis among some hundred other fish.

BREEDING HABITS

Nothing is known of the breeding habits of *kiyi*. Female specimens collected as late as October 17 and 20, 1917, showed eggs approaching maturity, and probably the species spawns during October or November. October is said to be the time of spawning in Lake Michigan.

FOOD

The contents of 20 stomachs of specimens taken off Alpena, Mich., on September 19, 1919, in more than 60 fathoms consisted almost exclusively of Mysis. One specimen had swallowed a Pisidium, one a developing Leucichthys egg, and three had picked up fragments of wood.

Leucichthys kiyi kiyi of Lake Superior

The *kiyi* of Lake Superior resembles the typical form in shape and appearance, but apparently it does not grow so large, as the largest individual seen measured only 204 millimeters, compared with a recorded maximum of 245 millimeters for the Lake Michigan form. The chief systematic characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (34) 36–41 (45).[3]
- Superior, (36) 37–41 (45).[4]

Lateral-line scales:
- Michigan, (71) 77–87 (91).
- Superior, (72) 76–84 (87).

L/H:
- Michigan, (3.7) 3.8–4.1 (4.3).
- Superior, (3.5) 3.7–3.9 (4.1).

H/E:
- Michigan, (3.6) 3.8–4.2 (4.3).
- Superior, (3.4) 3.5–3.8 (4.1).

Pv/P:
- Michigan, (1.1) 1.4–1.7 (2.1).
- Superior, (1.1) 1.3–1.5 (1.7).

Av/V:
- Michigan, (0.9) 1–1.3 (1.4).
- Superior, (0.9) 1–1.2 (1.4).

It appears that the Superior kiyi has somewhat fewer scales in the lateral line and an average larger head and eye and longer pectoral fins. As the Superior specimens are much smaller than those that have been examined from Michigan, the differences in proportions involving the head and eye are such as might be expected and a comparison of these characters is not conclusive. In addition, the Superior form has, on the average, a longer anal base but with only slightly if any more anal rays, and in relation to the head a shorter snout, longer jaw, and longer gill rakers. Except for the head-snout proportions, which for Superior specimens is (3.3) 3.5–3.7 (4.1)[5] and for Michigan specimens (3.2) 3.4–3.6 (3.9), and for anal rays, which for Superior specimens are (10) 11–12 (14)[6] and for Michigan specimens (9) 10–12 (16),[7] the other characters are, for the most part, so variable that they are not given in fuller detail than is shown in the analysis of 10 specimens from each lake in Tables 49 and 53.

[3] These and unmarked figures for Lake Michigan are based on an examination of 174 specimens that range in length from 122 to 245 millimeters.

[4] These and unmarked figures for Lake Superior are based on an examination of 81 specimens ranging in length from 132 to 204 millimeters.

[5] Sixty-six specimens.

[6] Sixty-two specimens.

[7] One hundred and forty-four specimens.

The color of no live fish has been recorded, but probably it does not differ from that of Michigan specimens. Alcoholics do not differ materially in details of pigmentation, except that the anal and the ventrals more often show pigment.

At least the males develop pearl organs in the breeding season. Specimens obtained in November and December, 1922, had traces of nuptial excrescences, but most of them had been lost by friction before the specimens were received. The development of the pearls probably is like that of other members of the genus.

VARIATIONS

Virtually all the specimens collected have been taken off Marquette, Mich., and nearly all are equal in size, so that there are no data on age or racial variations.

The smallest collected individual, 132 millimeters long, was found sexually mature.

COMPARISONS [8]

The kiyi closely resembles *hoyi* and at all times may be confused with it. All other species in Lake Superior attain greater size than *kiyi*, and therefore it can be confounded only with juveniles of these species.

Kiyi has fewer gill rakers on the first branchial arch, more scales in the lateral line, longer paired fins, and the base of the anal fin is relatively longer than in *hoyi*. The body shape, as seen from the side, is less elliptical in *kiyi* on account of the more sudden rise of the predorsal contour. The characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- *kiyi*, (36) 37–41 (45), with 24 per cent more than 40.
- *hoyi*, (37) 41–44 (49), with 83 per cent more than 40.

Lateral-line scales:
- *kiyi*, (72) 76–84 (87), with 88 per cent more than 75.
- *hoyi*, (65) 69–78 (84), with 29 per cent more than 75.

Pv/P:
- *kiyi*, (1.1) 1.3–1.5 (1.7), with 10 per cent more than 1.5.
- *hoyi*, (1.4) 1.5–1.8 (2), with 76 per cent more than 1.5.

Av/V:
- *kiyi*, (0.9) 1–1.2 (1.4), with 7 per cent more than 1.2.
- *hoyi*, (0.9) 1.1–1.3 (1.6), with 36 per cent more than 1.2.

L/AB:
- *kiyi*, (7) 8–9 (10), with 8 per cent more than 9.
- *hoyi*, (7.5) 9–10 (11.5), with 58 per cent more than 9.

The dorsal contour of the head in *kiyi* is more or less convex and the premaxillaries more vertical than in *hoyi*, in which there is almost a straight line from the tip of the premaxillaries to the occiput. The effect of these lines on the outline of the head, as seen from the side, makes the head of *kiyi* more elongated and obtuse triangular, while that of *hoyi* is rather broad and acute triangular with the mouth at a higher level. The anal fin is more often pigmented in *kiyi*. The body of *kiyi* is somewhat darker, as a rule.

For differences between *kiyi* and *zenithicus*, see page 381, between *kiyi* and *reighardi*, page 411, and between *kiyi* and *nigripinnis*, seepage 427.

[8] Figures are given in this section for all collected specimens of each species except for proportions of *artedi*, which are given or those specimens less than 225 millimeters in length.

Kiyi can be confused only with small *artedi,* as the former is not known to grow large. The body shape of *kiyi* is ovate, as seen from the side, as compared with the elongate elliptical form of *artedi;* the gill rakers on the first branchial arch are fewer, and the paired fins, maxillary, head, and eye are relatively longer, as will appear from the figures given:

Gill rakers on the first branchial arch:
- *kiyi,* (36) 37–41 (45), with 24 per cent more than 40.
- *artedi,* (41) 45–48 (53).

L/H:
- *kiyi,* (3.5) 3.7–3.9 (4.1).
- *artedi,* (4) 4.2–4.6 (4.8), with 92 per cent more than 4.1.

H/E:
- *kiyi,* (3.4) 3.5–3.8 (4.1), with 3 per cent more than 3.9.
- *artedi,* (3.4) 4–4.2 (4.5), with 77 per cent more than 3.9.

H/M:
- *kiyi,* (2.2) 2.4–2.5 (2.6).
- *artedi,* (2.5) 2.7–3 (3.2), with 88 per cent more than 2.6.

Pv/P:
- *kiyi,* (1.1) 1.3–1.5 (1.7).
- *artedi,* (1.6) 1.9–2.2 (2.3), with 90 per cent more than 1.7.

Av/V:
- *kiyi,* (0.9) 1–1.2 (1.4).
- *artedi,* (1.4) 1.5–1.8 (1.9), with 95 per cent more than 1.4.

In addition, *kiyi* has, on the average, fewer lateral-line scales, a longer snout, and a longer mandible. Few specimens of *artedi* have been found sexually mature under 200 millimeters, while *kiyi* commonly is mature at 140 millimeters.

GEOGRAPHICAL DISTRIBUTION

All my data on the occurrence of the *kiyi* in Lake Superior (11 records) are assembled in Table 52 and are platted in Figure 3. By comparison with a similar table for *hoyi* (Table 60), it appears that *kiyi* is distributed by no means so generally as the former; and from all the data at hand it can be stated with certainty only that the species occurs in the deeper waters of the southern half of the lake. Its absence in the inspected catches from apparently suitable depths in the northern sector must not be taken to indicate its absence in this area, however, especially when its rarity in the south, except during the breeding season, is taken into consideration; and further investigation probably will discover the species throughout the lake where conditions are suitable.

BATHYMETRIC DISTRIBUTION

Kiyi is preeminently a deep-water form in Lake Superior, as in all the other lakes in which it is known to occur. Of the 11 lifts that have yielded specimens, 4 were made at unknown depths, but probably from at least 40 fathoms. Only one of the rest was made as shallow as 40 to 50 fathoms (record 11). The remaining specimens collected were taken from sets that, if they ranged as shallow as 40 or 50 fathoms, extended also to greater depths (records 3, 9, and 10). Except during the spawning season (records 5 and 6), the majority of specimens collected came from a gang of nets set in 100 fathoms (record 2). It is interesting to note by comparison with Table 60, which shows the data on the occurrence of *hoyi,* that *kiyi* does not necessarily occur everywhere at depths of more than 40 or even 60 fathoms, but for the present we may say that during the year the species ranges between the depths of 40 and 100 fathoms. As no *kiyi* occurred in the shallow-water sets that took *hoyi*, the inshore limit of their range, at least when not spawning, probably may be set around 40 fathoms. There are no data to fix the maximum depths which the species frequents.

RELATIVE ABUNDANCE

As, on account of its small size, *kiyi* has no commercial importance, it is not fished for, and its abundance can only be determined relative to that of *hoyi*, which is like it in respect to size and usefulness. Except possibly in the lifts made in late November and early December, 1922 (records 5 and 6), when the species was spawning, *kiyi* never has been anything but rare in the inspected catches; and except for the records made off Marquette, Mich., Apostle Islands, Wis., and Coppermine Point, Ontario (records 3, 9, 10, and 11), all of them from nets extending into 40 fathoms, it never has been taken in company with *hoyi*. On these four occasions only stray specimens were found entangled with the latter.

BREEDING HABITS

Specimens collected as late as October 3, 1917, off Grand Marais, Mich., were not yet ripe, although females taken on this date showed eggs approaching the ripe state. Of 13 specimens received from off Marquette, Mich., on November 22, 1922, 9 were males from which milt could be forced and the 4 females had eggs nearly ripe. Of the 39 fish received from the same source on December 5, 1922, only 6 were males, and of the 33 females the majority were spawning or spent. These data indicate that the spawning season falls in late November or early December.

Unfortunately there have been no exact localities recorded for these spawning fish taken off Marquette, but Prof. J. N. Lowe, of the Northern Normal School, who sent the specimens, states that they were taken off Granite Island, probably in 70 fathoms. This information then fixes at least one spawning ground for the species in the lake, and doubtless there are others.

Leucichthys kiyi orientalis (new subspecies) of Lake Ontario

The *kiyi* of Lake Ontario attains about the same maximum size as the typical form, except that in virgin waters extreme examples measured 250 millimeters and a single specimen of 263 millimeters was seen. The general appearance of the two forms is the same, but the Ontario representative differs rather markedly in several characters. Values for certain of these are compared below:

Gill rakers on the first branchial arch:
- Michigan, (34) 36–41 (45).[9]
- Ontario, (41) 43–46 (48).[10]

Lateral-line scales:
- Michigan, (71) 77–87 (91).
- Ontario, (71) 76–87 (91).

L/H:
- Michigan, (3.7) 3.8–4.1 (4.3).
- Ontario, (3.8) 4.1–4.2 (4.4).

H/E:
- Michigan, (3.6) 3.8–4.2 (4.3).
- Ontario, (3.6) 3.9–4.2 (4.4).

Pv/P:
- Michigan, (1.1) 1.4–1.7 (2.1).
- Ontario, (1.5) 1.7–2 (2.2).

Av/V:
- Michigan, (0.9) 1–1.3 (1.4).
- Ontario, (1) 1.2–1.4 (1.6).

[9] These and succeeding figures are based on an examination of 174 specimens ranging in length from 122 to 245 millimeters.

[10] These and succeeding figures for Lake Ontario are based on an examination of 135 specimens ranging in length from 148 to 263 millimeters.

The specimens from the two lakes are of approximately the same average size, and the figures given are comparable, therefore. It appears that the Ontario form has many more gill rakers, much shorter paired fins, and a somewhat shorter head. Other characters, as number of scale rows around the body, number of fin rays, and mandible length, are approximately as in the typical form. The Ontario representative tends to have, on the average, longer gill rakers, a shorter dorsal, a broader caudal, and blunter head, but these characters are so variable within each race that no further account of their variability is given than is found in the detailed comparison of 10 specimens from each lake in Tables 49 and 55.

The form appears sufficiently well marked to merit a name, and I propose to call it *orientalis*. Specimen No. 54064 of Table 55, taken on July 19, 1921, off Wilson, N. Y., in 65 fathoms is designated as the type. It is catalogued as No. 88352 in the United States National Museum.

The color in life is not different from that of the typical form. Alcoholics show, on the average, more pigment on the head and body and on the abdominal fins, especially on the ventrals and the anal.

At least the males of the species develop pearl organs in the breeding season. Specimens collected in the latter part of July, 1921, off Wilson, N. Y., had traces of pearls, and specimens taken in early September off Oswego, N. Y., showed well-developed pearls. For the most part these have been lost by friction in the preserved specimens, so that no detailed description is possible, but in general they are distributed over the head and body and have the same general shape, size, and location on the scale as in other members of the genus whose breeding dress has been described.

VARIATIONS

Racial variations.—No differences are observable between the groups of specimens collected from the various parts of the lake, but it is not improbable that, if sufficient numbers were gathered together, local races might be differentiated.

Size variations.—Most of the collected specimens have been gilled in 2½-inch nets and are therefore longer than 200 millimeters, so that there are no groups of specimens of different sizes available to determine how the body parts change in size with growth.

Four specimens as small as 148 to 177 millimeters long have been seen, and all had maturing gonads.

COMPARISONS [11]

Kiyi can be confused only with *hoyi* or possibly *nigripinnis prognathus*. *Kiyi* and *hoyi* attain about the same maximum size and resemble one another rather closely. The shape of the body, as seen from the side, is decidedly less elliptical in *kiyi*, as the predorsal contour rises rather abruptly from the occiput and the head is rather more elongated. Absolute differences in characters that can be expressed numerically are wanting, but there are several characters that show average differences, and by the use of these most specimens can be identified properly.

[11] Figures in this section are given for all specimens collected except those of proportions for *artedi*, which are based on specimens 225 millimeters and more in length.

Lateral-line scales:
kiyi, (71) 76–87 (91), with 89 per cent more than 76.
hoyi, (63) 68–76 (81), with 8 per cent more than 76.

H/E:
kiyi, (3.6) 3.9–4.2 (4.4), with 7 per cent more than 4.2.
hoyi, (3.7) 4–4.5 (4.7), with 39 per cent more than 3.7.

H/ad:
kiyi, (2.7) 3.2–3.7 (4.1), with 15 per cent more than 3.7.
hoyi, (3.2) 3.6–4.3 (5), with 72 per cent more than 3.7.

Scale rows in front of dorsal and ventrals:
kiyi, (40) 41–44 (47), with 79 per cent more than 41.
hoyi, (37) 40–41 (46), with 25 per cent more than 41.

The ventrals are also somewhat longer, relative to the distance from their insertion to that of the anal (Av/V), in *kiyi*. As *kiyi* spawns in August and *hoyi* in November or later, the state of development of the sex organs will often be serviceable also in separating individuals of the two species.

As only one specimen of *prognathus* is known to exist in collections, it is not possible to give criteria for distinguishing the two forms, but there are decided differences between the two in respect to absolute size attained and the time of spawning. The largest collected *kiyi* measures only 263 millimeters, and nets of 2½-inch mesh are required for the capture of the species, while *prognathus* was commonly larger than 300 millimeters and was taken only in nets of 3-inch or larger mesh. The species differed, also, in time of spawning. *Kiyi* spawns in August, while *prognathus* is said to have spawned in January.

Usually *kiyi* can be distinguished at once from *artedi* by the more ovate body outline, as seen from the side, as in the former the predorsal contour is strongly arched. In addition, *kiyi* has fewer gill rakers on the first branchial arch, a larger head and eye, a longer mandible, and paired fins. These characters are compared below for the two species:

Gill rakers on the first branchial arch:
kiyi, (41) 43–46 (48), with 15 per cent more than 46.
artedi, (41) 46–50 (54), with 67 per cent more than 46.

L/H:
kiyi, (3.8) 4.1–4.2 (4.4), with 5 per cent more than 4.3.
artedi, (3.7) 4.3–4.7 (4.9), with 74 per cent more than 4.3.

H/E:
kiyi, (3.6) 3.9–4.2 (4.4), with 7 per cent more than 4.2.
artedi, (3.9) 4.1–4.4 (4.9), with 56 per cent more than 4.2.

Pv/P:
kiyi, (1.5) 1.7–2 (2.2), with 11 per cent more than 2.
artedi, (1.7) 1.9–2.1 (2.5), with 38 per cent more than 2.

Av/V:
kiyi, (1) 1.2–1.4 (1.6), with 7 per cent more than 1.4.
artedi, (1.3) 1.5–1.8 (2), with 94 per cent more than 1.4.

Mandible compared with upper jaw:
kiyi, shorter, 2 equal, 30 longer, 98 or 75 per cent longer.
artedi, shorter, 130 equal 121 longer, 77 or 23 per cent longer.

Kiyi spawns in August and *artedi* spawns in late November, so that the state of development of the sex organs, particularly of females, also is a valuable character for separating the two species.

A discussion of the distinctions between *kiyi* and *reighardi* is given on page 414.

GEOGRAPHICAL DISTRIBUTION

The records on the occurrence of *kiyi* in Lake Ontario are given in Table 54 and are shown platted on the lake chart in Figure 7. For the most part they are derived from the use of the special 2½ and 2¾ inch nets. It appears that *kiyi* was taken out of every port from which the nets were set, and as the ports are distributed along the shore line of the lake it may be concluded safely that *kiyi* occurs throughout the waters of the lake where suitable conditions obtain.

BATHYMETRIC DISTRIBUTION

The chief data on the depth distribution of the kiyi are derived from the use of the 2½ and 2¾ inch nets, which were set under my direction during the summers of 1921 and 1923. A few specimens have been seen, also, that were taken accidentally in the nets of larger mesh. All nets were set between the depths of 20 and 75 fathoms and in every locality took specimens of the species. No effort was made to determine the limits of the range of the species, so that for the present it can be stated only that individuals of the species range during the year between 20 and 75 fathoms.

RELATIVE ABUNDANCE

The experimental nets did not take *kiyi* abundantly at any time, but it is interesting to record the relative abundance of this and the other species taken with it. On July 19, 1921, 6½ miles N. by W. ½ W. of Wilson, N. Y., in 65 fathoms (record 12), 75 per cent of the catch was of *kiyi*. On June 25, 1921, 5 miles north, in 50 fathoms (record 10), *kiyi* comprised 40 per cent of the fish taken; on July 4, 1921, 7 miles off Braddock Point Light, in 65 fathoms (record 8), the percentage was about one-third, and on July 12, 1921, 8½ miles NNW. of Sodus Point, N. Y, in 60 fathoms (record 7), about one-fourth. But few *kiyi* were taken in other lifts made 20 miles S. by W. of Presque Isle Light, Ontario, on June 10, 1921, in 40 to 50 fathoms (record 2); on June 29, 1921, 13 miles E. ½ S. of Bronte, Ontario, in 40 to 50 fathoms (record 1); on June 23, 1921, 3 miles north of Wilson, N. Y., in 30 fathoms (record 9), on July 16, 1921, 5 miles north, in 50 fathoms (record 11), and on July 21, 1921, 2 miles north, in 20 fathoms (record 13); on August 30, 1923, 14 miles west of Sandy Pond, N. Y., in 60 fathoms (record 3); and on September 4, 1923, 8½ miles W. by N. ½ N. of Oswego, N. Y., in 70 to 75 fathoms (record 6). The specimens taken in the 3-inch nets off Selkirk and Oswego, N. Y. (records 4 and 5), were accidental captures.

It must be borne in mind that, unlike Lakes Michigan and Huron, in which grounds suitable for deep-water Leucichthys or chubs have been located through seasons of experience, most of Lake Ontario never has been exploited for these species, and the areas where they occur most abundantly are as yet unknown. For this reason the experimental nets, from the use of which these data on relative abundance are derived, were of necessity set at random in the lake, with depth alone as the directing factor, and therefore it can not be expected that the nets will yield conclusive data on absolute abundance or even on relative abundance. In the case of the kiyi, from our knowledge of the habits of the species in other lakes such observations as have been recorded may be taken to indicate that the center of abundance of *kiyi* is attained in depths of 60 fathoms or more.

BREEDING HABITS

No spawning *kiyi* have been taken. Males collected on July 19 and 21, 1921, off Wilson, N. Y., were pearled, and females showed well-developed ova, although none were by any means ripe. Males and females taken on September 4, 1923, off Oswego, N. Y., were spent, but the males still showed pearl organs. Females from the University of Toronto collection taken off Port Credit, Ontario, on March 28, 1926, showed ovaries that had not been spent recently. It is apparent, then, that the spawning season for the species must fall in August or thereabouts. At what depths or on what bottom the eggs are laid is not known.

LEUCICHTHYS HOYI Gill

THE BLOATER (FIG. 23)

Argyrosomus hoyi Gill, in Hoy, 1872, p. 99, Lake Michigan off Racine; Milner, 1874, pp. 86–87, in part, Lake Superior; not of Evermann and Smith, 1896; not of Jordan and Evermann, 1911.

Argyrosomus prognathus Evermann and Smith, 1896, pp. 314–317, in part, Lakes Huron and Michigan.

Leucichthys johannæ Jordan and Evermann, 1911, pp. 24–26, in part, Lakes Huron and Michigan; not Pls. III or V.

Leucichthys hoyi has been described from Lake Michigan but occurs also in Lakes Nipigon, Superior, Huron, and Ontario. In all five bodies of water it is characterized by its relatively small size, which is seldom over a maximum of 200 millimeters except in two of the lakes (Michigan and Ontario), where it grows regularly large enough to be of commercial importance; its terete body form, as seen from the side, and relatively few lateral-line scales. The Nipigon race differs chiefly in having, on the average, a higher number of gill rakers on the first branchial arch and of scales in the lateral line, and a proportionally longer head, eye, maxillary, and paired fins. The Superior form has a proportionally larger head and eye and longer paired fins and maxillary. The Huron form differs but little in its systematic characters. In Lake Ontario the species seems to be different chiefly in having, on the average, more gill rakers, a proportionally smaller eye, and possibly a somewhat longer head and pectorals. All forms, so far as has been ascertained, prefer relatively shallow water, namely, depths of about 30 fathoms except in Lake Ontario, where they have been found most commonly between 50 and 60 fathoms. The breeding habits are but imperfectly or not at all known, but in Lakes Michigan and Huron the species spawns in late February and early March, and in the other lakes it is known that it does not spawn before December.

Type

A specimen about 137 millimeters long has been selected from two mutilated specimens in the United States National Museum, both bearing the type No. 8902, collected in Lake Michigan off Racine, Wis., probably in March, 1872, by Dr. P. R. Hoy. The reasons for making this selection are given on page 312.

Leucichthys hoyi of Lake Michigan

The bloater is probably the commonest Leucichthys in Lake Michigan. It is one of the smallest members of the genus in the Great Lakes Basin, but in Lake Michigan it is taken abundantly in the 2½-inch chub nets and also in some numbers in those of 2¾-inch mesh. The largest example seen measures 265 millimeters. The shape of the body, as seen from the side, is elliptical even in the largest or in the deepest individuals; that is, the dorsal contour rises in a smooth curve from the occiput to the insertion of the dorsal fin and slopes gently into the caudal peduncle. The opposite ventral profiles correspond approximately, except that specimens from deep water, particularly the smaller ones, are usually extremely bloated and, unless the gas in the air bladder is released at once, the body remains distorted. Larger individuals have thicker belly walls and do not bloat so conspicuously. The body is usually only moderately deep; the depth most often is contained 3.8 to 4.2 times in the total length. The body is moderately compressed, but with growth the width increases, and the largest specimens are often as subterete in body form as *artedi*. The head is moderate, rather broadly triangular viewed from the side, and is contained (3.6) 4–4.2 (4.6)[12] times in the total length. Its dorsal profile is straight or but faintly convex. The premaxillaries are directed forward and downward and usually make an angle of about 40° with the horizontal axis of the head. Their position is influenced by the frail mandible, which is more or less conspicuously pigmented, provided with a more or less conspicuous symphysial knob, and which in most specimens projects beyond the upper jaw, in that case forcing the premaxillaries to assume a more horizontal position. The mandible in less than one-third of the specimens in the collection is only equal to the upper jaw, but only very rarely is it shorter. The maxillary is moderately long, is contained (2.3) 2.5–2.6 (2.8)[13] times in the head length, and it always shows at least some pigment. The snout, viewed from the side, is pointed. It is usually a trifle shorter than the large eye, which is contained (3.3) 3.7–4 (4.5) times in the head length. The gill rakers on the first branchial arch number (13) 15–16 (18) + (23) 26–28 (31) = (37) 41–44 (48). There are (60) 67–77 (84) scales in the lateral line; only 2 per cent of all specimens examined have 80 or more. Scale rows around the body just in front of the dorsal and ventrals number (38) 40–42 (44),[14] just in front of the adipose and anus (31) 32–34 (35),[14] and around the caudal peduncle at its commencement (22) 23–25 (26).[14] The dorsal rays number (7) 9–10,[15] anal rays (10) 11 (13),[15] ventral rays (10) 11 (12),[15] pectoral rays (14) 15–16 (17),[15] and the branchiostegal rays 8 to 9.[15]

The paired fins are rather long. The pectorals are contained (1.3) 1.7–2 (2.5) times in the distance from their origin to that of the ventrals, and the ventrals are contained (1) 1.2–1.4 (1.7) times in the distance from their origin to that of the anal. The dorsal margin of the pectorals is usually nearly straight.

The color in life is not essentially different from that as described for *johannæ*. In alcohol all color eventually fades and leaves obvious details of pigmentation. The entire dorsal surface is strewn thickly with very fine pigment dots, which, however, do not lend a conspicuous darkened effect except in the prenarial area, where they are concentrated usually. There is sometimes a narrow dark streak down the back, due possibly to differential preservation of the flesh but certainly not to pigment. The pigmentation diminishes on the sides and often is absent below the lateral line but

[12] These and succeeding figures, unless otherwise designated, are based on an examination of 1,161 individuals ranging in length from 82 to 265 millimeters.

[13] One hundred and eight specimens.

[14] Twenty-five specimens.

[15] Thirty specimens.

usually is present on the cheeks, particularly on the oculars. The tip of the mandible is pigmented but seldom is conspicuously dark. The preorbital region is like the cranium in respect to pigmentation, and the maxillary always shows more or less of pigment. All the fins are pale, but the caudal and dorsal are darkest. These show a more or less faint dusky hue on their distal margins. The pectorals often show faint pigment on their longest rays; the anals sometimes have a few dots on the membranes between the rays, but the ventrals, except in very rare cases, are immaculate.

During the breeding season pearl organs are developed by males and by at least some females. Their development apparently is not very different from that described for *johannæ.* However, there are occasionally one or two much smaller pearls flanking the central one of the scales of the scale rows of the sides, and on the scales of the rows dorsad and ventrad to the fourth above and the sixth below there are regularly two or three or even more pearls on each scale, the disparity in size decreasing as the back and belly are approached and the distribution and shape becoming more irregular.

VARIATIONS

Racial variations.—It will be seen from Table 56 that a considerable number of specimens has been collected from almost every port visited. The lowest number from any locality is 8 from Platte Bay, and from all but 5 of the 16 other stations from which specimens were preserved 34 or more specimens have been examined. These collections are fairly uniform in respect to size of individuals, with the exception of the Michigan City and Northport lots, which have a greater proportion of large specimens. Compared in all their important systematic characters, as number of gill rakers on the first branchial arch and of scales in the lateral line, and the relative size of head, eye, and paired fins, there are no differences discernible between the various groups except such slight ones as might be due to inequality in size of the various individuals composing the groups, namely, changes in proportion that are the result of growth.

There is another possibility of racial differentiation, namely, according to habitat. In Lake Huron, for example, it has been observed that specimens from the deepest water differ in certain characters from their shore relatives (see p. 458), but in Lake Michigan it has not been possible, from the collection I have accumulated, to establish any such differences. My specimens, however, do not lend themselves to any such comparisons, as they were collected over a period of several of the warmest months, and it is known that the bloaters move nearer shore at certain seasons, so that a given habitat in the same locality might be occupied by different races during a season. A study of environmental races, then, must be undertaken first in a definite and restricted area over a period of time. For the present all that can be said about variation is that the collection of about 1,000 individuals from 17 stations scattered along the lake's shore does not disclose any striking variation tendencies.

Size variations.—By far the greater number of specimens collected are less than 200 millimeters in length, and the largest ones are but little over that limit. In Table 57 five specimens over 200 and five under 200 millimeters in length are compared extensively, and in Tables 8 to 11 all the specimens over 200 millimeters in length are compared in certain characters with those smaller. The size differences being slight, no marked contrast is to be expected in the figures for the two classes, but it does appear from the tables that the larger specimens have a somewhat smaller head and eye and shorter paired fins.

Individuals usually have been found to be maturing sexually at 140 millimeters. One specimen of 114 millimeters in length apparently was approaching sexual maturity.

COMPARISONS[16]

Hoyi most nearly resembles *kiyi*. A discussion of the differences between the two forms is given on page 436. The differences between *hoyi* and *johannæ, alpenæ, zenithicus, reighardi,* and *nigripinnis* are given on pages 352, 366, 390, 403, and 419.

Hoyi is distinguishable from *artedi* chiefly by the lower number of gill rakers on the first branchial arch and of scales in the lateral line, by the larger head, longer maxillary and ventral fins, and the length of the lower jaw, which in *hoyi* is practically in all cases equal or longer than the upper but in *artedi* is equal or more often shorter. Those characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- *hoyi*, (37) 41–44 (48), with 5 per cent more than 45.
- *artedi*, (41) 46–50 (55), with 86 per cent more than 45.

Lateral-line scales:
- *hoyi*, (60) 67–77 (84), with 7 per cent more than 77.
- *artedi*, (68) 77–87 (94), with 88 per cent more than 77.

L/H:
- *hoyi*, (3.6) 4–4.2 (4.6), with 13 per cent more than 4.2.
- *artedi*, (4) 4.2–4.5 (4.6), with 66 per cent more than 4.2.

H/M:
- *hoyi*, (2.3) 2.5–2.6 (2.8), with 16 per cent more than 2.6.
- *artedi*, (2.4) 2.7–3 (3.1), with 86 per cent more than 2.6.

Av/V:
- *hoyi*, (1) 1.2–1.4 (1.7), with 8 per cent more than 1.4.
- *artedi*, (1.3) 1.5–1.7 (2), with 93 per cent more than 1.4.

In general *hoyi* has also a deeper, less terete body than *artedi*, particularly when small, and the head, as seen from the side, is more sharply pointed. The body and fins of *hoyi* are also less pigmented. The state of development of sex organs, especially in females, may often assist in separating individuals of the species, as *hoyi* spawns in March and *artedi* in November.

GEOGRAPHICAL DISTRIBUTION

In Table 56 are given all my data on the occurrence of the bloater in Lake Michigan. They are also shown platted on a map of the lake in Figure 4. There are 53 observations made by me from the 1½-inch bait nets, which catch small fish to bait the trout hooks; from the 4 to 4½ inch trout and whitefish nets, the 2⅜ to 2¾ inch chub nets, and from the pound nets. In the first two kinds of nets only small individuals are taken usually, those in the trout and whitefish nets being caught only accidentally by entangling their jaws in the netting. In the chub nets

[16] Figures in this section are given for all collected specimens, except the proportions for *artedi*, which are based on an examination of specimens less than 225 millimeters in length.

small fish are accidentally entangled also, but large numbers of larger specimens become gilled, particularly in the 2⅜ and 2½ inch nets, and are brought to the market along with the other species of Leucichthys that comprise the catches. The bloaters may even be so numerous in these nets that they are caught to the virtual exclusion of all other Leucichthys. These three types of netting are the only kinds of gill netting exployed on the lake, and some type or all types are in use out of all the fishing ports. At every port from which catches were examined from depths of more than 75 feet some specimens of the bloater have been collected, and specimens also have been taken from the pounds set in shallow water out of two ports. As these ports are well distributed along the lake's shores, it is safe to conclude that the bloater may be found throughout the lake at suitable depths.

BATHYMETRIC DISTRIBUTION

In the 1½-inch bait nets the bloaters and other small Leucichthys are taken to bait the trout hooks that are in use during most of the calendar year out of certain ports. Such nets are set during most of the season at about 26 to 40 fathoms. Catches of these nets were examined on seven occasions (see p. 354), and *hoyi* always were found (records 9, 12, 19, 27, 35, 41, and 43). A few specimens were taken by me in test nets of 1½-inch mesh lifted on July 21 and 23, 1923, in Platte Bay, Mich., from 8 to 12 and 15 to 25 fathoms, respectively, and on July 25, 1923, off Lees Point in Grand Traverse Bay from 6 to 16 fathoms (records 38, 39, and 44).

In the 2⅜ to 2¾ inch chub nets some bloaters probably always are present. They are either large enough to gill or are caught by the jaws in the netting. Taken in this fashion, specimens are recorded from chub gangs examined in March, 1919 and 1921, April, 1921, May, 1922, June, 1920, July and August, 1923, and August, September, October, and November, 1920, at depths between 18 fathoms (off Michigan City, Ind., on November 19, 1920) and 71 to 90 fathoms (off Rock Island, Wis., on August 19, 1920) (records 25 and 5).

The trout and whitefish nets of 4 to 4½ inch or larger mesh are set usually in less than 40 fathoms. No lifts of such nets ever were examined, but specimens were brought in by pilots of vessels from their large-meshed nets off Washington Harbor, Wis., 5 miles west and 3 miles WNW. of Boyer Bluff on August 18 and 19, 1920, in 20 to 24 fathoms (records 2 and 4); 30 miles NNW. of Michigan City, Ind., on November 19, 1920, in 48 to 50 fathoms (record 23); 7 miles NW. by N. of Ludington, Mich., on August 30, 1920, in 14 to 26 fathoms (record 33); 9 miles northwest of Manistee, Mich., on August 28, 1920, in 28 to 32 fathoms (record 36); and 13 miles SE. ½ E. of Manistique, Mich., on August 11, 1920, in 20 fathoms (record 51).

The bloaters of a marketable size also are said to run commonly into the pound nets in summer, at least at Port Washington on the Wisconsin shore, and specimens were taken by me in the pounds there on September 27, 1920, in 5 fathoms of water (record 13). Small individuals were found abundantly in a pound in Grand Traverse Bay at the same depth on July 26, 1923 (record 45). The University of Michigan collection contains 13 small specimens taken off Ludington, Mich., "within 150 yards of shore." These may have been taken in pounds but more probably were seined.

The data thus show that the bloater has a very wide depth range in the lake. It is known to run from shore down to depths of 90 fathoms, and it is possible that it strays to even greater depths.

RELATIVE ABUNDANCE

Data from the 1½-inch bait nets.—The bloaters are taken most abundantly in the 1½-inch bait nets. These nets do not take bloaters exclusively, but I have not seen any catches made by them in which the bloater was not the predominating species. In only five catches, however, have percentages of abundance been ascertained, namely, from 5 miles SE. by E. of Sheboygan, Wis., on September 28, 1920, in 30 to 32 fathoms (record 9); from 5 miles E. ½ S. of Port Washington, Wis., on September 25, 1920, in 30 fathoms (record 12); from 14 miles NNW. of Michigan City, Ind., on March 2, 1921, in 26 fathoms (record 27); from off Northport Point, Mich., on June 23, 1920, in 28 to 40 fathoms (record 41); and from the west arm of Grand Traverse Bay on July 18, 1923, in 30 to 40 fathoms (record 43). In lifts Nos. 9, 12, and 27 the percentage of *hoyi* was 75 to 96. In the lift off Northport and Traverse City 50 to 60 per cent of the catch was of *hoyi*.

In view of the composite nature of the catch of these nets nothing positive about the habits of the small *hoyi* can be gleaned from the testimony of the fishermen who employ them. All, however, are agreed that the best depth for bait is about 30 fathoms on very soft clay or mud bottom. Virtually all the hook fishermen interviewed agree that bait is most difficult to obtain during May, June, and July, and that it is most abundant after late fall. From the accounts of the occurrence of *hoyi* in the catches of other gear it will appear that these observations probably would apply to small *hoyi*.

Data from the 2⅜ to 2¾ inch chub nets.—It has been stated already that the summer of 1920 was very unfavorable for chub fishing (see p. 354), and therefore the conclusions given below regarding abundance are not so satisfactory as might be wished.

In any nets of larger mesh than 2½ inches only extreme examples of the species can gill, and therefore the percentages of *hoyi* taken in the chub nets from any of the Michigan ports, which use a minimum mesh of 2¾ inches for chubs, are not to be compared with those from Wisconsin and Indiana, where the mesh of such nets is usually smaller. The largest percentage taken in examined catches made by nets from Michigan ports is 22 per cent of 1,400 pounds of chubs caught on October 4, 1920, 9 miles north of Point Betsie in 60 to 70 fathoms (record 37).

Only occasional specimens occurred in the chub lifts (2¾-inch mesh) on June 22, 1920, and July 31, 1923, off Cathead light in 40 to 60 fathoms (records 40 and 42); on June 29, 1920, 5 miles N. by E. of Charlevoix, Mich., in 40 to 55 fathoms; on August 10, 1923, 8 miles NNW. of Big Rock Point and on August 11, 1923, 3 miles NW. ½ W. in 35 to 60 fathoms; on August 21, 1923, from an unknown locality (records 46, 48, 49, and 50); and on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms (record 52). They were rare also in lifts of similar nets made on August 23, 1920, 12 miles E. by S. of the Sturgeon Bay ship-channel mouth in 60 to 70 fathoms (record 6), but only 50 pounds of fish were taken in the lift.

In the lift of the 2⅜-inch nets made on August 16, 1920, 8 miles south of Green Island in Green Bay in 16 fathoms (record 53), and the lift of 2½-inch nets made on November 15, 1920, 20 miles ESE. of Milwaukee, Wis., in 28 to 35 fathoms on the spawning grounds of *zenithicus* (record 18), no *hoyi* were gilled, but a number of small individuals were caught by the jaw. Chub lifts made with 2½-inch nets on August 18, 1920, 4 miles west of Boyer Bluff in 18 to 24 fathoms took 50 per cent bloaters (record 1); on August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms, 68 per cent (record 7); on September 25, 1920, 18 miles E. ½ S. of Port Washington, Wis., in 65 to 48 fathoms, 53 per cent (record 11);[17] on September 3, 1920, 22 miles NW. by N. ½ N. of Michigan City, Ind., in 30 to 40 fathoms, 42 per cent (record 20); on October 11, 1920, 20 miles N. by W. ¾ W. in 30 to 40 fathoms, 34 per cent (record 21); on November 19, 1920, 17 miles NNW. in 28 to 32 fathoms, 50 per cent (record 24); on March 2, 1921, 21 miles NNW. in 30 fathoms, 81 per cent (record 28); and on March 4, 1921, 15 miles NW. by N. ½ N. in 28 fathoms, 96 per cent (record 29).

Bloaters comprised 15 per cent or less of the catches of 2½-inch nets made on August 19, 1920, 20 miles E. ½ N. of Rock Island, Wis., in 71 to 90 fathoms (record 5); on September 23, 1920, 27 miles ESE. of Milwaukee, in 60 fathoms (record 16); on November 8, 1920, 18 miles NNW. of Michigan City, Ind., in 30 to 38 fathoms (record 22), and on November 19, 1920, 10 miles NNW. in 18 fathoms (record 25) and 17½ miles NW. by N. ¾ N. in 32 fathoms (record 26). Lifts 18, 22, 25, and 26 were composed largely or almost exclusively of spawning *zenithicus*, and the absence of *hoyi* is to be expected therefore. Lift 24, which was made out of Michigan City, Ind., at about the same time, and which shows 50 per cent of *hoyi*, may have been made outside the spawning area of those fish.

These records thus show that the lifts made by the 2½-inch gill nets between the depths of 18 and 50 fathoms, excepting those made on the spawning grounds of *zenithicus* in November, have percentages of bloaters between 34 and 96. The one lift from 16 fathoms in Green Bay and from 28 to 35 fathoms off Milwaukee gilled no fish of this species, and the lifts from depths of 60 fathoms or more took only occasional specimens, except that from off Point Betsie on October 4, 1920, which had 22 per cent *hoyi*. Considering the fact that nets of 2¾-inch mesh were used, the percentage is high and indicates that bloaters possibly were numerous on these grounds at that time.

Data from the pound nets.—In two localities the occurrence in the pound nets, among the herring, of numbers of fish, which from the descriptions given are probably bloaters, has been reported. At Port Washington, Wis., D. H. Smith says that in early July a good run of such fish enters his pounds. The fish sometimes remain ashore all during the month. F. C. Kimball reports 1,200 pounds of these fish on June 23, 1919, from three pound nets off Michigan City, Ind., and a lighter catch for a few days thereafter. They occur in the nets in varying numbers every year at this season, according to Mr. Kimball. Marketable bloaters were taken by me on September 27, 1920, in Mr. Smith's pound nets at Port Washington in 5 fathoms

[17] The nets in this case were set along the bank that slopes up to a large reef, and most of the *hoyi* taken were on the shoal end of the gang.

of water (record 13); and numbers of small individuals were collected on July 26, 1923, in a pound in Grand Traverse Bay (record 45). In view of these records, the fact that no other Leucichthys is known to venture so near the shore in summer (excepting *alpenæ*, which does not answer the fishermen's description) tends, in my opinion, to substantiate the identification of the fish reported above as *hoyi*.

From the data from all sources it appears that at some season of the year the bloater may be regularly common from the shore waters out to depths of 50 fathoms. In such situations it is taken abundantly by the pound nets, 1½-inch bait nets, and 2⅜ to 2¾-inch chub nets. On one occasion it has been known to be common in water deeper than 50 fathoms, but numbers of individuals may not venture often to such depths except where they are in proximity to shoals, as on the edges of banks and reefs. It is likely, furthermore, that large and small individuals have a different behavior, as on several occasions the latter occurred not uncommonly in the meshes of nets that would have gilled full-grown specimens easily if they had been present (records 18 and 52); but the population density of both classes of individuals probably fluctuates between the limits designated above.

BREEDING HABITS

The time of spawning of the species and several of its breeding areas are known. On March 20, 1919, 12 miles west of Grand Haven, Mich., in 50 to 55 fathoms, and on March 24, 1919, off Milwaukee, Wis., in 50 fathoms (records 31 and 15), such specimens as were collected from the chub nets were spent or sexually ripe. It is not known that the nets in either case were on the actual spawning grounds of the species, but they could not have been far removed. On March 2, 1921, a lift of 2½-inch gill nets made 21 miles NNW. of Michigan City, Ind., in 30 fathoms (record 28) contained 81 per cent of bloaters, most of which were spawning or nearly ripe. A lift made on March 4, 1921, 15 miles NW. by N. ½ N. of the same port in 28 fathoms had 96 per cent of bloaters (record 29).

The character of the bottom is unknown. No traces of bottom material were present on the anchor stones, and as clay is found commonly sticking to the anchors when the nets are lifted from such bottom, it may be that the bottom on this occasion was sandy. Most of the fish were ripe, and in the nets there were often two to four fish side by side in the meshes, probably having been gilled in the act of spawning or attempting to spawn. The specimens taken in the gang averaged larger than any other catch of *hoyi* seen on the lake and contained the largest individuals I have ever collected. There were fewer small individuals entangled in the netting than is usual at other seasons of the year, and possibly the small individuals have their own spawning areas. The lift of fish was very light (1,000 pounds in about 5 miles of netting, six nights out), considering the fact that the fish were spawning, and it may be that the bulk of the species was spawning on other grounds near by or had not yet come onto the grounds.

In a letter dated February 21, 1925, Lester Smith, of Port Washington, reports that large quantities of bloaters, heavy with spawn, are being taken in the shallow waters off that port. Considering probabilities, there seems to be no reason to doubt Mr. Smith's identification, and his observations may be taken to supplement my own.

The time of spawning, then, appears to be during March. It may begin in certain areas or at certain seasons even as early as late February. The species has been found spawning at a depth of 28 fathoms, but it may spawn in shallower or deeper water. The character of the bottom selected is not known. Breeding grounds are known to exist off Grand Haven, Mich.; Michigan City, Ind.; and Milwaukee and Port Washington, Wis.; but considering the wide distribution and abundance of the species, there are no doubt others to be found off most of the other ports on the lake.

Leucichthys hoyi of Lake Huron

The Lake Huron form is like the Michigan form in respect to body shape and other systematic characters, but it seldom grows so large. The largest specimen obtained in the lake measures only 221 millimeters, as compared with 265 millimeters for Lake Michigan, and only nine individuals have been seen over 200 millimeters in length, whereas in Lake Michigan such fish are taken often in commercial quantities. The principal systematic characters capable of numerical expression are compared for the two forms below:

Gill rakers on the first branchial arch:
- Michigan, (37) 41–44 (48).[18]
- Huron, (37) 40–43 (47).[19]

Lateral-line scales:
- Michigan, (60) 67–77 (84).[18]
- Huron, (63) 68–76 (84).

L/H:
- Michigan, (3.6) 4–4.2 (4.5).
- Huron, (3.5) 3.8–4.1 (4.5).

H/E:
- Michigan, (3.3) 3.7–4 (4.2).
- Huron, (3.3) 3.6–3.8 (4.2).

H/M:
- Michigan, (2.3) 2.5–2.6 (2.8).[20]
- Huron, (2.3) 2.4–2.6 (2.7).

Pv/P:
- Michigan, (1.3) 1.7–2 (2.5).
- Huron, (1.4) 1.7–1.9 (2.2).

Av/V:
- Michigan, (1) 1.2–1.4 (1.6).
- Huron, (1) 1.2–1.4 (1.7).

It appears from these figures that the two forms are quite similar and that they differ only in that the head and eye average proportionally somewhat larger in the Huron form, but these differences may well be due to inequality in size of the individuals of the groups compared.

The color in life is not conspicuously different from that of the Lake Michigan specimens. Preserved fish are also little different.

Pearl organs are developed by males in the breeding season, as evidenced by breeding fish taken at Harbor Beach, Mich., on March 15, 1919. Females probably also have pearls, but those in the collection had none, possibly having lost them by friction in transit, as did many of the males. The development is not different from that described for the Lake Michigan specimens, except that there are, on the average, fewer dorsolateral and ventrolateral scale rows, on the scales of which two or more pearls appear regularly. The pearls of the back and belly are also less scattered and more often are grouped around the free edge of the scale. It is possible,

[18] These figures for Lake Michigan are based on an examination of 1,161 specimens from 82 to 265 millimeters in length. The other unmarked figures are given for 1,024 individuals between the length limits of 82 and 199 millimeters, inclusive.

[19] These figures for Lake Huron, excepting those for H/M, which are given for 58 specimens, are based on an examination of 607 specimens between the lengths of 79 and 221 millimeters, inclusive. There are only 4 specimens less than 100 millimeters in length and only 9 over 200 millimeters, and their exclusion from the tables does not affect the range of the figures given.

[20] One hundred and eight specimens.

however, that such differences are due to the difference in size of specimens examined from the two lakes. Those from Lake Michigan were chiefly over 20 centimeters in length, while those from Lake Huron were all smaller.

VARIATIONS

Racial variations.—There appears to be a racial differentiation according to habitat in the same locality, which is manifested by rather conspicuous structural changes. Below are compared, for seven characters, five groups of specimens, two taken from depths of 30 fathoms or less, two from depths of 60 fathoms or more, and one group from Cheboygan, Mich., taken in a gang set from 35 to 50 fathoms. One group in each of the first two habitats was collected at Alpena, Mich. The others originated in other parts of the lake, but confirm the comparison. The specimens of the various groups are of comparable size.

Gill rakers on the first branchial arch

No.	30 fathoms			60 fathoms			30–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
37	2	0	2	4	1	5	1
38	7	9	16	13	4	17	0
39	11	7	18	31	10	41	7
40	19	30	49	49	23	72	6
41	27	45	72	59	36	95	17
42	34	31	65	54	44	98	18
43	16	24	40	42	27	69	16
44	7	19	26	15	12	27	8
45	1	2	3	6	3	9	1
46		1	1		4	4	3
47					1	1	1

Lateral-line scales

No.	30 fathoms			60 fathoms			35–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
63							1
64	1		1				0
65	2	2	4	3	2	5	1
66	0	5	5	2	6	8	2
67	2	5	7	2	4	6	5
68	13	6	19	15	4	19	6
69	10	14	24	8	12	20	8
70	17	14	31	29	12	41	6
71	14	7	21	24	11	35	6
72	12	25	37	32	16	48	7
73	14	21	35	27	9	36	6
74	15	21	36	28	20	48	7
75	11	18	29	29	14	43	12
76	6	12	18	18	8	26	3
77	4	7	11	8	10	18	2
78	4	3	7	10	6	16	3
79	1	5	6	11	1	12	3
80		1	1	4	0	4	
81	2	2	4	3	3	6	
82				0	2	2	
83				0	1	1	
84				1		1	

L/H

Ratio	30 fathoms			60 fathoms			35–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
3.5					1	1	
3.6				7	2	9	
3.7		2	2	36	13	49	5
3.8	3	2	5	56	31	87	8
3.9	9	16	25	71	30	101	17
4.0	38	39	77	84	50	134	31
4.1	46	49	95	19	26	45	13
4.2	15	30	45	3	12	15	5
4.3	11	21	32	1	0	1	2
4.4	1	4	5		1	1	
4.5	1	2	3				

H/E

Ratio	30 fathoms			60 fathoms			35–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
3.3	0	1	1		1	1	2
3.4	1	4	5	10	5	15	11
3.5	5	9	14	26	27	53	13
3.6	24	35	59	62	35	97	23
3.7	41	41	82	69	41	110	22
3.8	38	40	78	56	32	88	12
3.9	12	17	29	27	17	44	6
4.0	3	22	25	14	5	19	2
4.1		2	2	2	2	4	
4.2				2		2	

Pv/P

Ratio	30 fathoms			60 fathoms			35–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
1.4				3	3	6	
1.5		2	2	13	6	19	1
1.6	1	5	6	41	21	62	11
1.7	6	31	37	63	32	95	14
1.8	26	53	79	58	42	100	26
1.9	25	28	53	32	22	54	12
2.0	29	39	68	17	16	33	8
2.1	12	9	21	5	14	19	1
2.2		1	1	2	3	5	

Av/V

Ratio	30 fathoms			60 fathoms			35–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
1.0				4	1	5	
1.1	3	2	5	36	21	57	5
1.2	19	29	48	110	48	159	20
1.3	36	49	85	68	52	120	24
1.4	32	58	90	32	28	60	25
1.5	9	24	33	8	12	20	4
1.6	2	6	8				1

Mandible

Length	30 fathoms			60 fathoms			35-50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
Longer than upper	27	62	89	240	149	389	38
Equal to upper	64	99	163	23	20	43	40

The deep-water fish appear to have a proportionally larger head, longer paired fins (especially ventrals), and a longer mandible than those from the shallower waters. In most cases the 35-50 fathom group conforms to neither of the two but appears often to be intermediate, as might be expected. Whether specimens from 30 and 60 fathoms are always, at all seasons, so characterized is not known, and it is quite probable that there is a migration during the year of all schools of bloaters over a considerable bathymetric range, so that the fish taken throughout the season at a definite depth might very conceivably be of several schools.

The bloaters taken from the various ports on the lake agree, in the systematic characters examined, with one or the other of the two groups compared above, so that there is no evidence so far that there are geographical races in the lake.

Size variations.—Only nine specimens over 200 millimeters in length have been collected, and therefore the usual size groups can not be compared. It is not likely, however, that the changes correlated with growth are different for this form than for other Leucichthys in the lakes.

Specimens 110 millimeters long usually have been found to show maturing sex organs.

COMPARISONS

Hoyi is most like *kiyi* and young *artedi*. A discussion of the differences between *hoyi* and *kiyi* is given on page 440.

From the small *artedi* the bloater is distinguished by its less elongated and more bloated body shape, fewer gill rakers on the first branchial arch, fewer scales in the lateral line, and relatively longer head, eye, maxillary, and paired fins. These characters, excepting the first, are compared below:

Gill rakers on the first branchial arch:
hoyi, (37) 40–43 (47),[21] with 2 per cent more than 44.
artedi, (40) 45–50 (53),[22] with 89 per cent more than 44.

Lateral-line scales:
hoyi, (63) 68–76 (84), with 12 per cent more than 76.
artedi, (68) 76–86 (98),[22] with 86 per cent more than 76.

L/H:
hoyi, (3.5) 3.8–4.1 (4.5), with 13 per cent more than 4.1.
artedi, (4) 4.2–4.5 (4.8), with 89 per cent more than 4.1.

[21] The figures in this section for *hoyi* (except for H/M and H/S, which are given for 58 specimens) are based on an examination of 907 specimens ranging between 79 and 221 millimeters in length.

[22] These figures for *artedi* are given for 308 specimens ranging in length from 125 to 371 millimeters. Figures not so marked are based on an examination of 135 specimens between the lengths of 125 and 225 millimeters.

H/E:
hoyi, (3.3) 3.6–3.8 (4.2), with 16 per cent more than 3.8.
artedi, (3.6) 3.8–4 (4.4), with 66 per cent more than 3.8.

H/M:
hoyi, (2.3) 2.4–2.6 (2.7), with 7 per cent more than 2.6.
artedi, (2.5) 2.7–2.9 (3.2), with 89 per cent more than 2.6.

Pv/P:
hoyi, (1.4) 1.7–1.9 (2.2), with 21 per cent more than 1.9.
artedi, (1.7) 1.9–2.1 (2.3), with 68 per cent more than 1.9.

Av/V:
hoyi, (1) 1.2–1.4 (1.7), with 1 per cent more than 1.5.
artedi, (1.3) 1.6–1.7 (1.9), with 84 per cent more than 1.5.

On the average the mandible in *hoyi* probably is longer than the upper jaw more often than in *artedi*, and certainly it is seldom shorter, while in *artedi* it is frequently shorter. The state of development of sex organs frequently is a valuable criterion, also. Specimens of *hoyi* are found to mature sexually as small as 110 millimeters, while *artedi* usually do not mature under 160 millimeters. *Hoyi* spawns in February or March and *artedi* in November, so that the state of maturity of the sex organs also may be a character. *Hoyi*, as a rule, is much less pigmented, especially on the dorsal surface.

The distinguishing characters between *hoyi* and *johannæ*, *alpenæ*, *zenithicus*, and *nigripinnis* are, in the main, the same as described for these forms for Lake Michigan on pages 352, 366, 390, and 419, except that in the case of Huron the difference in size attained by *hoyi* and these four species is still more marked. Necessary modifications of the comparisons cited are given below:

Gill rakers on the first branchial arch:
hoyi, (37) 40–43 (47), with 3 per cent more than 44.
johannæ, (25) 27–31 (35).[23]
alpenæ, (31) 33–37 (41),[24] with 24 per cent more than 36.
zenithicus, (32) 35–37 (41),[25] with 47 per cent more than 36.
nigripinnis, (40) 46–50 (52),[26] with 83 per cent more than 44.

Lateral-line scales:
hoyi, (63) 68–76 (84), with 12 per cent more than 76.
johannæ, (67) 77–86 (91), with 92 per cent more than 76.
alpenæ, (70) 76–83 (91),[24] with 74 per cent more than 76.
zenithicus, (70) 72–81 (88),[25] with 56 per cent more than 76.
nigripinnis, (72) 77–83 (88), with 81 per cent more than 76.

Pv/P:
hoyi, (1.4) 1.7–1.9 (2.2), with 21 per cent more than 1.9.
johannæ, (1.2) 1.5–1.7 (2), with 3 per cent more than 1.9.
alpenæ, (1.6) 1.8–2 (2.4), with 41 per cent more than 1.9.
zenithicus, (1.7) 2–2.2 (2.6), with 73 per cent more than 1.9.
nigripinnis, (1.2) 1.4–1.7 (1.9).

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[23] Figures for *johannæ*, for gill rakers, are given for 441 specimens; for scales for 258 specimens. All others are based on an examination of 92 specimens ranging in length from 132 to 199 millimeters.

[24] Figures for *alpenæ*, except those for scales, are based on an examination of 204 specimens between the lengths of 131 and 209 millimeters. Figures for scales are given for 323 specimens of all sizes.

[25] Figures for *zenithicus*, except those for scales, are based on an examination of 77 specimens ranging in length from 139 to 199 millimeters. Those for scales are given for 144 specimens of all sizes.

[26] Figures given for *nigripinnis* are based on an examination of 134 specimens ranging in length from 208 to 371 millimeters.

H/E:

hoyi, (3.3) 3.6–3.8 (4.2), with 16 per cent more than 3.8.
johannæ, (3.6) 4–4.2 (4.5), with 95 per cent more than 3.8.
alpenæ, (3.6) 3.8–4.1 (4.4), with 78 per cent more than 3.8.
zenithicus, (3.5) 3.7–4.1 (4.3), with 60 per cent more than 3.8.

H/S:

hoyi, (3.5) 3.7–3.8 (4.2), with 78 per cent more than 3.6.
johannæ, (3.1) 3.3–3.5 (3.6).
alpenæ, (3.3) 3.4–3.6 (3.9), with 23 per cent more than 3.6
zenithicus, (3.5) 3.7–4.1 (4.3), with 53 per cent more than 3.6.

The ventrals in *hoyi* average shorter, possibly, than in *nigripinnis* and longer than in *alpenæ* and *zenithicus*.

Zenithicus spawns in late September and early October in Lake Huron, instead of November, as in Lake Michigan. The size at which sex organs begin to mature is less for *hoyi* than for any of the chubs, being about 110 millimeters, as compared with 220 millimeters for *nigripinnis*, 165 millimeters for *johannæ*, 160 millimeters for *alpenæ*, and 139 millimeters for *zenithicus*.

GEOGRAPHICAL DISTRIBUTION

Lake Huron proper.—The records in Table 58 (see also fig. 5), with the exception of Nos. 30, 34, and 35, are from my own observations and show that the bloater occurs off Cheboygan and Harbor Beach, Mich., in 30 to 50 fathoms in the 2¾ and 1½ inch gill nets; off Rogers, Mich., in 35 fathoms in the 2¾-inch nets; and off Alpena, Mich., in 14 to 100 fathoms in the 4½, 2¾, and 1½ inch nets. Off Tobermory, Ontario, the fishermen also report that bloaters are extremely abundant in June in the 4½-inch nets in 30 fathoms. As physical conditions apparently are no different in other portions of the lake, it is likely that the bloater occurs throughout the lake at depths of 14 to 100 fathoms.

North Channel.—According to the statements of three fishermen, the bloater is taken in the North Channel off Gore Bay Light in 20 to 25 fathoms. There is still deeper water off Meldrum Bay, in which the bloater probably also is found.

Georgian Bay.—On December 3, 1919, a 1½-inch net lifted from 15 fathoms in Colpoy Bay (record 41) had a few bloaters. This is the only record for bloaters in less than 50 fathoms for the bay, though in more than 50 fathoms they are taken in the chub nets as in Lake Huron. There is then no reason to suppose that the bloater does not occur thoughout the bay, as there are wide areas that are covered by about 30 fathoms of water.

BATHYMETRIC DISTRIBUTION

The bloater has no commercial value, and though large numbers often become entangled by the jaws in the chub nets and in the trout and whitefish nets, they are never brought to market. However, nets are set for them in American waters by the hook fishermen, who use them as bait for the trout hooks. These nets are of 1½-inch mesh and are set at about 30 fathoms throughout the fishing season, which for the hook fishermen embraces virtually the entire calendar year with the exception of the closed season for trout.

1. *Data from the 1½-inch bait nets.*—On Lake Huron there were two ports from which such nets were operated in 1917—Alpena and Harbor Beach, Mich.

Records 8, 22, 32, and 33 were made from these nets in 1917 and 1919. I also lifted a 1½-inch net set at other depths on three occasions with the chub gangs—off Cheboygan, Mich., on October 15, 1919, on the spawning grounds of *zenithicus* in 35 to 50 fathoms (record 4); off Alpena on September 13, 1919, in 60 fathoms (record 21); and in Colpoy Bay on December 3, 1919, in 15 fathoms on the spawning grounds of *alpenæ* (record 41). Bloaters were taken in all sets.

2. *The 2¾ to 3 inch chub nets.*—Bloaters were taken in the chub nets in Lake Huron in 35 to 50 fathoms from off Cheboygan on July 21, September 29, and October 1, 1917 (records 1, 2, and 3); from off Rogers, Mich., in 35 fathoms on October 14, 1917 (record 5); from off Alpena in 60 to 100 fathoms on August 13 and September 12, 14, 18, 19, 20, and 21, 1917, and September 13 and 18, 1919, June 30 and July 2, 5, and 7, 1923 (records 6, 10, 11, 14–18, 21, and 24–28); from off Harbor Beach, Mich., in 50 fathoms on October 27, 1917 (record 31); and in Georgian Bay in 52 to 70 fathoms off Lions Head on July 30 and October 6, 1919 (records 36 and 37), off Wiarton on July 28 and 30, 1919, and in 10 to 25 fathoms on November 28, 1919 (records 38, 39, and 40).

3. *The 4½-inch trout and whitefish nets.*—The records for the 4½-inch nets made from boats fishing off Alpena, Mich., show bloaters at depths of 15 to 24 fathoms in 1917 on September 7, 12, 14, 17, 22, and 26; in 20 to 30 fathoms on September 16, 1919; and in 14 to 20 fathoms in 1923 on July 10 (records 7, 9, 12, 13, 19, 20, 23, and 29). They are also reported from off Alpena, Mich., in 24 to 30 fathoms in the 4½-inch nets in November (record 30); from off Tobermory, Ontario, in 30 fathoms in June (record 34); and from off Gore Bay Light in the North Channel in August in 20 to 25 fathoms (record 35).

4. *Seines.*—The University of Michigan collection contains two small specimens that were seined in the spring of 1926 off Port Huron, Mich., with *Notropis atherinoides*.

These data thus show that bloaters become ensnarled in the chub and trout nets in water as shallow as these nets usually are set, namely, 14 fathoms, and in the chub nets as deep as these usually are set (100 fathoms), and that they also may occur in seine hauls made on the beaches. The species probably occurs in depths of more than 100 fathoms.

RELATIVE ABUNDANCE

The hook fishermen have found that at only about 30 fathoms can bloaters be taken in numbers sufficient for their purposes. John Hollander, a hook fisherman at Harbor Beach, tells me that from August 1 until the middle of October, when the bait nets are pulled in, bait is scarce anywhere. It is particularly rare during the first half of this period. He says he is unable to find the fish by moving the nets into deeper water or into shallower water. When the nets are put back on November 1 the bloaters are abundant until March. Then for a month they are scarce. There is no explanation for this scarcity except by assuming that the fish are swimming off the bottom, or that they have migrated to distant grounds, or that for some reason they avoid the netting.

I have stated already that bloaters are caught only by accident in the nets of mesh coarser than 1½ inches, but that, nevertheless, great numbers are often caught in the 2¾ and 4½ inch nets. I have pointed out before that nothing is known about the conditions under which small fish become ensnarled in such netting, and therefore the number of bloaters taken by nets too large to gill them may be no accurate gauge of their abundance. The same, however, may be said of nets in which they could gill, and for the present it seems worth while to record the relative abundance of the fish captured accidentally, particularly when the results are fairly constant and are supported by data obtained from the 1½-inch nets, which must be considered as a more effective apparatus of capture and therefore likely to yield more reliable evidence of abundance.

Only on one occasion did I see bloaters numerous in the large-meshed nets, namely, on October 14, 1917, off Rogers, at the 35-fathom end of a 2¾-inch chub gang (record 5). Only occasional specimens occurred in nets at that depth off Cheboygan on July 21, September 29, and October 1, 1917 (records 1, 2, and 3), and conditions obviously were unsuitable for their capture. However, the fishermen report bloaters in such numbers in their trout nets as to be a nuisance. Off Tobermory in June in 30 fathoms and off Alpena in November in 24 to 30 fathoms (records 30 and 34) the bloaters are said to be so abundant in the 4½-inch nets that it requires several hours to clear the nets of them. The fishermen then often turn the steam hose on the nets to cook the fish and afterwards remove them by shaking the nets.

At other situations bloaters have not been seen or reported to be caught abundantly in large-meshed nets. Only few or occasional specimens were taken in the lifts of the 2¾ to 3 inch chub nets from 60 to 100 fathoms made in Lake Huron off Alpena, Mich., on August 13 and September 12, 14, 18, 19, 20, and 21, 1917, September 13 and 18, 1919, and June 30, and July 2, 5, and 7, 1923 (records 6, 10, 11, 14–18, 21, and 24–28); from 50 fathoms off Harbor Beach, Mich., on October 27, 1917 (record 31); and in Georgian Bay in 52 to 70 fathoms off Lions Head on July 30 and October 6, 1919 (records 36 and 37), off Wiarton on July 28 and 30, 1919, and in 10 to 25 fathoms on November 28, 1919 (records 38, 39, and 40). It is not known that bloaters ever are absent entirely from such lifts, though it is conceivable that they might be. In August, at 20 to 25 fathoms, they are said to be common in the 4½-inch nets off Gore Bay in the North Channel (record 35). During September, 1917, off Alpena, bloaters were brought in not infrequently from the 4½-inch gangs in 15 to 24 fathoms. The total number of fish taken from these gangs on these dates was not great, but the relative number of the species taken by them at various depths is significant. For example, at 24 fathoms (record 12) 52 specimens were taken; at 16 to 20 fathoms (record 7) 19 specimens; at 17 fathoms (records 19 and 20) 20 and 3 specimens; at 15 to 17 fathoms (record 9) 4 specimens; and at 15 fathoms (record 13) 2 specimens. An unknown number of specimens was caught in the 4½-inch nets off Alpena on September 16, 1919, in 20 to 30 fathoms, and on July 10, 1923, in 14 to 20 fathoms (records 23 and 29). The data in this paragraph receive additional significance when the captures of the special 1½-inch nets referred to on page 463 are considered. The set made off Cheboygan in 35 fathoms captured bloaters abundantly. Off Presque Isle Light, Mich., in 60 fathoms, only 112 specimens were taken, which under the conditions of the set indicates few fish in that area; and in Georgian Bay off Wiarton, in 15 fathoms, only 25 fish were gilled, likewise indicating a rarity of the species. The results in the last-named case may have been influenced by the presence of *alpenæ*, which had been spawning on the grounds.

The data reviewed indicate that the bloater can be captured most abundantly at depths of about 30 fathoms, though at times it may be relatively uncommon at that depth. Numerous individuals often become entangled in large-meshed nets at that depth, and occasional specimens are known from these nets between 10 and 100 fathoms. It appears that the abundance of the species decreases toward the extremes of the zone of distribution.

BREEDING HABITS

Not even the hook fishermen know when the fish spawn. The same opinion as to the spawning season is held for the bloaters as for the chubs, namely, that they spawn all the year round. However, there is no evidence to support such a belief except that eggs are found in the fish during most of the season; but these eggs are not ripe when found. Specimens taken on December 3, 1919, in Colpoy Bay and on December 9, 1917, at Harbor Beach were not yet ripe. On March 14, 1919, Mr. Hollander wrote me from Harbor Beach that bloaters were then very scarce. Fish of this species which he collected for me on March 15 were spent females and pearled males. As the males are not found with pearls later in the year, it is certain that these fish had been on the spawning grounds a short time previous to March 15 (probably in February), and that for this reason they are scarce in March in the bait nets at 30 fathoms. At what depth and on what bottom they spawn is not known.

FOOD

Doctor Hubbs has examined the contents of 26 stomachs of specimens taken off Alpena, Mich., in September, 1917 and 1919, in 30 fathoms or less, and of 36 specimens from 60 fathoms and deeper, of 42 stomachs from specimens taken off Cheboygan, Mich., on October 15, 1919, and 1 taken in Georgian Bay on July 30, 1919.

The shallow-water specimens from Alpena had eaten from 60 to 98 per cent Pontoporeia. Almost all stomachs contained Pisidium more or less abundantly, and also wood and seed fragments. Sand, cinders, adult-insect remains, and Mysis were found occasionally. Stomachs of the deep-water fish from Alpena showed that Mysis constituted almost the sole food. Six stomachs had Pontoporeia and nine fragments of wood. Pisidium, insect larvæ, sand, or pebbles were found in very small quantities in occasional stomachs. The Georgian Bay fish (also from deep water) had eaten only Mysis.

The Cheboygan specimens from intermediate depths had eaten Mysis more frequently than Pontoporeia. Some stomachs had predominantly the one, some the other, but both forms occurred in most, indicating (in view of the rarity of Mysis and the abundance of Pontoporeia in the stomachs of the Alpena fish from 30 fathoms or less, and the reversed ratio in the stomachs of those from 60 fathoms or more) that the zones of distribution of the two forms overlap at about 35 fathoms. Pisidium and vegetable fragments are also frequent articles in the Cheboygan stomachs, and the casually swallowed items are the same as those given in the previous paragraph. In addition, Leucichthys eggs occurred in 10 of the stomachs, usually in small numbers, except that they comprised 94 per cent of the contents of one stomach.

(These eggs undoubtedly were of *zenithicus*, as the bloaters were taken on the spawning grounds of this species.) One fish had eaten chiefly wheat, one had found bryozoan statoblasts, and one contained a fish scale.

It seems that the bloater will eat whatever occurs in his environment. It is possible that the species feeds heavily on fish spawn.

Leucichthys hoyi of Lake Superior

The bloater of Lake Superior resembles the Michigan form in shape and general appearance, but apparently it does not grow so large. The largest individual collected measures 251 millimeters, but specimens over 200 millimeters were taken rarely, though nets that would have gilled them were set in many situations in the lake where their presence might have been expected. (See p. 382.) The systematic characters of the two forms that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (37) 41–44 (48).[27]
- Superior, (37) 41–44 (49).[28]

Lateral-line scales:
- Michigan, (60) 67–77 (84).[27]
- Superior, (65) 69–78 (84).[28]

L/H:
- Michigan, (3.6) 4–4.2 (4.5).
- Superior, (3.4) 3.7–4 (4.2).

H/E:
- Michigan, (3.3) 3.7–4 (4.2).
- Superior, (3.2) 3.6–3.8 (4).

H/M:
- Michigan, (2.3) 2.5–2.6 (2.8).
- Superior, (2.2) 2.3–2.5 (2.7).

Pv/P:
- Michigan, (1.3) 1.7–2 (2.5).
- Superior, (1.4) 1.5–1.8 (2).

Av/V:
- Michigan, (1) 1.2–1.4 (1.6).
- Superior, (0.9) 1.1–1.3 (1.6).

These figures indicate that the Superior form has a proportionally larger head and eye and longer paired fins and maxillary. There are also, on the average, slightly fewer scale rows around the body at the various points of count.

The color in life is about the same in the two forms except for minor details of pigmentation. Superior specimens appear, on the average, to be a trifle more pigmented. The anal fin, especially, is as often with some pigment as it is immaculate.

No individuals were taken during the breeding season, so that nothing is known about the development of pearl organs. Very probably they are developed as in others of the Great Lakes Leucichthys and likely are not different from those described for the typical form.

VARIATIONS

Racial variations.—Most of the specimens were collected from off the Apostle Islands, and there is no sufficient number of specimens comparable in size taken from any other locality for comparison. No material is available either to determine whether there are any shallow-water and deep-water races occurring out of the same port. In view of the fact that the transition to deep water is abrupt almost every-

[27] These figures for Lake Michigan are based on an examination of 1,161 individuals from 82 to 265 millimeters in length. The other figures for Lake Michigan are given for 1,024 specimens between the limits of 82 and 199 millimeters, except the H/M values, for which 108 specimens were measured.

[28] These figures for Lake Superior are based on an examination of 335 specimens ranging in length from 107 to 251 millimeters. Figures dealing with proportions, excepting those for H/M (which are based on 61 specimens), are given for 291 specimens from 107 to 199 millimeters in length.

where in Lake Superior, there would be room for such raciation, but the bloaters seem to be most common along these banks and seldom are found below them.

Size variations.—In Table 61 five individuals 200 millimeters or longer are compared extensively with five shorter. Below are given values for certain characters for 44 specimens over 200 millimeters in length and 291 smaller ones:

L/H:
 Large specimens, (3.7) 3.9–4.1 (4.3).
 Small specimens, (3.4) 3.7–4 (4.2).

H/E:
 Large specimens, (3.7) 3.9–4 (4.3).
 Small specimens, (3.2) 3.6–3.8 (4).

Pv/P:
 Large specimens, (1.4) 1.7–2 (2.2).
 Small specimens, (1.4) 1.5–1.8 (2).

Av/V:
 Large specimens, (1.1) 1.2–1.4 (1.5).
 Small specimens, (0.9) 1.1–1.3 (1.6).

It appears, as is usual, that the head, eye, and paired fins become proportionally shorter with growth.

Individuals over 130 millimeters in length usually have been found to be sexually mature.

COMPARISONS [29]

The characters that separate *hoyi* from *kiyi* (to which it most nearly approaches) are given on page 443. A discussion of the differences between *hoyi* and *zenithicus* is given on page 381, between *hoyi* and *reighardi* on page 411, and between *hoyi* and *nigripinnis* on page 427.

From *artedi*, *hoyi* is distinguished chiefly by the fewer gill rakers on the first branchial arch, fewer lateral-line scales, larger head and eye, longer paired fins and maxillary, and by the mandible, which in *hoyi* is hooked and usually longer than the upper jaw, while in *artedi* it is seldom hooked and usually equal or shorter. The aforementioned characters, which can be expressed numerically, are compared below:

Gill rakers on the first branchial arch:
 hoyi, (37) 41–44 (49), with 10 per cent more than 44.
 artedi, (38) 45–48 (53), with 87 per cent more than 44.

Lateral-line scales:
 hoyi, (65) 69–78 (84), with 7 per cent more than 78.
 artedi, (72) 84–93 (105), with 92 per cent more than 78.

L/H:
 hoyi, (3.4) 3.7–4 (4.3), with 11 per cent more than 4.
 artedi, (4) 4.2–4.6 (4.8), with 97 per cent more than 4.

H/E:
 hoyi, (3.2) 3.6–3.8 (4.3), with 18 per cent more than 3.8.
 artedi, (3.4) 4–4.2 (4.5), with 84 per cent more than 3.8.

H/M:
 hoyi, (2.2) 2.3–2.5 (2.7), with 6 per cent more than 2.5.
 artedi, (2.5) 2.7–3 (3.2), with 99 per cent more than 2.5.

Pv/P:
 hoyi, (1.4) 1.5–1.8 (2.2), with 11 per cent more than 1.8.
 artedi, (1.6) 1.9–2.2 (2.3), with 74 per cent more than 1.8.

Av/V:
 hoyi, (0.9) 1.1–1.3 (1.6), with 10 per cent more than 1.3.
 artedi, (1.4) 1.5–1.8 (1.9).

[29] Figures given in this section are based on all collected specimens, except for proportions of *artedi*, which are based on specimens less than 225 millimeters long.

The body shape of *hoyi* is also less elongated, the flesh is softer, and the color is likely to be paler. The state of the sex organs also may serve to separate the smaller individuals, as *hoyi* matures at about 130 millimeters while few *artedi* are mature under 200 millimeters.

GEOGRAPHICAL DISTRIBUTION

All my data on the occurrence of *hoyi* in Lake Superior are given in Table 60. They are shown in Figure 3 platted on a map of the lake. The 16 records were made chiefly from nets of 2½ to 4½ inch mesh, in which individuals were ensnarled accidentally; but on two occasions the catches of the 1½-inch bait nets were examined. There are sufficient data to warrant the conclusion that the bloater occurs throughout Lake Superior and even in the north bays where suitable conditions are found.

BATHYMETRIC DISTRIBUTION

Only by the use of 1½-inch nets can it be ascertained definitely what are the limits of the bloater's zone of distribution. No lifts of these nets were seen by me from less than 40 fathoms. Nets of 2½ to 4½ inch mesh were lifted on several occasions from shallower water, and in several such gangs bloaters were caught. They were not present in two lifts of such nets made in September from 11 and 14 fathoms, but occurred in several lifts set as shallow as 15 to 20 fathoms. From depths of more than 40 fathoms, where the nets were set on a bank and extended from shallow water to depths of 90 fathoms, specimens were taken in the 1½ to 4½ inch nets. The only specimens taken in depths of 80 to 90 fathoms, where such depths did not occur immediately at the foot of a bank, were caught in a lift made off Bread Rock, Ontario, on October 4, 1921, in 80 to 90 fathoms (record 15). Five other lifts of gangs of such nets made off Grand Marais and Marquette, Mich., Michipicoten Island and Coppermine Point, Ontario (see Table 24), from depths of 60 to 100 fathoms, took no bloaters among the small fish accidentally captured.

It is likely, then, that the bloater ranges along the banks down to depths of 90 fathoms but does not wander out into the vast areas that are covered by such depths. How close to shore it goes is not known, but in summer specimens have been taken as shallow as 15 fathoms.

RELATIVE ABUNDANCE

In Lakes Michigan and Huron the species appears to prefer depths of about 30 fathoms for the greater portion of the year, but in Lake Superior there are very restricted areas of shoal water and the descent from shore to the plains (which are overlaid by depths of 60 to 100 fathoms and more) is abrupt. It is on these banks that the species has been found most abundantly. Thus, in the 4½-inch nets, which in the 2 or 3 miles of their length extended from depths of 40 to 90 fathoms, specimens were occasionally or commonly found entangled, namely, on July 14, 1922, 25 miles north of South Twin Island, Wis.; on July 15, 1922, 14 to 18 miles NW. by N. of South Twin Island and 20 miles northwest of Rocky Island, Wis.; and on September 14, 1921, and July 17, 1922, off Terrace Point, Minn. (records 6, 7, 8, 10, and 11). Occasional specimens were taken similarly on August 24, 1921, 21 miles west, and on August 25, 1921, 6 miles NNW. of Ontonagon, Mich., in 15 to 45 and 20 to 38 fathoms, respectively; on July 17, 1922, 20 miles NE. by E. of Duluth, Minn., in 30 to 40 fathoms (record 9); in Thunder Bay on September 15, 1923, inside Thunder Cape in 31 fathoms; on September 17, 1923, inside the Welcome Islands in 23 fathoms; on September 19, 1923, off Sawyer Bay in 49 fathoms; and on September 29, 1923, off Salter Island in 42 fathoms (records 3, 4, 12, 13, 14, and 16). Only one specimen was found in the 2½ and 2¾ inch nets lifted on July 11, 1922, between Cat and South Twin Island in 15 to 20 fathoms (record 5), and two were taken on October 4, 1921, off Bread Rock in 80 to 90 fathoms (record 15). None occurred in the lifts of gangs of 3 to 10 miles of 4½-inch nets lifted on October 3, 1917, off Grand Marais, Mich., in 65 fathoms and deeper; on August 5 and 11, 1921, 31 miles N. ¾ E. and 18 miles NE. by N. of Marquette, Mich., in 80 to 100 fathoms; on June 26, 1922, off Alona Bay, Ontario, in 60 fathoms, and on June 19, 1922, 6 miles northeast of the east end light of Michipicoten Island in 15 to 35 fathoms. Small stretches of the special 2½ to 2¾ inch nets lifted on several occasions from 11 to 80 fathoms had no fish of this species. The lifts of large-meshed nets, in which small fish become entangled, of course, can offer no conclusive data on their abundance in the vicinity of such nets, as it is not known under what conditions these fish become entangled in the netting. It is interesting in this connection, however, to point out that in the gangs mentioned above, lifted off Grand Marais, Mich., on October 3, 1917, off Marquette, Mich., on August 5 and 11, 1921, and off Alona Bay, Ontario, June 26, 1922, small *kiyi* and *zenithicus* were ensnarled; and it is at least probable that *hoyi*, had they been present, would have been taken in the same manner. In the 1½-inch bait nets lifted on June 14, 1922, in Whitefish Bay from 40 to 50 fathoms (record 1) and on August 8, 1921, 6 miles NE. ¾ N. of Marquette, Mich., from 42 to 65 fathoms (record 2), the species was fairly common. The hook fishermen, however, are not able continually to find enough bait for their hooks at those depths, but often are forced to set them nearer shore, where they probably take other species of fish.

Concerning the proportion of other fish that occur in the bait nets nothing is known. It is very likely, however, that small *zenithicus* are taken regularly among the bloaters at depths of 40 to 50 fathoms. *Kiyi* probably does not come so shallow often and *artedi* seldom so deep.

The data thus indicate that the bloater occurs most abundantly along the banks that border the deep-water plains. Specimens have been taken as shallow as 15 and as deep as 80 or 90 fathoms, but they are commonest, so far as is known, between he depths of 35 and 50 fathoms.

BREEDING HABITS

Nothing is known about the breeding habits of the species except that the specimens taken up to October 4, 1921, showed no mature ovaries. Occasional females that had ova rather larger than those of their companions have been taken during the summer at several ports, and it might be expected that these individuals would spawn earlier than the rest. It is not certain, however, that the ova would ripen prematurely even though their growth was precocious originally. Fishing operations usually are suspended from early December until spring, so that unless the fish spawn before December (which they probably do not) the time and place of their spawning will not be determinable readily.

Leucichthys hoyi of Lake Nipigon

The bloater of Lake Nipigon has the same general form of body as the Lake Michigan race, but there are average differences in the proportional lengths and in the number of some of the multiple parts. It appears, however, that the species does not commonly grow so large as in Lake Michigan. In virgin waters only 13 specimens over 200 millimeters in length were obtained, and the largest specimen measured only 231 millimeters, whereas in Lake Michigan examples of over 200 millimeters are very common and the maximum recorded size is 265 millimeters. The most conspicuous characters of the two forms are compared below:

Gill rakers on the first branchial arch:
- Michigan, (37) 41–44 (48).[30]
- Nipigon, (40) 42–46 (48).[31]

Lateral-line scales:
- Michigan, (60) 67–77 (84).[30]
- Nipigon, (66) 73–80 (85).[31]

L/H:
- Michigan, (3.6) 4–4.2 (4.5).
- Nipigon, (3.6) 3.8–4 (4.2).

H/E:
- Michigan, (3.3) 3.7–4 (4.2).
- Nipigon, (3.1) 3.6–3.8 (4).

H/M:
- Michigan, (2.3) 2.5–2.6 (2.8).
- Nipigon, (2.2) 2.3–2.4 (2.5).

Pv/P:
- Michigan, (1.3) 1.7–2 (2.5).
- Nipigon, (1.2) 1.4–1.7 (1.9).

Av/V:
- Michigan, (1) 1.2–1.4 (1.6).
- Nipigon, (1) 1.1–1.3 (1.5).

It appears, thus, that the Nipigon form tends to have a slightly higher average number of gill rakers on the first branchial arch and of scales in the lateral line, and a proportionally longer head, eye, maxillary, and paired fins. The number of dorsal rays also tends to become greater. The usual range is not changed, but there are more specimens that register in the upper limits. The scale rows around the body average fewer, the branchiostegals more, the mandible longer, and the height of the anal fin in proportion to its base length (AC) averages greater; that is, the rays are longer. For some values for most of these characters, see the detailed comparison of 10 specimens from each lake given in Tables 57 and 63.

The color in life was not recorded but probably is not different from that of the Michigan form. Alcoholic specimens show, in general, less pigment than the typical form. The distribution of the pigment on the body is about the same, but the pigment dots on the dorsal surface usually are fewer and rather coarser, and the pectoral and anal fins, as well as the ventrals, are usually immaculate. Even the dorsal and caudal may be very pale but usually are smoky. The maxillary, which is always pigmented in the Lake Michigan form, may be immaculate, also, but usually shows more or less of pigment over its proximal half.

No specimens were seen ready to spawn, so that it is not known to what extent pearl organs are developed. The nuptial dress probably is no different from that described for the Lake Michigan form.

[30] These figures for Lake Michigan are based on an examination of 1,161 individuals from 82 to 265 millimeters in length. The other figures are given for 1,024 specimens less than 200 millimeters long, except the H/M value, for which 108 specimens were measured.

[31] These figures for Lake Nipigon are based on an examination of 174 specimens ranging in length from 106 to 231 millimeters. The other figures, except those for H/M, which are based on 82 specimens, are given for 158 specimens less than 200 millimeters long.

VARIATIONS

Racial variations.—Not enough specimens have been collected to determine whether there is more than one race in the lake. There are no indications, however, from the material obtained from several localities that such races, if they exist, are marked by conspicuous external features.

Size variations.—Only 13 specimens longer than 200 millimeters were obtained. Five of these are extensively compared in Table 63 with five under 200 millimeters. The meager data of this table indicate little, but it is likely that the usual changes of growth obtain, namely, that large fish tend to have a proportionally smaller head and eye and shorter paired fins.

Individuals have been found approaching sexual maturity at 134 millimeters, but some specimens below 157 millimeters show no indications of spawning during the year. Beyond the last-named limit, all specimens were found to be maturing.

COMPARISONS [32]

A discussion of the differences between *hoyi* and *zenithicus*, *reighardi*, and *nigripinnis* is given on pages 386, 408, and 432.

From *artedi* and *nipigon*, *hoyi* is distinguished by its longer mandible, fewer gill rakers on the first branchial arch, and longer maxillary. Certain of these characters are compared below:

Gill rakers on the first branchial arch:
- *hoyi*, (40) 42–46 (48), with 4 per cent more than 46.
- *artedi*, (41) 46–49 (53), with 74 per cent more than 46.
- *nipigon*, (54) 56–59 (66).

H/M:
- *hoyi*, (2.2) 2.3–2.4 (2.5), with 13 per cent more than 2.4.
- *artedi*, (2.6) 2.7–2.8 (3).
- *nipigon*, 2.5–2.7 (3.1).

Hoyi is also much less pigmented than the others and has a larger head than *artedi*. The specimens of *nipigon* are too large for comparison with those of *hoyi* in this character.

GEOGRAPHICAL DISTRIBUTION

All the data for the specimens of the species that I have examined from Lake Nipigon are given in Table 62 and are shown platted on the map of the lake in Figure 2. They are derived from the various apparatus that has been used on the lake. The places from which bloaters have been collected are sufficiently scattered over the lake to justify the conclusion that they occur throughout its extent where suitable ecological conditions obtain.

DEPTH DISTRIBUTION

The only nets employed by me in Lake Nipigon were the 2½ and 2¾ inch gill nets and in these no *hoyi* were gilled, but such specimens as they took became

[32] Values in the comparison are given for all the collected specimens.

ensnarled in the netting. Numbers of bloaters are taken in the same manner in the 4½-inch whitefish nets, and all the specimens listed in Table 62 probably were caught in gear of these types. Through the use of these nets alone nothing definite can be ascertained about the depth range of the species, as the capture of individuals is accidental; and, moreover, it is very likely that they also took bloaters, when set at other depths, of which no record was made. The records, however, show no specimens in less than 15 fathoms, from which nets were lifted on August 1, 1922, in Ombabika Bay and on July 29, 1924, in Orient Bay (records 9 and 4). The set lifted on September 3, 1923, in Humboldt Bay, which took a number of bloaters, extended from 6 to 35 fathoms and obviously was set on a bank (record 7), but it is not known that any fish were caught at the shallow end of the gang. The deepest record is the capture of specimens on July 25, 1924, off Blackwater River in 54 fathoms (record 6). Present data, therefore, indicate that the bloater ranges between the depths of 15 and 54 fathoms, but these data do not fix the limits of the zone of distribution.

RELATIVE ABUNDANCE

The only criterion of the abundance of the species is the frequency of the accidental captures of specimens in the nets set for other species. On July 26, 1922, off Macdiarmid in 30 fathoms (record 1) bloaters were common. In another lift of the same kind and quantity of netting made by me on July 25, 1922, off the source of the Nipigon River in 10 to 15 fathoms, and in a lift made with half the quantity of netting on July 28, 1922, 2½ miles south of Livingston Point in 56 fathoms, no specimens were taken. No statements of frequency of occurrence accompany the records in Table 62, and in the absence of more information on this point no conclusions can be drawn, but it is interesting that the one observation suggests that the depth preference may be as in Lake Michigan.

BREEDING HABITS

Nothing is known about the time or place of spawning of the species. Specimens were taken only between July 25 and October 26. Those on the earliest date had not spawned recently, and those on the latest were not yet ripe. Two females had ova in a considerably more advanced state of development than the rest and apparently were nearly ripe, but the 15 other specimens showed no indications that they would spawn soon. Occasional females with ova larger than those of the bulk of the race were found among the specimens collected during the summer, and a similar condition has been reported for the species in Lake Superior. (See p. 469.)

Leucichthys hoyi of Lake Ontario

The bloater of Lake Ontario is like that of Lake Michigan in respect to general appearance and to the size commonly attained. The largest example collected measured 277 millimeters, as compared with 265 millimeters, which is the largest specimen from Lake Michigan; but as in Lake Michigan, very few fish over 250 millimeters were collected. The important systematic characters of the two forms are compared below:

Gill rakers on the first branchial arch:
- Michigan, (37) 41–44 (48).[33]
- Ontario, (39) 42–47 (50).[34]

Lateral-line scales:
- Michigan, (60) 67–77 (84).[33]
- Ontario, (63) 67–76 (82).[34]

L/H:
- Michigan, (3.9) 4.1–4.3 (4.6).
- Ontario, (3.8) 4–4.2 (4.6).

H/E:
- Michigan, (3.8) 3.9–4.1 (4.5).
- Ontario, (4) 4.1–4.4 (4.7).

H/S:
- Michigan, (3.5) 3.6–3.9 (4.1).[35]
- Ontario, (3.4) 3.6–3.8 (4.1).[36]

H/M:
- Michigan, (2.3) 2.5–2.6 (2.8).[37]
- Ontario, (2.4) 2.5–2.7 (2.8).[38]

Pv/P:
- Michigan, (1.6) 1.8–2.1 (2.3).
- Ontario, (1.4) 1.7–2 (2.2).

Av/V:
- Michigan, (1.1) 1.3–1.5 (1.7).
- Ontario, (1.1) 1.3–1.5 (1.6).

Mandible compared with upper jaw:
- Michigan, equal 326, longer 726.
- Ontario, equal 52, longer 199.

From these data it appears that the Ontario form has, on the average, rather more gill rakers on the first branchial arch, a proportionally smaller eye, and possibly a somewhat longer head and pectorals. The mandible seems to project more often beyond the upper jaw in Ontario specimens. The body of Ontario specimens, on the whole, is also slightly more elongated and more compressed than in the Michigan specimens, especially in the larger ones, which in Michigan often become conspicuously wide. In other matters, as fin rays, scale rows, etc., the two forms are in virtual agreement.

The color in life is not conspicuously different from that of the Michigan race, except that pigmentation usually is more extensive and intensive. Alcoholics often show those areas that are most pigmented in the Michigan form (as the entire dorsal surface, the preorbital area, and mandible tip) conspicuously dark, and pigment usually extends farther on the sides, even to below the lateral line. The fins also are darker, except the ventrals, which remain immaculate. The anal more often shows pigment dots on its membranes, and the pectorals always show at least some pigment but usually not more than a lining of black on the dorsal edge.

The males, at least, develop pearl organs in the breeding season. Only one pearled fish has been collected, and many of the excrescences on it have been removed by friction, but from those remaining I conclude that the development of the breeding adornment probably is not different from that described for the Michigan form.

VARIATIONS

Racial variations.—No differences are observable between the groups of specimens collected from the various parts of the lake, but it is not improbable that, if sufficient numbers were gathered together, local races might be differentiated. No material is available, either, to determine whether the depth inhabited affects the orm of the body and its parts.

[33] Figures so marked for Lake Michigan are based on an examination of 1,161 specimens ranging in length from 82 to 265 millimeters. All undesignated figures are given for 137 individuals ranging between the lengths of 200 and 265 millimeters.

[34] Figures so marked for Lake Ontario are based on an examination of 258 specimens ranging in length from 128 to 277 millimeters. Undesignated figures are given for 236 specimens ranging in length from 200 to 277 millimeters.

[35] Seventy-five specimens.

[36] Two hundred and fifteen specimens.

[37] One hundred and eight specimens.

[38] One hundred and thirteen specimens.

Size variations.—By far the majority of specimens collected have been gilled in 2½-inch nets and therefore are longer than 200 millimeters. Five individuals over 200 millimeters in length and five smaller are extensively compared in Table 65. It appears that the larger specimens tend to have a proportionally smaller head and eye, more body depth, and possibly shorter paired fins.

The smallest specimen collected measured 128 millimeters and was a female with maturing ova.

COMPARISONS

Hoyi approaches both *kiyi* and *artedi* rather closely, but usually may be separated from *artedi* by a consideration of several characters. *Hoyi* has a relatively longer maxillary, snout, paired fins, mandible, head, and eye, and the body is more compressed as a rule and less elongated. The mandible also is frailer in *artedi* and seldom shows the symphysial knob of *hoyi*. The shortness of the mandible alters the shape of the head, which, seen from the side, is less sharply triangular in *artedi*. Characters that are of taxonomic use and that can be expressed numerically are given for the two species below: [39]

Gill rakers on the first branchial arch:
- *hoyi*, (39) 42–47 (50), with 4 per cent more than 47.
- *artedi*, (41) 46–50 (54), with 52 per cent more than 47.

Lateral-line scales:
- *hoyi*, (63) 67–76 (82), with 8 per cent more than 76.
- *artedi*, (66) 73–82 (89), with 54 per cent more than 76.

L/H: [40]
- *hoyi*, (3.8) 4–4.2 (4.6), with 18 per cent more than 4.2.
- *artedi*, (3.7) 4.3–4.7 (4.9), with 89 per cent more than 4.2.

H/E: [40]
- *hoyi*, (4) 4.1–4.4 (4.7), with 12 per cent more than 4.4.
- *artedi*, (3.9) 4.1–4.4 (4.9), with 22 per cent more than 4.4.

H/M:
- *hoyi*, 2.5–2.7 (2.9), with 10 per cent more than 2.7.
- *artedi*, (2.5) 2.7–2.9 (3.3), with 60 per cent more than 2.7.

H/S:
- *hoyi*, (3.4) 3.6–3.8 (4), with 16 per cent more than 3.8.
- *artedi*, (3.4) 3.7–4 (4.5), with 47 per cent more than 3.8.

Pv/P:
- *hoyi*, (1.4) 1.7–2 (2.2), with 8 per cent more than 2.
- *artedi*, (1.7) 1.9–2.1 (2.5), with 38 per cent more than 2.

Av/V:
- *hoyi*, (1.1) 1.3–1.5 (1.6), with 7 per cent more than 1.5.
- *artedi*, (1.3) 1.5–1.8 (2), with 72 per cent more than 1.5.

Mandible compared with upper jaw:
- *hoyi*, shorter 5 equal 47 longer 199 or 79 per cent longer.
- *artedi*, shorter 130 equal 121 longer 77 or 23 per cent longer.

A discussion of the differences between *hoyi* and *kiyi* is given on page 446 and between *hoyi* and *reighardi* on page 414. In view of the fact that only one specimen of the Ontario representative of *Leucichthys nigripinnis* is preserved, it is not possible

[39] Figures for counts are given for all collected specimens. Proportions are given for specimens 225 millimeters or more in length in the case of *artedi* and for *hoyi* for those 200 millimeters or longer.

[40] These proportions are those most affected by growth, and as the *artedi* average considerably larger, the figures have no other value than to indicate that in general *artedi* has a somewhat smaller head and eye.

to state what distinctive features the race possessed. It is certain, however, that in point of absolute size attained it far exceeded *hoyi*, and the shape of the body, to judge from the specimen and from representatives of the species in other lakes, is more ovate in side view in *nigripinnis prognathus* and elliptical in *hoyi*.

GEOGRAPHICAL DISTRIBUTION

All my data on the occurrence of *hoyi* in Lake Ontario are given in Table 64 and are shown platted on a chart of that lake in Figure 7. For the most part they are gathered from the use of 2½ and 2¾ inch gill nets set by me from the various ports on the lake, but some observations on the species also have been made from 3-inch herring nets and 4¾-inch whitefish nets lifted from these ports. As specimens were found in the experimental nets out of every port from which they were set, and as the ports visited are widely scattered along the lake's shores, it is safe to conclude that *hoyi* occurs throughout the lake where suitable ecological conditions obtain.

BATHYMETRIC DISTRIBUTION

It has previously been stated that the only sources of data on the occurrence or distribution of any of the deep-water Leucichthys were the experimental nets referred to in the preceding paragraph. These nets were set for the most part only at such depths at which two or more species might be expected to occur, and no efforts were made to determine the depth range of any form. The records show small individuals ensnarled in the 4¾-inch whitefish nets off Bronte, Ontario, in 16 fathoms on June 30, 1921 (record 3), and gilled specimens in the 2½-inch nets off Wilson, N. Y., in 20 fathoms on July 21, 1921 (record 18). These are the shallowest sets in which any Leucichthys were observed by me in Lake Ontario. The deepest water explored by me was 70 to 75 fathoms, from which nets were lifted off Oswego, N. Y., on September 4, 1923 (record 10) and some *hoyi* were present in the catch of these nets. Records 7, 11, 13, and 17 show them to have occurred in nets lifted from depths of 60 to 65 fathoms out of Sandy Pond, Sodus Point, Charlotte, and Wilson, N. Y. It may be said, then, that the species ranges between 16 and 75 fathoms, but the figures do not set the limits of the zone of distribution.

RELATIVE ABUNDANCE

From many of the experimental sets made during the summers of 1921 and 1923 but few fish were taken, due, no doubt, in part, at least, to want of experience with conditions out of the various ports rather than to their actual rarity in the neighboring waters; but from most of those lifts that could be considered profitable from the fisherman's point of view the relative abundance of the species has been tabulated. On June 25, 1921, and on July 16, 1921, 5 miles north of Wilson, N. Y., in 50 fathoms, and on July 19, 1921, 6½ miles N. by W. ½ W. in 65 fathoms (records 15, 16, and 17), bloaters constituted 60, 90, and 25 per cent, respectively, of the catch. On July 4, 1921, 7 miles north of Braddock Point Light in 65 fathoms (record 13), 66 per cent of the fish taken were bloaters; and on July 12, 1921, 8½ miles NNW. of Sodus Point, N. Y., in 60 fathoms (record 11), they comprised 75 per cent of the lift. The species was not uncommon in lifts made on June 10 and 16, 1921, 20 miles S. by W. of Presque Isle Light, Ontario, in 40 to 50 fathoms (records 4 and 5), but the percentage was not ascertained. Few specimens were taken on November 23, 1917, off Winona, Ontario (record 1); on June 29, 1921, 13 miles E. ½ S. of Bronte, Ontario, in 40 to 50 fathoms (record 2); on June 23, 1921, and July 21, 1921, 3 miles north and 2 miles north of Wilson, N. Y., in 30 and 20 fathoms, respectively (records 14 and 18); on September 4, 1923, 8½ miles W. by N. ½ N. of Oswego, N. Y., in 70 to 75 fathoms (record 10); and on August 30, 1923, 14 miles west of Sandy Pond, N. Y., in 60 fathoms (record 7). The scarcity of fish in the 3-inch nets lifted on July 13, 1921, off Sodus Point, N. Y. (record 12); on September 1, 1923, off Nine-Mile Point, N. Y., in 30 fathoms (record 9); on July 11, 1921, 5 miles NNW. of Nine-Mile Point, N. Y., in 25 to 35 fathoms (record 8); and on August 24, 1923, 9 miles west of Sandy Pond, N. Y., in 25 to 28 fathoms (record 6), shows nothing conclusive about the abundance of the species, as the mesh of such nets is too large to take the species. Similarly, the rarity or absence of specimens from the 4½ and 4¾ inch whitefish nets is of no interest in this connection because the fish could only have become entangled accidentally in such netting.

Thus, the few observations on record show that the bloaters, though occurring between the depths of 16 and 75 fathoms, are most abundant, at least in summer, between the depths of 50 and 65 fathoms.

BREEDING HABITS

Except for a single example found among the spawning herring collected off Winona, Ontario, on November 23, 1917 (record 1), and one received from J. R. Dymond, of the University of Toronto, taken off Port Credit, Ontario, on March 28, 1926, no specimens of the species were seen between the dates of September 4 and June 10. None of the individuals collected as late as September showed any approach to sexual ripeness, and the fish collected in early June clearly had not spawned recently. The specimen taken on November 23, 1917, was a male with pearl organs and was therefore ready or nearly ready to spawn. The one taken on March 28, 1926, was a spent female. The spawning season, then, probably falls sometime between these dates.

LEUCICHTHYS ARTEDI LeSueur

THE BLUEBACK. THE CISCO. THE HERRING. (FIGS. 24, 25, AND 26)

Coregonus artedi LeSueur, 1818, pp. 231–232, "Lake Erie, and at Lewiston, upper Canada."
Argyrosomus artedi Evermann and Smith, 1896, pp. 305–309, pl. 21, Great Lakes.
Leucichthys artedi Jordan and Evermann, 1911, pp. 17–19, figs. 8 and 9, Lakes Huron, Erie, and Ontario; Dymond, 1926, p. 63, Pl. IV, Lake Nipigon.
Coregonus albus LeSueur, 1818, p. 232, Lake Erie (not of other authors).
Salmo (Coregonus) harengus Richardson, 1836, III, pp. 210–212, pl. 90, fig. 2, Georgian Bay.
Leucichthys harengus Jordan and Evermann, 1911, pp. 6–8, figs. 2 and 3, bays of Lakes Huron and Michigan.
Leucichthys harengus arcturus Jordan and Evermann, 1911, pp. 7–8, fig. 4, Lake Superior.
Coregonus clupeiformis De Kay, 1842, p. 248, Pl. LX, fig. 198, Lake Ontario; Agassiz, 1850, pp 339–342, Lake Superior. (Not of Mitchill.)
Argyrosomus cisco Jordan, 1875a, pp. 135–138, Lake Tippecanoe, Ind.
Leucichthys cisco Jordan and Evermann, 1911, pp. 10–12, fig. 5, lakes of northern Indiana and southern Wisconsin.

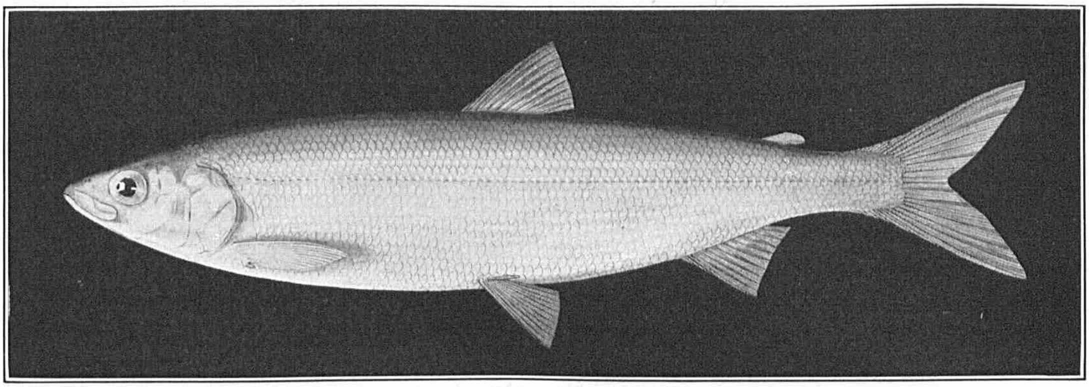

FIG. 24.—*Leucichthys artedi artedi* Le Sueur, the herring. Specimen, 244 millimeters long, taken in Lake Huron in Saginaw Bay in 4 fathoms on October 25, 1917

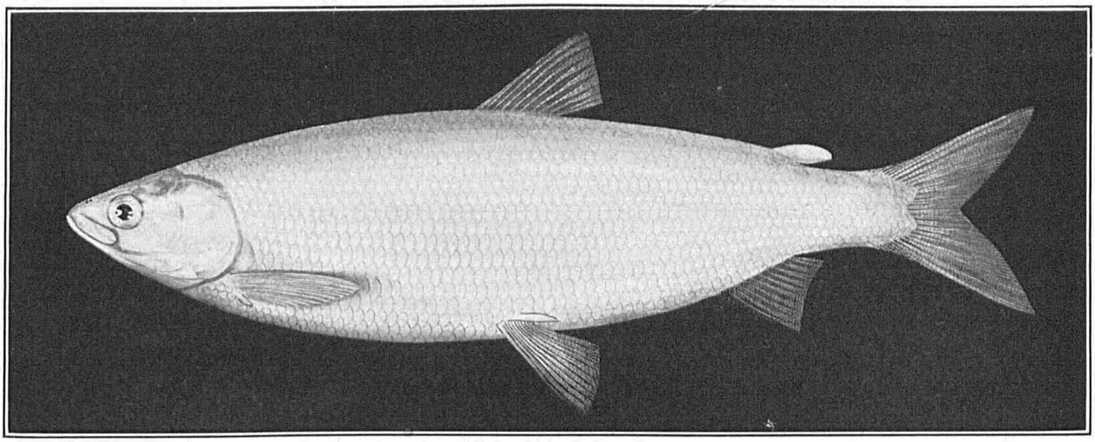

FIG. 25.—*Leucichthys artedi albus* Le Sueur, the Erie cisco. Male, 233 millimeters long, taken in Lake Erie off Sandusky, Ohio, on November 29, 1920

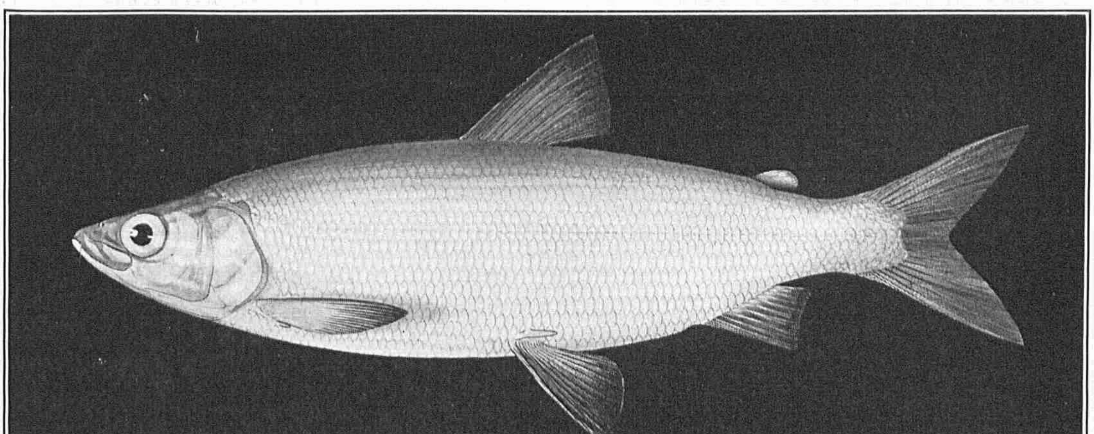

FIG. 26.—*Leucichthys artedi manitoulinus* Jordan and Evermann. Male, 250 millimeters long, taken in the North Channel of Lake Huron off Cutler, Ontario, on November 11, 1917

Leucichthys cisco huronius Jordan and Evermann, 1911, pp. 12–13, fig. 6, Pl. II, Lakes Michigan, Huron, and Erie.
Argyrosomus tullibee Evermann and Smith, 1896, pp. 320–322, pl. 28, Lake of the Woods (possibly also *Salmo* (*Coregonus*) *tullibee* of Richardson, 1836).
Leucichthys tullibee Jordan and Evermann, 1911, pp. 32–34, figs. 17 and 18, Winnipeg Basin.
Coregonus tullibee bisselli Bollman, 1889, p. 223, Rawson and Howard Lakes, Mich.
Argyrosomus tullibee bisselli Evermann and Smith, 1896, p. 322, lakes of southern Michigan.
Leucicthys artedi bisselli Jordan and Evermann, 1911, p. 20, fig. 10, lakes of southern Michigan.
Argyrosomus eriensis Jordan and Evermann, 1909, pp. 165–167, fig. 1, Lakes Erie and Huron.
Leucichthys eriensis Jordan and Evermann, 1911, pp. 20–22, fig. 11, Lakes Erie and Huron.
Argyrosomus huronius Jordan and Evermann, 1909, pp. 167–169, fig. 2, Lakes Erie and Huron.
Leucichthys manitoulinus Jordan and Evermann, 1911, pp. 31–32, fig. 16, North Channel of Lake Huron.
Leucichthys ontariensis Jordan and Evermann, 1911, pp. 13–14, fig. 7, Lake Ontario.
Leucichthys supernas Jordan and Evermann, 1911, pp. 22–23, fig. 12, Lake Superior.
Leucichthys macropterus Bean, 1916, pp. 25–26, Lake Erie.

The type specimen is not extant. The species was described as *Coregonus artedi*, the herring salmon, from "Lake Erie and Lewiston, upper Canada," by LeSueur in the May, 1818, number of the Journal of the Academy of Natural Sciences of Philadelphia. A second species was described by LeSueur in the same publication under the name *Coregonus albus*, "Lake Erie whitefish," but this form was distinguished from *artedi* in no other characters than in being less fusiform, deeper bodied, in having the back elevated from the nape to the dorsal fin, and "the proportions much stronger in body, fins, and scales"; and though a figure was given of what may be taken for a herring, apparently drawn from memory, there is nothing about this figure to indicate that LeSueur had the true whitefish in mind. No specimens on which were based the descriptions of either species are known to exist, and the practice of ichthyologists has been to attach the name *artedi* to the Lake Erie herring and to call the Lake Erie whitefish *albus*. This procedure does not take into consideration the fact that Lewiston is on the Niagara River below the falls and that any herring taken from that vicinity probably would not be the common Lake Erie type, and lets the fact that LeSueur called his *albus* the "whitefish" outweigh the considerations of his having failed to point out in his description or to indicate in his drawing the striking difference in the position of the mouth of the whitefish as compared with that of the herring. If, on the other hand, we assume that LeSueur got a Lake Ontario herring at Lewiston and then a herring from Lake Erie (which, by the way, was obtained much more easily in the early days than the whitefish), his descriptions are applicable, especially if by "stronger proportions" (by which he distinguishes *albus* from *artedi*) he meant greater depth of body, longer fins, and larger scales. According to this view, then, the Lake Ontario shallow-water herring, which also occurs sparingly in Lake Erie, is the type race of *artedi*, and the name *albus* may be used for the common Lake Erie race and for the deep-water race that is known to exist in the western waters of Lake Ontario and elsewhere.

The lake herring is the most widely distributed and the most variable species of Leucichthys in the Great Lakes Basin. The range of variations lies between the slim terete herring of Lake Superior (an extreme of the *artedi* type) and the deep, compressed herring of Erie, the *albus* type, or the still more extreme tullibee [41] of the western Canadian lakes represented by the dark-colored *manitoulinus* in the North Channel of Lake Huron. While a school in a given locality usually presents a uniform appearance, specimens that show an approach to the extremes often may be found in it.

In all the Great Lakes and Lake Nipigon and in many of the deeper inland glacial lakes of the basin the species *Leucichthys artedi* occurs, and it is represented by races that resemble more or less closely one of these types. This variability in external appearance has confused systematists, and in the absence of information on their natural history many of these races have been described as distinct species. In the latest revision of the coregonids of the Great Lakes, Jordan and Evermann (1911) accredit seven such species and one subspecies to the Great Lakes. They are listed here under the synonomy of *L. artedi*, and the reasons therefor are given under the various systematic accounts of that species. Two subspecies of *artedi* are recognized—*albus*, typically of Lake Erie but occurring also in Lakes Superior and Ontario, and *manitoulinus* of the North Channel of Lake Huron. Typical *artedi* are found in all the lakes.

Leucichthys artedi artedi and artedi albus of Lake Erie

The lake herring, while probably the most important commercial species in Lake Erie, does not attain great size as a rule. The specimens taken in the 3-inch gill netting, which is legal now everywhere and is employed most generally in their capture, do not average a pound in weight regularly. However, specimens weighing 1½ pounds are not rare, expecially in the western sector, and individuals weighing 5 or 6 pounds have been reported. The shape of the body is usually decidedly fusiform, elongate, and subterete in specimens of little depth and shortened and more or less compressed in deeper individuals. In side view the shape usually is decidedly elliptical. The dorsal profile in that case rises gradually and evenly from the tip of the premaxillaries to the insertion of the dorsal and curves gently from the dorsal to the caudal peduncle. The ventral profile is like the dorsal, except that from the tip of the mandible to the ventrals and from the ventrals to the caudal peduncle the lines are more curved than the opposite dorsal lines. Often in the case of specimens from the western waters over 1 pound in weight, and sometimes in the case of deep specimens not more than ½ pound in weight, there is a sudden rise from the occiput for one-fourth to one-third the distance to the dorsal insertion, so that there is more or less of a hump in the occipital region of such individuals. In the western sector the herring apparently grow larger (superficial examination of the scales indicates that they also grow faster than those in the deeper waters of the east), and jumbos (large individuals) are much more frequent than elsewhere in the lake. Jordan and Evermann (1909), influenced by these characters, recognized this form as a distinct species under the name *eriensis*.

Rate of growth and body shape have been found to be so variable in the case of the lake herring, and as this form differs in no way from other herrings in habit,

[41] Probably *Salmo (Coregonus) tullibee* of Richardson (1836), though it can not be stated so positively until material is known for the type locality. Until this is available, the name may stand for the tullibee of Lake of the Woods and Lake Winnipeg, which I consider members of the *Leucichthys artedi* species group.

and as all, including the long, slender, blue-backed type (the *cisco huronius* of Jordan and Evermann), may be taken in the same spawning school, the various types can not be considered more than races. The satisfactory differentiation of these races still remains to be made. The depth of the body is very variable and ranges between the limits of (2.8) 3.3–3.7 (4.8),[42] the figures being highest in the "blueback" or typical *artedi*. The width of the body also is variable. In the *albus* form it comprises about 49 or 50 per cent of the depth but in typical *artedi* may be more than 60 per cent. The head is more or less compressed, broadly triangular in side view, and is contained (4.1) 4.3–4.7 (5.2) times in the total length. Its dorsal profile is more or less convex. The premaxillaries are always pigmented and are very short, scarely longer than wide; they usually make an angle of 45° to 55° with the horizontal axis of the head. The snout is obtuse in side view, short, sometimes equal to or shorter than the eye, never much longer, and is contained (3.6) 3.8–4 (4.5) times in the head length. The eye is relatively small, is usually situated in the second quarter of the head length (though often in the smallest specimens encroaching on the third), and is contained (3.8) 4.2–4.5 (4.9) times in the head length. The maxillary is always pigmented except on its distal end, is short, and is contained (2.5) 2.7–2.9 (3.3) times in the head. The mandible is also always pigmented, is rather weak, and is usually equal to or shorter than the upper jaw, though often somewhat longer. The gill rakers on the first branchial arch number (15) 16–18 (20) + (26) 28–31 (33) = (41) 44–48 (53).[43] The scales in the lateral line number (64) 71–81 (89),[44] their number directly influencing the size of the body scales. Scale rows[45] around the body just in front of the dorsal and ventrals number (38) 40–42 (46), just in front of the adipose and anus (31) 32–34 (36), around the caudal peduncle at its commencement (23) 24–25 (27). The paired fins are short. The pectorals are contained (1.6) 1.9–2.1 (2.5) times in the distance from their insertion to that of the ventrals, and the ventrals are contained (1.4) 1.6–1.8 (2.1) times in the distance from their insertion to that of the anal. There are (8) 9–11[45] dorsal rays, 10–12 (13)[45] anal rays, (10) 11 (12)[45] ventral rays, and (14) 15-16 (18)[45] pectoral rays.

The general appearance in life is silvery, with a faint pinkish to purplish iridescence on the sides. The underlying color on the back is blue green to pea green of moderate intensity, except in the case of the "blueback," which is usually deep blue green. This color extends on the sides about halfway to the lateral line and then pales gradually to the colorless belly, becoming more bluish below the lateral line. The cranial and preorbital patches are present and vary in color like the back. The effect of the general color is deepened by the uniform but inconspicuous fine pigmentation, which covers the back to about halfway to the lateral line. On the sides the pigment grows less and disappears entirely below the lateral line about halfway to the belly. The pigment dots on the cranium, in the preorbital area, and on the maxillary are abundant but so fine as to cloud only slightly the whiteness of the cartilage; but in the prenarial region, on the premaxillaries, and on the mandible

[42] These and other figures, unless otherwise designated, are based on an examination of 103 specimens ranging in length from 225 to 402 millimeters. Values for both forms are grouped together as many specimens occur that are intermediate. The higher values for L/D, Pv/P, Av/V, L/H, and for scales and scale rows are from typical *artedi*.

[43] Three hundred and thirteen specimens.

[44] Seven hundred and fifty specimens.

[45] Forty specimens.

they are more concentrated and give a darker hue to these areas. The cheeks and iris are silvery, with faint iridescence. The dorsal and caudal fins are sprinkled with pigment and the distal ends are darker, but not conspicuously so, except sometimes on the shortest rays of the caudal. The abdominal fins are whitish transparent without conspicuous pigmentation, though the anal and pectorals often have a sprinkling of pigment.

All color fades in alcohol and leaves the details of pigmentation more obvious. The dorsal and caudal show a more conspicuous dark band on their tip, and the back of the "blueback" remains decidedly darker.

Pearl organs are present to some extent on all males in the breeding season and probably on all females. They are developed best in the males and are indicated only faintly in females. Their development is not different in general from that described for the chub (p. 350), except that the irregular pearls on each scale in the predorsal and preventral areas possibly may be more numerous in this form.

VARIATIONS

Racial variations.—In Lake Erie, Jordan and Evermann (1911) found three species of lake herring, which were named by them *Leucichthys cisco huronius*, *L. artedi*, and *L. eriensis*. In addition, Bean (1916) described a form *L. macropterus* from a single specimen obtained at Erie, Pa. No other individuals like it have been collected and none have been seen by any of the numerous fishermen interviewed by me on Lake Erie, so that it may be assumed that Bean had a monstrosity. Clemens (1922), in following Jordan and Evermann, distinguished the three species reported by them for the lake and two others, *L. harengus* and *L. prognathus*. The form *harengus* is distinguished very unsatisfactorily from *cisco huronius* by Jordan and Evermann themselves, and *L. prognathus* is a deep-water form that is taken seldom in any of the other Great Lakes in less than 60 fathoms and therefore is not likely to be found inhabiting Erie, with a maximum recorded depth of about 30. Doctor Clemens, however, expresses his uncertainty about the applicability of the names *harengus* and *prognathus* to his forms, and the consideration of them as belonging to Erie may be dismissed for the time being.

The fishermen of Lake Erie find no differences in the Leucichthys of the lake except that those of the eastern end, where the water is deepest and where the population is densest, average smaller and those on the shallow western flat, where herring are few, more often attain exceptional size (1 pound or more). All are considered herring and, so far as the fishermen know, all spawn together. From an examination of several thousand specimens from the eastern end of the lake taken out of Dunkirk and Barcelona, N. Y., Erie, Pa., and Port Dover, Ontario, and from the western end of the lake taken out of Sandusky, Ohio, Monroe, Mich., and Merlin, Erieau, Ridgetown, and Port Stanley, Ontario, it is possible to understand the conclusions at which the systematists and fishermen have arrived. In Lake Erie there is a slim terete form, typical *artedi* (*cisco huronius* of the writers cited), that is distinguishable from the much more numerous *albus* form (*artedi* of the writers cited) by its shallower, less compressed body, shorter paired fins, smaller adipose fin, more numerous scales and scale rows, and darker color of the back. Such of these characters as can be expressed numerically are compared for the two forms in Table 67.

In all respects these slim terete individuals resemble the shoal herring of Lake Ontario and the upper lakes, and as they are relatively rare and occur but very rarely in the eastern part of the lake, it may be that they are immigrants from the upper waters through the Detroit River, or they may be only rare examples of the extreme development possible to the species. Certainly they spawn along with the typical Erie form, as spawning specimens of both sexes were found in a catch of spawning herring at Sandusky, Ohio, in November, 1920, and unless there is Mendelian segregation, their characters would be unrecognizable in the second generation.

The other herring at the western end of the lake are but slightly differentiated from those of the east. The most important difference is the greater average size of the catch. The gill nets used throughout the lake are of the same mesh, and while specimens weighing over 1 pound are rare, relatively, in the east, they may at times at least be common in the west. These fish of greater size—jumbo herring—are the *eriensis* of Jordan and Evermann and are found by Clemens to grow more rapidly than the *artedi* (of his paper) of the deep water to the east. Except that larger individuals are sometimes somewhat humped at the nape (see p. 478) and that the mandible is less often longer than the upper jaw in the western specimens,[46] there are no constant differences. There are indications that the eastern form may have somewhat more scales in the lateral line and somewhat different proportions, at least as concerns head, eye, maxillary, paired fins, and depth; but the two groups compared were of individuals of different average size, and those proportions that appear to be different are precisely those that are influenced by growth. Experience indicates, furthermore, that the course of a curve like that which might be platted from the data given for lateral-line scales may be altered in either direction to the extent in which the two groups differ from one another by the addition of more data obtained from specimens from another catch. Both jumbos and other herring are found in the same spawning school.

The *eriensis* of Jordan and Evermann, which is characterized chiefly by its large size, according to these authors appeared in the catches but a few years before their discovery of it. For many years before Lake Erie had been fished intensively, and no species could have escaped discovery, as these writers seem to imply. On the other hand, the phenomenon of increased size of individuals in a depleted area is not new and has been demonstrated conspicuously in the case of the Lake Erie herring since. The herring were depleted first in the west and were produced more abundantly then toward the east. The jumbos, then, were caught farther to the east, and it is believed by most of the fishermen on the eastern Canadian shore that the fish in these localities have been larger latterly, on the average, than formerly. W. D. Bates, of Ridgetown, Ontario, says that until about 1898 the herring occurred in his pounds in enormous schools and were so small and thin that they were of little value. A fish 1 pound in weight was rare. Now his catch of this species is very light, but individuals frequently weigh 2 to 3 pounds.

The occurrence of relatively large numbers of individuals with long mandibles in the deep water of the east end of the lake confused Clemens and caused him to

[46] In eastern specimens the mandible is shorter than the upper jaw in 241 specimens, equal in 256, and longer in 211; figures for western fish are 42, 35, and 15, respectively.

segregate these individuals under the name *prognathus*. However, he found the rate of growth of the long-jawed specimens to be like that of their associates. On October 25, 1920, I examined several hundred specimens from a lift of some thousands of pounds of herring taken off Port Dover, Ontario (the source of Clemens's specimens), and found them to be typical *albus;* so there seems to be no reason to believe that any other Leucichthys, least of all the deep-water *prognathus*, occurs in Lake Erie. The tendency of individuals of a shallow-water species living in deep water to acquire a longer mandible is illustrated by *L. hoyi*, also. (See p. 460.)

Size variations.—Only a few specimens are available for a comparison of changes with growth. In Tables 8 to 11 are shown the relative proportions of large and small specimens, and in Table 67, 10 specimens under 200 millimeters are compared extensively with 3 groups of 10 each of specimens larger than 200 millimeters. Only between the large and small individuals taken at the eastern end of the lake can comparisons be drawn satisfactorily, as these presumably are related genetically. In the case of these the data indicate (as was to be expected) that the head and eye are relatively larger in the small individuals. The paired fins also appear to be longer and the depth less.

Specimens under 17 centimeters in length have been taken only in the eastern waters and have been found to be sexually immature. Larger individuals usually have been mature. In western waters no mature specimens have been seen smaller than 23 centimeters.

COMPARISONS

Leucichthys artedi and *Coregonus clupeaformis* are the only coregonids known from Lake Erie. The generic distinctions are quite evident, and the species are not confusable.

GEOGRAPHICAL DISTRIBUTION

Herring occur in schools, and these formerly occurred not only out of every port on the lake but in almost every situation in it. Almost since the beginning of fishing operations the herring has been an important factor in the commercial fisheries, and for many years it has been their mainstay, particularly in the eastern waters. In the west, on the flat westward from Sandusky, the schools have been so depleted that herring fishing has been virtually abandoned in this area for 25 years. The middle grounds (that is, the 100-mile stretch between Point Pelee on the west and Long Point on the east, which has a maximum depth of 14 fathoms) until about 1920 produced several million pounds of herring annually. Since 1925 the deep hole to the east of Long Point also has been depleted, and the herring, once present in supposedly inexhaustible quantities, is commercially near extinction. In Table 66 are given data for the specimens that I have collected.

METHODS OF CAPTURE

Gill nets are used most widely for taking the species. Until recently, nets of meshes as small as 2¾ inches were allowed by some States on the ground that the herring in the eastern waters were smaller than those elsewhere, but the legal net is now everywhere of 3-inch mesh. The gill nets are commonly of exceptional depth (often as much as 25 feet deep) and in that case are called bull nets. There is a growing sentiment against their use, and most of the States already have enacted laws limiting the depth of gill nets. Whether bull nets or narrower nets are used, it has been the universal practice for more than 10 years to float them at certain seasons at least. They are buoyed off the bottom by the use of air cans and may be set in any stratum, the distance off the bottom varying with the ascertained location of the schools of fish. When the fish are spawning in the fall the nets usually are sunk to the bottom. Westward of Port Stanley to Point Pelee, on the Canadian shore only, some herring are produced by pound nets. Some are taken in pound and crib nets elsewhere on the lake, but the quantity is relatively small.

It appears, thus, that originally herring were so numerous that they occupied every situation in the lake and could be captured at any season. The pound nets took them on shore often throughout the season but usually most abundantly during June and July. In the last decades they have been obtainable in gill nets in certain sections of the lake in the spring, but the best fishing outside the spawning run was to be had by floating the nets in the summer. In the fall when the fish collected to spawn they were taken more or less abundantly over most of the lake, especially the eastern half.

SEASONAL MOVEMENTS

Originally herring were so abundant that in parts of the lake, at least, they could be taken in commercial quantities at any time of the year by nets set on the bottom. In later years the schools became decimated, some of them even exterminated, and the fish could be captured only on the bottom at certain seasons and out of certain ports. The time finally came when the supply of the fish on the bottom became so uncertain as to make necessary the floating of nets off the bottom in order to supply the demand. Out of the practice of floating developed the bull net, a net four or five times deeper than the gill net formerly in use. This apparatus was floated also, and on account of the shallowness of the lake and the immensity of the netting employed the remaining schools were subject to capture virtually at the pleasure of the producers.

Data from the pound nets.—At present very few herring are taken in pounds anywhere on the lake. Occasionally a producer may make a total catch of a few thousand pounds in these nets, usually in June or November, but the species is no longer counted on as a mainstay of these fisheries. The testimony of the pound netters of the north shore indicates that June and July were usually the best months, with August usually poorest; but an examination of the records of the pound nets of W. D. Bates, at Ridgetown, and A. Crewe, at Merlin, shows that while the lifts usually were heaviest during these months, there have been years when good lifts of herring were made in every month from April to December. The presence of the fish on the shoals during these summers probably would be found to be due to unusually low summer temperatures.

Data from the gill nets.—In late years nets have been set for herring in the spring, when the fishing season opened on March 15 in the area between Port Stanley, Ontario, and Ashtabula, Ohio. The fish scattered about the 1st of June and reappeared about July 1 farther west, between Erieau, Ontario, and Cleveland, Ohio, and east in the deep water off Erie, Pa. The schools began to thin out toward the west on the central flat as summer advanced and to appear farther east, so that by

September 1 herring fishing began out of Dunkirk, N. Y., the extreme eastern port. Out of most of the ports, except those on the east hole, herring fishing was light during the latter part of September and October, but in November again heavy catches were made from Pelee Island on the west to the east end of the lake, with the greatest production in the east. In the summer months bull nets were used as a rule, floated at various depths according as the fish were high or low, though in the early days the fish are said to have been most abundant on the bottom in July and August. At other times narrow nets were fished on the bottom.

BREEDING HABITS

The herring formerly spawned out of virtually every port on the lake. The spawning grounds most frequented in late years were situated from 4 to 10 miles or more offshore, in depths, in the east end of the lake, of 15 to 25 fathoms, and in the west of about 10 fathoms. The bottom in these areas usually is clay, though there are stretches of gravel. A few, of course, also spawned in shallower water.

The time of spawning, according to all the fishermen, fell in late November to early December, being earlier or later, according to the season. Those in the east usually spawned latest. According to the records of A. Crewe, of Ridgetown, Ontario, the fish taken in his pounds were through spawning on November 26, 1917. As late as December 6 in 1920 they were just beginning to spawn. On November 24, 1924, I found the fish in these nets just beginning to ripen.

VALUE AS FOOD

The Erie herring is superior in quality to the herring of any of the other lakes, except possibly those from the deep water of western Lake Ontario. They are very much in demand as fresh fish, and the large examples frequently are sold as whitefish. They have also competed strongly with the chubs of the deeper lakes in the smoked-fish trade. While they are not quite so rich in oil as the latter, they are larger and more uniform in size. Until the collapse of the herring fisheries in 1925, there was no market for chubs in New York City.

Leucichthys artedi artedi of Lake Michigan

The Michigan form resembles the slender blueback of Lake Erie (typical *artedi*) rather than the common *albus*. A comparison of the principal taxonomic characters of the two forms follows:

Gill rakers on the first branchial arch:
- Erie, *albus*, (41) 44–48 (53).[47]
- *artedi*, (44) 46–50 (51).[48]
- Michigan, (41) 46–50 (55).[49]

Lateral-line scales:
- Erie, *albus*, (64) 71–81 (89).
- *artedi*, 76–86.
- Michigan, (68) 77–87 (94).[49]

L/H:
- Erie, *albus*, (4.1) 4.4–4.7 (5.2).
- *artedi*, 4.5–5 (5.2).
- Michigan, (4.1) 4.3–4.5 (5).

H/E:
- Erie, *albus*, (3.8) 4.2–4.5 (4.9).
- *artedi*, 4.1–4.5 (4.7).
- Michigan, (3.6) 4–4.2 (4.7).

[47] Figures of Lake Erie *albus* for proportions are given for 148 specimens ranging in length from 225 to 402 millimeters. Those for gill rakers are given for 298 specimens; for lateral-line scales, for 735.

[48] Figures for Lake Erie *artedi* are given for 15 specimens ranging in length from 229 to 341 millimeters.

[49] Figures for Lake Michigan so designated are based on an examination of some 391 specimens ranging in length from 127 to 367 millimeters. Those figures dealing with proportions are based on an examination of 148 individuals ranging in length from 225 to 367 millimeters.

H/M:
Erie, *albus*, (2.5) 2.7–2.9 (3.3).
artedi, 2.6–3 (3.3).
Michigan, (2.5) 2.7–3 (3.3).
H/S:
Erie, *albus*, (3.6) 3.8–4 (4.5).
artedi, 3.6–4 (4.2).
Michigan, (3.3) 3.7–4 (4.4).
Pv/P:
Erie, *albus*, (1.6) 1.9–2.1 (2.5).
artedi, 2.1–2.5.
Michigan, (1.6) 1.9–2.2 (2.6).

Av/V:
Erie, *albus*, (1.4) 1.6–1.8 (2.1).
artedi, 1.7–2 (2.1).
Michigan, (1.4) 1.6–1.8 (2.3).
L/D:
Erie, *albus*, (2.8) 3.3–3.7 (4.3).
artedi, 3.7–4.8.
Michigan, (3.6) 4–4.9 (5.3).

The figures show that the Michigan form differs from that of Erie *albus* most strikingly in having less depth of body. They indicate also that the former has, on the average, more gill rakers on the first branchial arch, more lateral-line scales, and a slightly larger head and eye. The mandible has been found to be longer than the upper jaw in only 8 per cent of the specimens over 225 millimeters in length and usually is equal or shorter. There are very few specimens of the Erie blueback or *artedi* form for comparison, but the Michigan race seems to be very like it. The only difference seems to be that the Michigan specimens have a larger head and eye and longer paired fins, but these differences may be due to the fact that the Michigan specimens average much smaller. The Michigan race seems, then, to merit the designation *artedi.*

The color in life is about like that of the blueback of Lake Erie. There is, as a rule, more pigmentation on Michigan specimens, particularly on the back and head. The ventrals frequently show some pigment, and the anal usually is dotted with black.

Pearl organs are developed, at least by the males. Specimens taken in Green Bay on November 11, 1920, showed pearls that differ in their development in no material way from that described for the typical form.

VARIATIONS

Racial variations.—There is a wide variation in all characters exhibited even by individuals from the same school (see Table 69), but it is likely that, if enough specimens were collected, at least the schools from certain areas of the lake would show tendencies to vary in a definite direction. Very few unusual specimens were seen from any part of the lake, and there is, therefore, no reason to believe that any races, sharply differentiated by external characters, such as *manitoulinus* in Lake Huron, occur in Lake Michigan. The fisherman, however, are of the opinion that two distinct races inhabit Green Bay. The one they catch in the summer at depths of 10 to 20 fathoms in gill nets, and the other is caught in fall on the shores in gill nets and pounds. The first mentioned are known as bluefins, in contradistinction to the blue-backed herring, which they are accustomed to take in shallower water. Except that the deep-water fish are paler and perhaps a trifle fatter and of deeper body, characteristics that might easily be induced by the environment, there are no apparent differences, and an examination of some 35 specimens of each supposed variety shows that the two groups do not differ in the systematic characters that ordinarily are variable in the species. A study of the rate of growth of specimens from both situations would, of course, also aid in determining their racial identity. In Table 69 are compared extensively 10 specimens from Green Bay—5 from the shore and 5 from the deepest water—and 9 taken at various ports on the lake.

Size variations.—Below are given, for the characters that vary most with growth, values for large fish (225 millimeters and over) and small ones (under 225 millimeters). More detailed figures are shown for some of these characters in Tables 8 to 11. Ten specimens under 200 millimeters are compared extensively with larger fish in Table 69, also.

L/H:
- Large fish, (4.1) 4.3–4.5 (5).
- Small fish, (4) 4.2–4.5 (4.6).

H/E:
- Large fish, (3.6) 4–4.2 (4.7).
- Small fish, (3.5) 3.7–4 (4.3).

H/M:
- Large fish, (2.5) 2.7–3 (3.3).
- Small fish, (2.4) 2.7–3 (3.1).

H/S:
- Large fish, (3.3) 3.7–4 (4.4).
- Small fish, (3.4) 3.6–3.9 (4.1).

Pv/P:
- Large fish, (1.6) 1.9–2.2 (2.6).
- Small fish, (1.6) 1.8–2.1 (2.5).

Av/V:
- Large fish, (1.4) 1.6–1.8 (2.3).
- Small fish, (1.3) 1.5–1.7 (2).

L/D:
- Large fish, (3.6) 4–4.9 (5.3).
- Small fish, (4.1) 4.4–5 (5.8).

Jaw:
- Large fish, equal or shorter, 92 per cent.
- Small fish, equal or shorter, 65 per cent.

It appears from these data that the eye and paired fins decrease proportionally in size with growth, the depth of the body becomes greater, and the jaw tends to become shorter. The head and snout do not change markedly in relative size, but they also appear to be a trifle shorter, relatively, in adults.

A few individuals of both sexes have been found sexually mature at 165 millimeters, but usually those smaller than 180 millimeters show no development of the sex glands.

COMPARISONS

Artedi is usually easily distinguishable from any of the deep-water Leucichthys. Its flesh is much less fat that that of any of these, and it is usually distinguishable from them by other characters also. Small individuals, however, sometimes closely resemble *hoyi*. A discussion of the differences between *artedi* and *hoyi* is found on page 452. The differences between *artedi* and *johannæ*, *alpenæ*, *zenithicus*, *reighardi*, *nigripinnis*, and *kiyi*, are given on pages 353, 366, 391, 403, 419, and 436.

GEOGRAPHICAL DISTRIBUTION

The herring of Lake Michigan occur in schools and are taken extensively at some seasons of the year out of virtually every port on the lake. The long stretches of sandy shore seem favorable for this species, and herring are abundant enough therefore in most places to make their capture profitable. Green Bay is the most productive area. I have collected specimens from virtually every port visited. The data for these are given in Table 68 and are platted on the lake chart in Figure 4.

METHODS OF CAPTURE

Most of the herring are taken in gill nets and pound nets with small-meshed pots. Gill nets are in use in Green Bay in the summer when the fish are offshore, in the winter through the ice, and also to some extent in the fall. They are used in many localities also where the run of herring is not heavy enough to warrant the placing of pounds. The size of the mesh of gill nets employed varies from 2⅛ to 2¾ inches, depending on the various State laws. Pound nets for herring are commonest in the Green Bay district, but a few are employed at various points along the shore line of every State bordering on the lake. In Green Bay of late years some have been operated in the winter.

SEASONAL MOVEMENTS

The herring schools are ashore both in spring and fall and in many places they probably stay near shore all winter. The schools are more or less pelagic, and their movements probably are influenced materially by the food supply, but it is interesting that they do not approach the shore when the water there is warmest.

Data on occurrence in the herring nets in spring and fall.—In Green Bay, according to R. F. Kleinke, the herring are found near shore as soon as the pound nets can be put in in April or May. After June they disappear from the shores but return in some numbers about the middle of September. They increase in abundance until the spawning time during November, and then they leave until the ice forms, when they are taken frequently under the ice. They are said to move erratically in the winter and frequently are absent from the netting grounds entirely for some days at a time. The deep-water form, which is taken most commonly in summer in the bay at depths of 10 to 18 fathoms, is said by some fishermen to be found there all the year round except when it comes ashore in November to spawn, while others maintain that it occurs in these depths only during the summer months. It is probable that all the fishermen have a basis for their statements, but that the first group catches chubs among the herring at certain seasons and are not able to distinguish them. It is certain that the catches examined by me on August 16, 1920, made in 11 to 16 fathoms between Green Island and Little Sturgeon (records 1 and 2), consisted exclusively of herring; and as the lake's heat budget was near its maximum at this season, it is clear that the fish found tolerable conditions at that depth in summer. Reasoning from analogy on the basis of the behavior of herrings elsewhere and of other coregonids, it is to be expected that they would move into shallower water as the waters cooled. At Port Washington, Wis., Delos Smith says the herring are found in the pound nets in 20 to 60 feet as soon as they can be set in April. The runs are heaviest in May, and by July 1 they are over. Occasionally a school comes into the nets in summer, but there is no herring fishing of consequence until after September 15. During October and early November the runs are at their height. The fall run, Mr. Smith states, consists of larger fish. At Milwaukee, Wis., George and Fred Tilly find the herring in 8 fathoms during April and May in gill nets, and again in October and November. At other times they pursue more valuable fish. Record 15 was made from the net of the Tilly brothers and shows that herring were caught in 10 to 15 fathoms off Milwaukee on March 24, 1919. F. C. Kimball, of Michigan City, Ind., says that the herring are found as soon as the pound nets are put in in April at depths of 18 to 30 feet on sand bottom. There are good lifts until early May. After that the schools are erratic in their movements and come ashore only when favorable currents have cooled the shore waters. In October the lifts are again heavy, and the fish are caught until the nets are blown out. On March 2, 1921, small herring were taken occasionally among the bloats by the 1½-inch gill nets set 14 miles NNW. in 26 fathoms and in the 2½-inch nets lifted on March 4, 1921, 15 miles NW. by N. ½ N. in 28 fathoms (records 22 and 23). Numbers of herring have not been recorded by me at greater depths in Lake Michigan; the presence of the fish at such depths may have been due to stormy conditions, which usually obtain in March. In that case the records, in all probability, could be duplicated out of any port where no ice is formed in winter. The pound nets are set at Grand Haven, Mich., about April 10, according to Mr. Mieras and Johannes Fischer, in 16 to 20 feet on sand. Herring are present at once and continue on the grounds during May and June. None are taken thereafter, because the pounds are pulled by September. However, Mr. Mieras does set gill nets for the white perch during September and October at depths of 6 to 15 fathoms, but he gets very few herring in them, although the mesh is suitable for their capture. At Manistee, Mich., the spring behavior of the herring, as reported by Peter and Hans Petersen, is like that recorded for Grand Haven. The Petersens do not fish herring in the fall. The accounts given for Northport, Mich., by Hans Anderson and Carl Schrader and for Traverse City, Mich., by Will Hopkins, Otto and Doner West, and Floyd Stiles are virtually the same as those recorded for Port Washington. The Northport fishermen and Mr. Hopkins say they have known the herring to remain along the shores under the ice in the bay. At Seul Choix, Mich., they appear to stay a little later than at any of the places so far mentioned, and Alex Goudreau says they are taken frequently in the pounds through July. Seul Choix is farther north than any of these places, and the water conditions may be slightly different.

Data on summer occurrence.—Except in Green Bay (and here only since about 1910), no herring are taken when they leave the shoals in spring. In Green Bay they certainly occur abundantly at depths of 11 to 16 fathoms in August. They were being taken in commercial quantities by gill netters between Green Island and Little Sturgeon on August 16, 1920, at these depths (records 1 and 2). A lift made on August 18, 1920, 4 miles west of Boyer Bluff near the outlet of Green Bay, in 18 to 24 fathoms (record 5), took about half herring and half *hoyi*, and most of the former were at the 18-fathom end of the gang. Specimens were collected from a similar gang lifted on August 18, 1920, 7 miles NNW. of Boyer Bluff in 11 fathoms (record 6), but it is not known how abundant herring were in this lift. The only other summer records that indicate that herring may have been abundant on the grounds in question were made off the northwest end of St. Martin's Island at the mouth of Green Bay on August 19, 1920, in 14 fathoms on rock bottom (record 10), and on August 11, 1920, 13 miles SE. ½ E. of Manistique, Mich., in 20 fathoms on sand (record 41). On both occasions herring (mostly individuals under 200 millimeters in length) were caught rather commonly in the 4½-inch trout nets by becoming ensnarled in their meshes. A few also were caught in the same manner on August 18 and 19, 1920, 5 miles west and 3 miles WNW. of Boyer Bluff in 20 to 24 fathoms on rock bottom (records 7 and 8). Other data collected in summer show a few stragglers in the pound nets in Grand Traverse Bay (Barrow's Harbor) on July 19 and 26, 1923 (records 38, 39, and 40), in 5 fathoms, a few in the 1½-inch gill nets set in 4 to 16 fathoms off Lee's Point on July 25, 1923 (records 34 and 36), and a single specimen seined on the shore of Lee's Point in the bay on July 25 (record 35). On July 21 and 23, 1923, 1½-inch gill nets set in 8 to 12 fathoms and 15 to 25 fathoms offshore 1½ miles south of Otter Creek in Platte Bay took 1 and 12 individuals, respectively (records 26 and 27). On the South Manitou Island off the light on July 30, 1923, a few stragglers were taken in seines, 1½-inch gill nets, and pound nets in 1 to 5 fathoms of water (record 28). Stray specimens also were collected off Manistee, Mich., on August 27, 1920, in pound nets in 4 fathoms (record 25), and off Seul Choix Point on August 20, 1920, at about the same depth (record 42). Records 17 and 18 show a few herring among the chubs taken on September 24, 1920, 9 miles NNE. of Milwaukee, Wis., at a depth of 22 to 25 fathoms, and on November 15, 1920, 5 miles E. by S. ½ S. in 12 fathoms. There are numerous records that show an occasional fish of this species being taken in the chub nets lifted from depths of 30 to 90 fathoms (vide records 9, 11, 12, 13, 16, 19, 21, 23, 29, and 31 for Washington Harbor, Sturgeon Bay, Algoma, Port Washington, Milwaukee, Michigan City, and Northport); but these fish may have been caught while the net was being set from schools traversing the upper strata. The few small examples taken in 1½-inch nets on June 23, 1920, off Northport Point and on July 18, 1923, in Grand Traverse Bay in 28 to 40 fathoms (records 30 and 37) possibly were caught in the same way.

On the other hand, it is not at all impossible or improbable that specimens normally stray to great depths. It has been shown that many of the Leucichthys have a very broad depth range, and it is known that other shoal-loving fish may occur in very deep water. On July 2, 1923, in Lake Huron, 20 miles E. by N. of the Alpena can buoy, a gang of chub nets brought up a sauger (*Stizostedion canadense griseum*) from 60 to 70 fathoms, and on July 5, 1923, a gang lifted 18 miles NE. ¾ E. of the same place from 80 to 100 fathoms had seven saugers and two 3-pound pike (*Esox lucius*). Virtually all the fish were alive, but the pike were very much emaciated. Probably they had been unable to see food in their novel environment.

Thus all the data show that the herring begin to come ashore in September and are at the height of abundance during October and November. In Green Bay and in Grand Traverse Bay some stay on the shoals under the ice, but it is not known that they remain along the shores of the lake in winter, and there are indications that they retire to deeper water. In early spring they come ashore again and are found here when the nets are set in early April. During June the catches dwindle, and after July 1 few herring are seen anywhere. A few stragglers occur on the shoals throughout the summer and also at depths of 60 fathoms and more, but the data we have indicate that the main schools are never in water deeper than 10 to 20 fathoms during the warmest months. It is possible that the schools are also pelagic at times in summer, as in Lake Superior.

BREEDING HABITS

In fall the herring migrate toward shore to spawn. Little is known by the fishermen as to when and where the eggs are laid. In Green Bay, off Oconto, Wis., males observed on November 17, 1920, were pearled, and about one-third of the females were nearly ripe. Only a few were spawning. The lifts were light at this time, however, which would indicate that spawning had not yet begun. R. F. Kleinke, at Menominee, Mich., says that the fish usually spawn toward the end of November in Green Bay, selecting sand bottom in 10 to 25 feet of water. Most of the spawning grounds, he says, are on the Michigan shore. The Oconto shoals are much frequented on the Wisconsin side. In Grand Traverse Bay and at Port Washington, Wis., the fishermen quoted previously inform me that spawning usually is not at its height until November 20. The fish spawn at these places on sand along shore at depths of 10 to 25 feet and remain on the spawning grounds into December. Farther south the spawning season apparently is later, as F. C. Kimball, of Michigan City, says that herring taken in early December have not yet begun to spawn.

VALUE AS FOOD

The Michigan herring are in no way superior as food to those from Huron or Superior, except possibly those from the deep water of Green Bay, but good markets are nearer, and therefore smaller quantities can be marketed with profit. Most of the herring taken on the western and southern shores are sold fresh; but elsewhere, especially to the northward, where transportation facilities are not so good, many are salted.

ABUNDANCE

There are no data on the present abundance of the species, except such as exist in the minds of the fishermen. In two places, Beaver Island and Gros Cap, the fishermen say the herring are now commercially extinct, and they are said to be much less abundant at Grand Haven than formerly. No protection has been afforded the species in the way of closed seasons, and the size of mesh allowed for their capture in all States is near the minimum that would take a marketable fish, and it would not be surprising if the species had been seriously reduced in numbers everywhere. It appears, however, that in Lake Michigan, as in the other lakes, those areas in which they were most abundant originally still know them in quantities that foreshadow no immediate extermination.

Leucichthys artedi artedi and artedi manitoulinus of Lake Huron

Five species of herring have been reported from Lake Huron by Jordan and Evermann (1911)—*harengus*, *cisco huronius*, *manitoulinus*, *eriensis*, and *artedi*. The first two are very unsatisfactorily differentiated from one another by their authors. They have been separated by very few characters, and these I do not hold to be valid. (See p. 492.) The two names, then, may be taken jointly to represent the common herring of Lake Huron. *Manitoulinus* is a well-differentiated form, but is known to intergrade with the common herring and is here regarded only as a local race. The status of *albus* as the common form of Erie and of *eriensis* and their relation to *cisco huronius* are discussed on page 480, where reasons are given for treating all the forms of the shore herring of the Great Lakes as races under the specific caption of *artedi*.

The common herring of Lake Huron resembles very closely the rare blue-backed slender variety of Erie. There is present in the North Channel a form (*Leucichthys manitoulinus* of Jordan and Evermann; fig. 26) that approaches in shape the common Erie type, but in its extreme development it is nearer in its characters to the deep-water *nigripinnis* of Lake Huron than to any herring in the Great Lakes. The common forms of the herring of Lakes Erie, Michigan, and Huron are compared in their chief characters below. The Michigan specimens are given as typical of *artedi* because there are only a few available examples of that form from Erie, and it has been shown that the forms from the two lakes are probably identical.

Gill rakers on the first branchial arch:
- Erie, *albus*, (41) 44–48 (53).[50]
- Michigan, *artedi*, (41) 46–50 (55).[51]
- Huron, *artedi*, (40) 45–50 (53).[52]

Lateral-line scales:
- Erie, *albus*, (64) 70–81 (89).
- Michigan, *artedi*, (68) 77–87 (94).
- Huron, *artedi*, (68) 76–86 (98).[52]

L/H:
- Erie, *albus*, (4.1) 4.4–4.7 (5.2).
- Michigan, *artedi*, (4.1) 4.3–4.5 (5.)
- Huron, *artedi*, (4) 4.3–4.6 (5).[53]

H/E:
- Erie, *albus*, (3.8) 4.2–4.5 (4.9).
- Michigan, *artedi*, (3.6) 4–4.2 (4.7).
- Huron, *artedi*, (3.7) 3.9–4.3 (5.1).

H/M:
- Erie, *albus*, (2.5) 2.7–2.9 (3.3).
- Michigan, *artedi*, (2.5) 2.7–3 (3.3).
- Huron, *artedi*, (2.6) 2.8–3 (3.3).

H/S:
- Erie, *albus*, (3.6) 3.8–4 (4.5).
- Michigan, *artedi*, (3.3) 3.7–4 (4.4).
- Huron, *artedi*, (3.5) 3.7–4 (4.3).

Pv/P:
- Erie, *albus*, (1.6) 1.9–2.1 (2.5).
- Michigan, *artedi*, (1.6) 1.9–2.2 (2.6).
- Huron, *artedi*, (1.7) 2–2.2 (2.6).

Av/V:
- Erie, *albus*, (1.4) 1.5–1.8 (2.1).
- Michigan, *artedi*, (1.4) 1.6–1.8 (2.3).
- Huron, *artedi*, (1.4) 1.6–1.8 (2.1).

L/D:
- Erie, *albus*, (2.8) 3.3–3.7 (4.8).
- Michigan, *artedi*, (3.6) 4–4.9 (5.3).
- Huron, *artedi*, (3.5) 4–4.7 (5.4).

These figures show that the Huron form is very like the *albus* form of Erie, except in body depth. The figures indicate that the former has possibly a few more gill rakers on the average, more scales in the lateral line, a larger eye, and much less body depth. The Huron fish seem to be very like the *artedi* of Lake Michigan and therefore may be given the same name. The inclusion of the extremely developed North Channel *manitoulinus* with the Huron specimens would lower the minimum value given in parentheses to the left in the case of L/H, H/E, H/M, Pv/P, Av/V, and L/D. As in every instance cited a proportion is involved, it follows that the North Channel individuals have a longer head, eye, maxillary, paired fins, and greater body depth.

The mandible has been found to be longer than the upper jaw in only 11 per cent of the Huron specimens and usually is equal or shorter, as in Lake Erie.

The color in life of most Huron specimens is very like that of the blueback of Erie, namely, deep blue green on the back, though often specimens are seen that are as pale as the common Erie type. The difference in coloration is particularly conspicuous when a school is seen swimming near the surface of the lake. A few will be lighter in color on the back than the rest. This, by the way, is no less true in any of the lakes. All Huron specimens, however, tend to show more pigmentation, particularly on the back and head. The ventrals, while often immaculate,

[50] Figures of Lake Erie *albus* for proportions are based on an examination of 148 specimens ranging in length from 225 to 402 millimeters, those for gill rakers on 298, and for lateral-line scales on 735.

[51] Figures for Lake Michigan *artedi* are given for 148 specimens ranging in length from 225 to 367 millimeters, except those for gill rakers and lateral-line scales, which are based on 391 fish.

[52] Figures for Lake Huron so designated are based on an examination of 343 specimens ranging in length from 125 to 371 millimeters. Those figures that deal with proportions are based on an examination of 215 specimens ranging in length from 225 to 371 millimeters.

[53] From proportional figures for Huron the 20 specimens of *manitoulinus* have been deducted.

particularly in Saginaw Bay and southward, often show a sprinkling of pigment; and at the north end of the lake and in the North Channel and in Georgian Bay individuals very frequently show pigment on all the abdominal fins. The herring taken in the North Channel at Cutler (subspecies *manitoulinus*) are considerably darker than those collected elsewhere. In such individuals the color of the back in life is blue green obscured by heavy pigmentation, which extends onto the sides of the body and of the head. The cranium is deep blue black, as is the snout. The abdominal fins are usually very heavily pigmented, especially on the longest rays, and the dorsal and caudal are likewise very dark. Specimens are taken frequently elsewhere in the North Channel which show an approach to these melanistic individuals, and specimens with heavily pigmented paired fins are not unusual in Lake Huron, particularly in the northern waters and in Georgian Bay.

All males and probably all females show pearl organs in the breeding season, which do not differ in their development from those described for the Lake Erie form.

VARIATIONS

Racial variations.—There is a wide variation in all characters exhibited by specimens from the same school, as may be seen in Table 71. The specimens from certain localities often show distinct tendencies to vary in certain directions, but, with the exception of the Cutler herring, none of these local forms have varied so far that they are conspicuously different from their neighbors. Many of these forms, however, would certainly show average differences in certain characters, but there have been so few specimens collected from any locality (except from Saginaw Bay) that it is not possible to give here a serious treatment of these differences. The fact that most of the characters that would be involved in such a comparison are proportional expressions, which vary in quality with the size of the individual, further reduces the significance of a study based on a few individuals. It may be worth while to point out, however, that what data I have indicate that the individuals from the North Channel will be found to have proportionally larger heads and eyes, darker color, and possibly shorter paired fins than those from Lake Huron proper and Georgian Bay.

I do not agree with the findings of Jordan and Evermann (1911), who, in describing *harengus* as occurring in Lake Huron but particularly in Saginaw and Georgian Bays, state that it differs from *cisco huronius* of Lake Huron proper and of Georgian Bay in having a gray color, less cylindrical body, smaller size, and especially in having a much smaller adipose fin. In point of color I have observed already that an occasional specimen may have a paler back, be it found in what part of the lake it may; but I have not been able, in my examination of several thousand individuals, to confirm the general observations of these authors as to the color differences of the bay forms and those of the open lake, nor have I been able to find that there were differences in the degree of lateral compression of the body. As for size, it is true that the fish in Saginaw Bay and some parts of Georgian Bay are of small size as a rule, but this is not always the case, for in the fall of 1917 in Saginaw Bay and in the fall of 1919 at Killarney, in Georgian Bay, I found a run of fish larger than usual. Furthermore, size can not be considered in general a specific character, because environmental conditions usually control the average or maximum size of the fish in a given locality. In the case of Saginaw Bay, where there has been extensive and continued operation of nets of a legally fixed mesh, it might be expected that the average size of the fish taken would be reduced. My contention receives the support of Doctor Van Oosten, also, who finds that most of the herring taken in Saginaw Bay are very young fish. The adipose fin is a rudimentary character and is too variable to have specific value. (See Table 71.)

Typical examples of the Cutler form are so different from the typical herring of Huron that they might readily be taken for a distinct species; in fact, they are almost identical with the deep-water blackfin, *nigripinnis*, in those characters that can be expressed numerically. They intergrade, however, with the typical herring of the channel and behave exactly like them, so that there is no doubt that they belong to the species group *artedi*. Furthermore, all those characters that have varied to produce this form are those that a study of *artedi* elsewhere shows to be fluctuating. All the herring of Lake Huron 225 millimeters or more in length are compared below with 20 individuals taken at Cutler: [54]

Gill rakers on the first branchial arch:
- Huron, (40) 45–50 (53).
- Cutler, (43) 44–47 (51).

Lateral-line scales:
- Huron, (68) 76–86 (98).
- Cutler, (69) 71–77 (81).

L/H:
- Huron, (4) 4.3–4.6 (5).
- Cutler, (3.9) 4–4.2 (4.3).

H/E:
- Huron, (3.7) 4–4.3 (5.1).
- Cutler, (3.4) 3.7–3.8 (4).

H/M:
- Huron, (2.6) 2.8–3 (3.3).
- Cutler, (2.5) 2.6–2.8.

H/S:
- Huron, (3.5) 3.7–4 (4.3).
- Cutler, (3.7) 3.8–4 (4.2).

Pv/P:
- Huron, (1.7) 2–2.2 (2.6).
- Cutler, (1.5) 1.6–1.7 (1.8).

Av/V:
- Huron, (1.4) 1.6–1.8 (2.1).
- Cutler, (1.1) 1.3–1.4 (1.6).

L/D:
- Huron, (3.5) 4–4.7 (5.4).
- Cutler, (3.4) 3.5–3.8 (4).

It appears from these figures that the Cutler form has a longer head, eye, maxillary, and paired fins, fewer lateral-line scales, and a much deeper body than the *artedi* of Huron. The body is also much more compressed and, as has been stated on page 492, much more pigmented throughout, and there are fewer scale rows. The shape, as seen from the side, is elliptical as in the others, and the lower jaw is usually equal to or somewhat shorter than the upper. Ten specimens are compared extensively in Table 71 in all the characters that can be expressed numerically.

Intergrades with the *artedi* form have been taken at Blind River on November 8, 1917, and at Kagawong, off Clapperton Island, on November 10, 1917. Those characters in which the two forms differ are given for these specimens in Table 72. The letter A follows the characters that approach the *artedi* type, the letter M those that approach the *manitoulinus* type.

Size variations.—Herring change but slightly in their systematic characters with growth. A comparison of the principal proportional characters follows. The fish are divided according as they are over or under 225 millimeters in length. In the one group there are 215 individuals, in the other 133. Detailed figures for several

[54] Jordan and Evermann (1911) say of the type of *L. manitoulinus:* "Type No. 64670, U. S. National Museum, a specimen 11 inches long from Blind River, North Channel, Lake Huron."

of these characters are given in Tables 8 to 11, and in Table 71, 10 small specimens under 200 millimeters in length are compared extensively.

L/H:
- Large fish, (4) 4.3–4.6 (5).
- Small fish, (4) 4.2–4.5 (4.8).

H/E:
- Large fish, (3.7) 3.9–4.3 (5.1).
- Small fish, (3.6) 3.8–4 (4.3).

H/M:
- Large fish, (2.6) 2.8–3 (3.3).
- Small fish, (2.5) 2.7–2.9 (3.2).

H/S:
- Large fish, (3.5) 3.7–4 (4.3).
- Small fish, (3.3) 3.6–3.9 (4.2).

Pv/P:
- Large fish, (1.7) 2–2.2 (2.6).
- Small fish, (1.7) 1.9–2.1 (2.3).

Av/V:
- Large fish, (1.4) 1.6–1.8 (2.1).
- Small fish, (1.3) 1.6–1.7 (1.9).

L/D:
- Large fish, (3.5) 4–4.7 (5.4).
- Small fish, (3.6) 4.2–4.9 (5.8).

Thus, small herring seem to have proportionally a somewhat larger head, eye, maxillary, snout, and possibly paired fins, and less depth than large fish of the same species.

Individuals as small as 160 millimeters have been found to be sexually mature, and a few have also been found immature at 200 millimeters, but usually specimens over 170 millimeters have exhibited maturing gonads. A closer relation, of course, will be found between age and maturity.

COMPARISONS

Artedi resembles closely only *nigripinnis*. Juvenile examples, however, might be confused with *hoyi*. A discussion of the differences between *artedi* and the other species of Leucichthys occurring in Lake Huron is given under this heading in the accounts of the various species.

GEOGRAPHICAL DISTRIBUTION

Herring occur in schools, and these are found out of virtually every port on Lake Huron, in the North Channel, and Georgian Bay. No commercial fishing operations whatever are conducted for herring from many of the fishing ports, and from but few are the operations carried on extensively; but whether fished for or not, the herring schools can not escape observation entirely. Some individuals always become entangled in the gill and pound nets set for whitefish and trout, while schools frequently enter harbors, where they may be captured by hand lines, or are encountered in the open lake. On the Canadian shore very few herring are taken for market. The catch of herring on the American shore is greatest in Saginaw Bay, while the region from Thunder Bay to Middle Island ranks second. The rest of the ports take the fish in relatively insignificant quantities. I have collected specimens from nearly every port visited. The data for these are given in Table 70 and are platted in Figure 5.

METHODS OF CAPTURE

Herring are caught both in pound and gill nets. They follow the leads of the pound nets readily, even though the mesh of these leads is so coarse that they could swim through them easily. I have seen them time and again swimming about in the pots of the whitefish pounds, the mesh of which is coarse enough to permit them to pass out; but they escape only when the pot is lifted. When it is desired to retain herring in the pounds the mesh of the pot must be reduced to about 2 inches. When gill nets are used (which is chiefly in the fall, when the fish are most abundant) the mesh in 2½ to 2¾ inches, or even 3 inches, depending on the locality. The question of the mesh that should be legal for herring has been much agitated. The fishermen claim that the herring always run small out of certain ports and that for this reason at these ports nets of smaller mesh are required. I have been able to collect no data on this subject, but I believe that probably there is no reason to doubt the statement of the fishermen.

SEASONAL MOVEMENTS

Like the whitefish, the herring schools move inshore in the early fall and out again in late spring. It is possible that for some localities, at least, there are two such movements—that the fish come in and go out both in fall and spring instead of remaining inshore all winter. There are not yet enough data on winter fishing to decide this point. To what these migrations are due has not been determined, but the fishermen believe that they are governed by changes in water temperature. The data collected from the fishermen bearing on these migrations all indicate that this explanation is at least plausible. These data are summed up in the following paragraphs:

Data on occurrence in the herring nets in spring and fall.—At Cheboygan, Mich., according to Louis Peets, the herring are in 20 feet of water on sand bottom from the middle of October until he pulls in his pounds (the last of November). In spring he finds them on these grounds again, but in diminished numbers. They remain until about June. Alfred Roberts says the behavior of the species is about the same at Harbor Beach, Mich. During June, however, when the main school has left, a school of larger herring comes in. These fish gill in 2½-inch nets, while for the others 2 to 2¼ inch nets are required. The large fish come in, the fishermen think, to feed on the "June flies," which are present in swarms at that time of the year. The June fly, from the description of the fishermen, seems to be a large Chironomus. Bért Andrews, of Port Huron, Mich., gives the following account of the species for that port:

"From the opening of navigation (April 1) until the end of June, and from the middle of October until ice forms, herring are taken out of Port Huron in pound nets in 25 feet of water. The largest numbers are caught from November 10 to the end of the month. Some are taken in 20 feet of water in gill nets all winter." At Middle Island and in Thunder Bay, from the middle of October until freezing, the Alpena and Rogers boats (according to the statements of the pilots of these boats) set 2¾-inch gill nets in 3 to 5 fathoms on gravel and bowlders. If conditions are favorable, the Alpena tugs set the nets back for a few lifts toward the end of March or the first of April. Records of James Morley show that about the middle of May the herring begin to come into the pound nets in 25 feet of water about Sulphur Island. They are gone from the end of July to the end of September. From the end of September until the nets are pulled out (in the middle of November) they are present again. The quantity taken at Sulphur Island is not great. Records show great fluctuation in the abundance of the fish in the nets from day to day in fall and spring and in the date of appearance and disappearance with the season.

The foregoing records are for the main lake, but reports concerning the Saginaw Bay schools, while more detailed, are little different in character. I am indebted to John Trudell and John Lixy, of East Tawas, for the records for that port and to W. P. Cavanaugh and Fabian Willets, of Bay City, for the records for the rest of the bay. The herring apparently move into the bay from the lake. About the middle of October the schools begin to appear in the pounds in 10 to 40 feet of water on clay bottom off East Tawas. A few days later they appear in the pounds on sand at White Stone Point, and about the first of November they are along the south shore of the bay. The fish remain at each of the above localities, except East Tawas, to spawn. At East Tawas only the small fish are left after November 20. Near the mouth of the bay some are known to remain under the ice. In the spring they are not found commonly at the south end of the bay. At Point au Grès none appear until April 20 to 25. At East Tawas they appear by May 15 and stay until July 15. At the Charity Islands they are said to occur until June 10 to 15. Huge swarms of small herring 1½ or 2 inches long are said to precede the runs of larger ones by a week in the fall along the shore from East Tawas to White Stone Point. They are not so common south of the latter point. There are few of these small fish in the spring. No one has identified these small fish positively, and they may be species of Notropis, which abound on the sandy shores of the lake.

There are few sources of data on the behavior of the herring on the Canadian shore, but such information as has been collected indicates that the Canadian fish behave as their brethren on the other side of the lake. At Wiarton, in Georgian Bay, Dan MacDonald says that the herring appear in his pounds in Colpoys Bay at any time during the fishing season until October, but that the biggest run is during the month of June. Throughout the season, however, the schools come and go without apparent reason. The hydrographic map shows only a very narrow shelf along the shore in this region, which possibly supports little food, and the herring thus are driven to seek food in the open bay. Their absence in the fall is due, no doubt, to the lack of suitable breeding grounds in Colpoys Bay. The bottom here is chiefly mud. The race at Cutler (*manitoulinus*) in the North Channel is occasionally the object of commercial fishing operations, particularly in the fall. Alex Purvis, of Gore Bay, who has fished the Cutler herring, says that one year about November 5 they were taken 2 miles outside of Johns Island, toward Gore Bay, in 8 to 10 fathoms. By the 10th they were around the islands in Cutler Bay in 12 feet of water. They enter the bay to spawn and usually remain about three weeks. After spawning they leave abruptly and are seen no more until the nets are put in in the spring. After the month of May they are gone once more until the following November. Where they spend the remaining portion of the year no one knows. It might be inferred from their dark coloration that they do not stray far from the neighborhood of the Spanish River, whose muskeg waters empty into the bay.

Data on summer occurrence.—The herring are not followed by fishermen after they move out of shallow water in June. Only a few casual observations made by the fishermen and by me are available for the period during which the herring are offshore. Various fishermen have told me that occasionally they see schools swimming in the open lake during the summer. They recognize the fish by their blue green color. The fishermen at Tobermory say that they may be caught in numbers in August in 14 to 16 fathoms in the channel between Yeo and FitzWilliam Islands in Georgian Bay. My own records from off Alpena, Mich., in September, 1917, seem to confirm those of the Tobermory fishermen. On September 8, 1917, I found a few small individuals (of which nine were preserved) in the 1½-inch nets at 30 fathoms (record 6). On September 10, 3 and 12 specimens were entangled in 4½-inch nets set at 20 and 15 fathoms, respectively (records 7 and 8). On September 12 one was taken in 15 to 17 fathoms (record 9). On September 14 eight were taken in these nets at 24 fathoms (record 10). On September 17 three were taken at 15 fathoms (record 11). On both September 22 and 26 six were taken in 17 fathoms (records 12 and 13). On September 20 and 25 herring were found in the stomachs of trout taken from 10 to 15 fathoms off Alpena. On September 5 they had not yet come as shallow as 3 fathoms (record 5). On September 24 a gang of 2¾-inch nets set from the can buoy to Sulphur Island in 8 to 10 fathoms three nights out got about 300 pounds of herring (record 14). On September 27, in the same place, 1,200 pounds were taken. On October 14, 1917, two herring were taken at 35 fathoms off Rogers, Mich., in a gang of 2¾-inch nets (record 3). These two individuals were the only ones taken, and their occurrence at this depth has no significance. It is possible, of course, that these specimens, as well as the occasional specimens previously mentioned, may have become entangled in the nets while the latter were being set or lifted; but in that case it might be expected that they would be found regularly in the chub lifts, also, unless, of course, the schools do not venture offshore as far as the chub grounds.

The records of the fishermen covering fishing operations for the herring thus show that they begin to come in to 20 to 30 feet of water in numbers sufficient for commercial purposes about the middle of October. They are caught then until the nets are pulled out on account of the weather, the last of November or the first of December. Probably they remain under the ice all winter on these grounds. The fact that a few are taken in the gill nets under the ice off Port Huron and in Saginaw Bay seems to warrant this assumption. In the spring, as soon as navigation opens, the nets take them on the same grounds as in the fall. The length of time during which the schools remain on the shoals varies with the locality. At Cheboygan and Cutler they are gone about June 1. At Port Huron, Harbor Beach, and Saginaw Bay they remain until about the last of June. At Alpena they may stay until the end of July. Of course, here as elsewhere on the lake an occasional specimen may be taken on the shoals almost all summer. After leaving the shoals the herring probably swim near the surface, as do the trout in June and July, and repair later to deep water. In August they are known at 15 to 16 fathoms between Yeo and FitzWilliam Islands and at similar depths off Alpena from September 10 to 26. A few records of the fishing tugs show them moving into 8 to 10 fathoms toward the end of September. Thirty-five fathoms is the maximum depth from which the species is known in the lake. Two specimens were taken at this depth from a gang of chub nets off Rogers on October 14, 1917.

BREEDING HABITS

The fall inshore migration is for the purpose of spawning. However, the fishermen can give no information as to when the fish actually deposit their eggs. Certainly they spawn in November, for a few males taken at Bay City on October 25, 1917, showed indications of pearls and females were nearly ripe, and the males taken at Cutler on November 11, 1917, were heavily pearled, while the two females were spawning. The herring fishermen say also that the catches are heaviest in November, which indicates that the individuals of the school are more numerous or more easily captured than usual. According to the majority of the reports, gravel or sand are preferred by the spawning fish.

VALUE AS FOOD

The flesh of the herring is dry and is considered by some as flavorless. Others find it very palatable. Whatever may or may not be its merits in this respect, the fishermen until recently received only 2 or 3 cents per pound, or less, for herring, and consequently they did not set nets for them when other fish were available.

ABUNDANCE

In view of the fact that market conditions have not encouraged the capture of herring, it appears their numbers have not been reduced seriously. At least in Saginaw Bay, where fishing has been most intensive, the fishermen report no decrease in late years. There is no doubt, however, that fish are much scarcer now than they were 25 years ago, and it is certain also that many more and better nets are being used from year to year. There are, of course, "off seasons" when, for various reasons, not many fish are taken in the bay, but on the whole there have always been plenty of herring to be had. This is true in spite of the fact that the fish have not been protected by a closed season and that few plants of fry have been made. There are, it seems, immense areas in the bay that are suitable breeding grounds for the species.

FOOD

From the examination (made by Carl L. Hubbs, of the Michigan University Museum) of the stomachs of 78 individuals collected in gill nets at an average depth of 10 fathoms off Alpena, Mich., from September 20 to October 16, 1917, plankton Entomostraca are found to comprise the bulk of the food. Two specimens taken in gill nets off Blind River, Ontario, on October 12, 1917, had eaten only Entomostraca. Thirty specimens collected from pound nets set in 5 fathoms off Bay City, Mich., on October 23, 1917, were feeding chiefly on larval May flies (Hexagenia). Other articles of food ingested in insignificant quantities by the Alpena and Bay City fish include larval Chironomidæ, Corixidæ, and Trichoptera, Asellus, fish scales, fishes, wood fragments, and algæ. Stomachs of 50 specimens taken in the summer of 1921 in Douglas Lake, Cheboygan County, Mich., and 50 specimens from Portage Lake, Washtenaw County, Mich., taken from July 1 to 15, 1920, in 7 to 10 fathoms, yield the same findings as in the case of the Alpena fish. F. M. Gaige, of the Michigan University Museum, reports that on September 26, 1910, the stomachs of herring taken by the fishermen off the Charity Islands in Saginaw Bay were full of the winged ants that abounded in swarms at that season.

The food of the herring varies, no doubt, with the season. When the schools are inshore they probably feed heavily on the larval insects that are present in the shallow water and on such other items of food as come in their way. At such times they are known to take the hook. Small spoons, pearl buttons, or minnows are the commonest baits used. At other times their food is probably largely plankton organisms, as they are not known to migrate in Lake Huron to the depths inhabited by Mysis, the chief food element of the deep-water Leucichthys, and no insect larvæ occur except along the shores.

Leucichthys artedi artedi and artedi albus of Lake Superior

The herring population of Lake Superior is constituted of the two types that are found in Lake Erie, except that the elongated terete form, which is rare in Erie, is the most abundant, and the deeper-bodied form, which is the predominating form of Erie, probably is confined to the warm bays on the north shore. In general, the systematic characters of the forms that occur in the two lakes are not very different. All collected specimens of both races are grouped together for each lake in the comparisons of the various systematic characters given below. There are available so few specimens of the rare types in both lakes that it does not seem worth while to separate them for comparison more than has been done in Tables 67 and 74, where 20 large *albus* and 10 large *artedi* for Lake Erie and 4 large *albus* and 6 large *artedi* for Superior are analyzed in detail.

Gill rakers on the first branchial arch:
- Erie, (41) 44–48 (53).[55]
- Superior, 38 (41) 45–48 (53).[56]

Laterial-line scales:
- Erie, (64) 71–81 (89).
- Superior, (72) 84–93 (105).[56]

L/H:
- Erie, (4.1) 4.3–4.7 (5.2).
- Superior, (4.1) 4.3–4.6 (5.1).

H/M:
- Erie, (2.5) 2.7–2.9 (3.3).
- Superior, (2.5) 2.7–3 (3.1).

H/S:
- Erie, (3.6) 3.8–4 (4.5).
- Superior, (3.4) 3.6–3.9 (4.3).

Pv/P:
- Erie, (1.6) 1.9–2.1 (2.5).
- Superior, (1.7) 2–2.2 (2.8).

Av/V:
- Erie, (1.4) 1.6–1.8 (2.1).
- Superior, (1.3) 1.6–1.8 (2.3).

L/D:
- Erie, (2.8) 3.3–3.7 (4.8).
- Superior, (3.7) 4.3–5 (5.9).

The data indicate that the Superior *artedi* has much less body depth and more lateral-line scales than the *albus* of Erie. The pectorals also are somewhat shorter and the snout usually a trifle longer. The counts indicate that the fin rays are, on the average, more numerous in the Superior fish, but these characters have not been investigated more closely than has been shown in Tables 67 and 74. The scale rows, of course, are also more numerous in the *artedi* form, wherever it may occur.

Comparing the two types of the two lakes with one another, it appears that the Superior *artedi* race probably has more lateral-line scales than individuals of that type in Lake Erie. Individuals of the *albus* of Superior can be matched exactly

[55] These figures for Lake Erie are given for 313 specimens ranging in length from 128 to 402 millimeters. Those for scales are based on 750 specimens of the same size range, but all figures for proportions are based on only 163 of the specimens 225 millimeters or more in length.

[56] These figures for Lake Superior are based on an examination of 257 specimens, which range in length from 135 to 435 millimeters. All figures dealing with proportions are given only for the specimens of this group 225 millimeters long or longer, which are 185 in number.

with Lake Erie specimens, except that the eye regularly may be a trifle larger in the former.

The color in life is like that of the Erie form, except that the deep blue green is the commonest shade. As in Lake Huron, fish with pale backs occur in any school. The body, especially the back and the cranium, is also more heavily pigmented as a rule. The fins average a trifle darker, too, except possibly the ventrals and the anal.

Pearl organs are developed in the species, but the specimens obtained in Thunder Bay on November 25, 1922, were so rubbed in transit that the extent of the development of nuptial adornment could not be ascertained. It is probably no different from that described for the species in the other lakes.

VARIATIONS

Racial variations.—There are two types of herring in Lake Superior, as there are in Lake Erie—the elongated, subterete form and the deeper, more compressed one. The latter closely resembles the common Erie type and occurs commonly, so far as is known, only in the shallow, warm bays at the north end of the lake. (Hankinson, 1916, Pl. XXVIII, *A*, gives a photograph of a specimen taken off Whitefish Point, Mich., on the south shore.) These bays, however, are connected freely with the main lake, and the long, slender type is therefore also of common occurrence in their waters, as are, of course, intergrades between the two. In fact, typical *albus* have not been found as commonly as the others, as will appear from the figures below. No careful study has been made of the races of herring in this or any other area, but in comparing 135 specimens from the north bay region with 118 specimens taken in the main lake on the eastern and southern shores,[57] certain tendencies of variation are indicated, which are expressed in some measure by the following:

Lateral-line scales:
- North bays, (72) 79–93 (100), with 19 per cent less than 80.
- Lake, (76) 84–92 (105), with 1 per cent less than 80.

Pv/P:
- North bays, (1.6) 1.8–2.2 (2.6), with 30 per cent less than 2.0.
- Lake, (1.8) 2.1–2.3 (2.5), with 9 per cent less than 2.0.

Av/V:
- North bays, (1.5) 1.6–1.8 (2), with 16 per cent less than 1.6.
- Lake, (1.3) 1.6–1.9 (2), with 6 per cent less than 1.6.

The figures show that the range is about the same for both groups, but this is due to the fact that the "north bays" group is made up of all fish that have been collected on the north shore, regardless of whether they probably were regular inhabitants of the bays; and the figures are interesting only inasmuch as they show tendencies of the bay fish to vary in the direction of the common Erie type. In Table 74 the first five specimens in the group of individuals 225 millimeters or more in length, four of them *albus* and one *artedi*, are from the north bays; the other five are *artedi* from the open lake. These two groups also show a difference in those characters that have been mentioned above and indicate further that the northern fish are deeper bodied.

[57] Neither group contains specimens assorted according to size, but the proportion of specimens under 225 millimeters in length is about the same for both.

Size variations.—In Table 74, 10 specimens less than 200 millimeters in length and 10 specimens more than 225 millimeters in length have been compared extensively, and in Tables 8 to 11 all the individuals less than 225 millimeters are compared in certain characters with those of 225 millimeters or more. Figures for the more important systematic characters that can be expressed numerically are abstracted below:

L/H:
- Large fish, (4.1) 4.3–4.7 (5.2).
- Small fish, (4) 4.2–4.6 (4.8).

H/E:
- Large fish, (3.6) 4.1–4.4 (5.1).
- Small fish, (3.4) 4–4.2 (4.5).

H/M:
- Large fish, (2.5) 2.7–3 (3.1).
- Small fish, (2.5) 2.7–3 (3.2).

H/S:
- Large fish, (3.4) 3.6–3.9 (4.3).
- Small fish, (3.5) 3.6–3.9 (4.1).

Pv/P:
- Large fish, (1.7) 2–2.2 (2.8).
- Small fish, (1.6) 1.9–2.2 (2.3).

Av/V:
- Large fish, (1.3) 1.6–1.8 (2.3).
- Small fish, (1.4) 1.5–1.8 (1.9).

L/D:
- Large fish, (3.7) 4.3–5 (5.9).
- Small fish, (4) 4.6–5 (5.2).

A study of these tables shows that the differences between the two groups is slight. The head and eye are proportionally somewhat larger and the depth somewhat less in smaller individuals. The paired fins possibly are also a trifle longer.

No specimens smaller than 190 millimeters have been found to be sexually mature, and the majority of those under 200 millimeters have been immature.

COMPARISONS

Typical *artedi* may be distinguished readily from any other Leucichthys in the lake. The differences between *artedi* and the other species of Leucichthys are given under the heading "Comparisons" in the accounts of these species.

GEOGRAPHICAL DISTRIBUTION

The herring of Superior occur in schools, as in the other Great Lakes, and the species is as widely distributed in Lake Superior. At Bayfield, Wis., and Port Arthur, Ontario, they are so abundant that extensive fishing operations are conducted for them during the fall; and at several other ports, particularly along the west shore, they are taken at some time of the season in commercial quantities. Specimens have been collected from every one of the 12 ports visited. The data for these are given in Table 73 and are shown platted on the map of the lake in Figure 3.

MODE OF CAPTURE

Virtually all herring caught in the lake are taken by means of gill nets. Except in Michigan, where 2¾-inch nets usually are employed, the regulation mesh is 2½ or 2⅜ inches. The nets are used on the bottom, as in the other upper lakes, except in the western waters, where it has been the custom for several decades to float them below the surface. This practice has been followed not only in summer but also in fall. The descent into deep water on the western Minnesota shore is precipitous virtually everywhere, and this hydrographic condition no doubt has forced the herring to a more strictly pelagic life than in localities where shoals obtain. The methods of floating nets are in principle like those employed on Lake Erie, but it is interesting that they were put into practice first on Lake Superior and were arrived at independently on the other lakes.

SEASONAL MOVEMENTS

The herring schools appear to spend more of their time near the surface in Lake Superior than in the other lakes, probably because its water is colder, and the seasonal inshore movements are not so pronounced. However, there is a definite congregation of the species on the shores in late fall, and it is at this time only that the schools become the object of intensive fishing operations.

Data on occurrence in the herring nets in fall.—At Grand Marais, Mich., according to William Doolan and Charles MacDonald, the herring come ashore on sand toward the end of October and remain until the ice forms in early December. At times, at least, in the fall they are in water as shallow as 3 or 4 fathoms. They are seen seldom under the ice, the fishermen say. At Marquette, Mich., the schools come ashore east to northwest of the city on sand bottom, according to Will Parker. They are present in commercial quantities about November 10 and remain until about the first week in December. At first they are in 8 to 9 fathoms of water but later move out to 14 or even 20. The account given for Ontonagon, Mich., by Earl Couture, and for the Apostle Islands, Wis., by M. B. Johnson, of Bayfield, are virtually the same as for Marquette, except that around the Apostle Islands the fish frequent somewhat shallower water. James Scott informs me that at Grand Marais, Minn., the fishermen begin commercial operations about the 1st of October. The nets are floated offshore at that time, about 4 fathoms below the surface. The lifts are heaviest in November, and during this month the nets are lowered to about 7 fathoms. Fishing is discontinued in early December. In Thunder Bay, out of Port Arthur and Fort William, Ontario, the schools begin moving in from the west between Pie Island and the mainland about the middle of November and spread northward and eastward. They remain until early December and depart then rather suddenly over the same course. While in the bay they are taken at depths of 6 to 25 fathoms on mud and clay bottom. Commercial fishing operations for the species in Thunder Bay date from the Great War, and almost incredible quantities were taken by the virgin fisheries. John and Lew Maloney, James and Frank Gerow, and Oscar Anderson, of Port Arthur, affirm the correctness of the above account.

Data on occurrence at other seasons.—At Marquette, Mich., W. A. Morrison says the herring are present in commercial quantities in his pound nets in 30 feet only for a short period in late June. At Grand Marais, Minn., according to the testimony of James Scott, they are fished for during the year in floated nets a mile or more offshore, except, of course, in the fall and for a short period in late July and early August, when they are hard on the beach. On July 17 and 18 schools of young of the year were seined by me at the mouth of the Devils Track River and in the Grand Marais Harbor (records 13 and 14). No older individuals were included in the seine hauls, but they could have avoided the net easily. Hankinson (1914) got fingerlings on the beach at Whitefish Point in mid-August, 1913. Fishermen out of most of the ports visited believe they have seen schools of herring swimming near the surface in the open lake during the summer months, and those who fish pound nets for trout and whitefish have recollections of seeing herring in the pot before the net is lifted during most of the pound-net season. As no herring are taken for commercial purposes during the summer, nothing else is known of the abundance of these fish at that season.

My records show that occasional specimens occurred in the pound nets on the north shore of the lake in Black Bay on July 20, 1922, in Moffat Strait and off Armour Point on August 10, 1922, on the east shore in Batchawanna Bay on June 17, 1922, and on the south shore in Marquette Bay on August 9, 1921 (records 15, 24, 25, 29, and 5). During the summer season my 2½ and 2¾ inch nets, which were set for deep-water Leucichthys, recorded a few stragglers at depths of 10 to 100 fathoms, namely, on June 14, 1922, 10 miles NW. by W. ¼ W. of Point Iroquois Light in Whitefish Bay in 38 fathoms (record 1); on August 5, 1921, 31 miles N. ¾ E. and on August 11, 1921, 18 miles NE. by N. of Marquette, Mich., in 100 to 80 fathoms (records 4 and 6); on August 24, 1921, 21 miles west, and on August 25, 1921, 6 miles NNW. of Ontonagon, Mich., in 15 to 45 and 20 to 38 fathoms, respectively (records 9 and 10); on July 11, 1922, between Cat and South Twin Islands in 15 to 20 fathoms (record 11); on July 17, 1922, 20 miles NE. by E. of Duluth, Minn., in 30 to 40 fathoms (record 12); on September 15, 1923, off Silver Island in 14 fathoms and in Thunder Bay off Thunder Cape in 31 fathoms; on September 17, 1923, in Thunder Bay inside the Welcome Islands in 11 fathoms; on September 19, 1923, in Thunder Bay off Sawyer Bay in 49 fathoms (records 17 to 20); on October 4, 1921, off Bread Rock in 80 to 90 fathoms (record 22); on September 25, 1923, in Moffat Strait in 13 to 14 fathoms (record 26); and on June 26, 1922, off Alona Bay in 60 fathoms (record 28). A few specimens were taken, also, entangled in the 4½-inch trout nets on August 16, 1921, 54 miles W. by N. of Ontonagon, Mich., in 25 to 80 fathoms; on June 19, 1922, in 15 to 35 fathoms, 6 miles northeast off the east end light of Michipicoten Island (records 8 and 27).

It has been pointed out before on preceding pages that fish may become entangled in the netting while it is sinking to the bottom, and the occurrence of individuals of the species in nets at extreme depths is therefore possibly accidental. Whether or no, many instances can be cited of stragglers of a shallow-water form occurring outside their normal depth range, and it would not be surprising if it were found that the herring at times do frequent profound depths.

All the accumulated data show that the herring come ashore in the fall and are present in commercial quantities from about the first or middle of November until early December. (It is noteworthy that the migration is later than or as late as in the lower lakes of the Great Lakes series, where the water probably cools more slowly.) In most localities they depart from the shores before winter and generally are not pursued thereafter until the following fall on account of the presence of more valuable species. An inshore migration in early summer is reported for some localities, and it is probably general, but at any rate the consensus of opinion of the fishermen and the meager data I personally have collected indicate that the schools do not go far below the surface during the warmer months. In the lower lakes the herring avoid the shoals only in the warmest weather and in winter, but in Superior the shoals probably seldom become warmer than is pleasant for them, and for this reason they can be caught, in some numbers at least, in the pound nets all summer. There is probably also a close relation between temperature and their food, but this matter is not yet understood.

It may be seen from Table 13 that the waters of Lake Superior probably never become very warm, compared with those of other lakes in the same latitude. The warmest temperatures, it appears, are recorded from Black Bay, Simpson Channel, and Moffat Strait, where conditions are much more tempered than in the open lake; but even here the highest surface reading of 16.3° is less than one of 19.5° recorded from a location in Lake Nipigon some 75 miles farther north two weeks earlier in the season. It is seen, also, that the temperature, even in midsummer, drops off rapidly below the surface, except in Black Bay, which is so shallow and isolated that its conditions approach those of an inland lake, so that at 4 fathoms in Moffat Strait and Armour Harbor the temperature readings are 9.7° and 9.8°, and at 5 fathoms in Simpson Channel the thermometer reads 6.6° (records 22, 25, and 15). It is apparent, then, that the herring do not have to undertake a very extensive vertical migration to find cold water, and that if food is present near the surface there are probably no other physical factors that deter them from taking advantage of it.

BREEDING HABITS

The inshore fall migration is for the purpose of spawning. The grounds frequented by the largest schools are those around the Apostle Islands and in Thunder Bay. Apparently there are also favorable areas for spawning along the Minnesota shore, but they must be quite restricted in area and must extend along the shore. There are doubtless many grounds of less importance than these all along the lake shore. The bottom frequented varies from clay and mud in Thunder Bay to gravel and bowlders along the Minnesota shore. Sand is selected commonly on the south shore, probably because the shoals are sandy in this area. The depth of spawning varies, according to the fishermen, from a few feet to 25 fathoms. The statement of James Scott that the nets are floated during the spawning season 7 fathoms below the surface indicates that possibly spawning takes place off the bottom. The apparent indifference of the species to the character of bottom may support this view. The spawning season usually embraces about the last two weeks of November.

VALUE AS FOOD

The herring of Lake Superior are, in large measure, salted in kegs, but some are frozen for consumption in the fresh state. The quality probably is not materially different from that of the Michigan or Huron varieties.

ABUNDANCE

The herring fisheries around the Apostle Islands are old and are famous throughout the lake region for their productiveness. Those in Canadian waters, situated chiefly in Thunder Bay, are not much more than 10 years old. In years past the herring have been taken in quantities sufficient only to supply the demands of a class of trade that wanted cheap salt or fresh fish, and the prices paid the fishermen have been so low that they could afford to fish only because fish could be captured easily and abundantly. Even under such conditions the herring have been much reduced in numbers, and with the increased effort that is certain to accompany the ever-increasing prices paid for these fish the species stands in danger of being decimated.

Leucichthys artedi of Lake Nipigon

The Lake Nipigon herring is similar to the Erie form, except that it is not known to grow so large. The largest specimen seen by me measured only 253 millimeters, while in Lake Erie individuals of more than 300 millimeters are common. The principal characters of systematic value that can be expressed numerically are compared below for the forms of the two lakes. On account of the small size of the Nipigon specimens the group of less than 225 millimeters is compared with the similar group from Erie (all of them necessarily *albus*, as no small *artedi* were collected in Lake Erie) in those characters that are expressed in proportional values. Figures are given also for a similar group of *artedi* from Lake Michigan.

Gill rakers on the first branchial arch:
- Erie, (41) 44–48 (53).[58]
- Michigan, (41) 46–50 (55).[59]
- Nipigon, (41) 46–49 (53).[60]

Lateral-line scales:
- Erie, (64) 71–81 (89).
- Michigan, (68) 77–87 (94).[59]
- Nipigon, (65) 71–76 (81).[60]

L/H:
- Erie, (3.9) 4.2–4.4 (4.7).
- Michigan, (4) 4.2–4.5 (4.6).
- Nipigon, (3.9) 4.1–4.3 (4.6).

H/E:
- Erie, (3.7) 3.9–4.1 (4.4).
- Michigan, (3.5) 3.7–4 (4.3).
- Nipigon, (3.5) 3.7–4 (4.1).

H/M:
- Erie, (2.5) 2.6–2.8 (3.1).
- Michigan, (2.4) 2.7–3 (3.1).
- Nipigon, (2.6) 2.7–2.8 (3).

H/S:
- Erie, (3.6) 3.7–4 (4.2).
- Michigan, (3.4) 3.6–3.9 (4.1).
- Nipigon, (3.6) 3.7–3.9 (4.2).

Pv/P:
- Erie, (1.6) 1.8–2 (2.2).
- Michigan, (1.6) 1.8–2.1 (2.5).
- Nipigon, (1.5) 1.6–1.8 (2).

Av/V:
- Erie, (1.3) 1.4–1.6 (1.8).
- Michigan, (1.3) 1.5–1.7 (2).
- Nipigon, (1.3) 1.5–1.6 (1.7).

L/D:
- Erie, (2.8) 3.6–4 (4.3).
- Michigan, (4.1) 4.4–5 (5.8).
- Nipigon, (3.8) 4.1–4.6 (5).

The figures show that the Nipigon race has, on the average, fewer lateral-line scales, less body depth, and longer pectoral fins than the *albus* form of Erie. The other differences can not be called significant in view of the disparity in the size of the specimens in the two groups. In respect to other characters given for the typical form under the general description the Nipigon form agrees rather closely, except that possibly the jaw tends to be a trifle longer and the fin rays tend to be slightly more numerous. Compared with small specimens of the *artedi* type of Michigan, which are probably very like those that might be found in Lake Erie, the Lake Nipigon race has still fewer lateral-line scales and still longer pectoral fins and probably also longer ventral fins than *albus*, but its body depth is greater on the average.

[58] The number of Erie fish examined to obtain the figures for gill rakers is 313, for lateral-line scales 750. The proportional figures are given for 125 individuals between the length limits of 128 and 224 millimeters, most of them more than 190 millimeters.

[59] Figures for Lake Michigan so marked are based on an examination of 391 specimens ranging in length from 127 to 367 millimeters. All figures for proportions are given for the specimens less than 225 millimeters in length, 150 in number.

[60] Figures for Lake Nipigon so designated are based on an examination of 84 specimens ranging in size from 138 to 253 millimeters. In other computations pertaining to Nipigon specimens 71 individuals ranging up to 225 millimeters are represented, most of them less than 190 millimeters long.

The color in life was not recorded. Fish observed swimming around the dock at Macdiarmid showed the characteristic blue green color on the back, and it is likely that the two forms are not very different in coloration. Preserved specimens from which all color has faded are only a trifle darker on the dorsal surface, and the fins also somewhat more pigmented. The anal and the ventrals frequently show more or less pigment.

No specimens were seen during the breeding season, and it is not known that pearl organs are developed. It is probable, however, that they are, and their development is not likely to differ from that exhibited by the species in the other lakes.

VARIATIONS

Racial variations.—So few specimens have been collected from any part of the lake that nothing can be said about the development of local races. No tendencies to vary in a definite direction are indicated by any of the specimens that I have seen.

Size variations.—Only 13 individuals 225 millimeters or more in length have been collected, and none of these are more than 253 millimeters long, so that it is not possible to form two contrasting size groups. The meager data given in Tables 8 to 11, where the specimens of 225 millimeters or more in length are compared in several characters with the group of smaller individuals, and Table 76, in which two specimens of less than 200 millimeters are compared extensively with eight of more than that limit, do not indicate any changes with growth, unless it be that the eye becomes relatively smaller. Specimens usually are sexually mature at 165 millimeters and occasionally even at 140.

COMPARISONS

In external characters *artedi* is very like *nipigon*. Apparently it does not grow so large as this form, which often is found over 300 millimeters in length, as compared with the largest collected *artedi* at 253 millimeters. The most trenchant difference between the two species, however, is the number of gill rakers on the first branchial arch, which in *artedi* are not known to number more than 53, while in *nipigon* no specimens are known with less than 54. The eye in *artedi* appears also to average distinctly larger. There are no specimens with a higher value for H/E than 4.1, and only two specimens of *nipigon* with a lower value than 4.1. The *artedi*, however, are on the average much smaller than the *nipigon*, and in specimens of comparable size the differences probably would not be so well marked. The maxillary, snout, and paired fins also average shorter in *artedi*, and the body has much less depth. No collected specimens of *artedi* have a value for L/D less than 3.8, while 66 per cent of the tullibees have a value less than 3.8. These characters may be compared better by consulting Tables 76 and 80, in which 10 specimens of each species are analyzed in detail. The fins of *artedi*, especially the paired fins and the anal, show less pigment than in *nipigon*, in which form almost all are invariably and often considerably pigmented. Another valuable criterion for separating the species is the state of the sex organs. No specimen of *nipigon* has been found to be sexually mature under 250 millimeters in length, while *artedi* usually is mature at 165 millimeters or less.

A discussion of the differences between *artedi* and the other species of Leucichthys in the lake is given under the heading "Comparisons" in the accounts of these species.

GEOGRAPHICAL DISTRIBUTION

As in the other lakes, the herring of Lake Nipigon move in schools, and these schools are seen often off the dock at Macdiarmid. No commercial fishing operations whatever are conducted on Lake Nipigon for herring, or for any other species of Leucichthys, for that matter, and all that is known about the occurrence and distribution of the species in the lake has been learned from the employment of small-meshed nets by the University of Toronto investigators and me. The data from these nets indicate that herring occur throughout the lake at suitable depths. The locations in the lake from which specimens have been obtained are given in Table 75, and they are platted in Figure 2.

SEASONAL MOVEMENTS

Nothing is known about seasonal movements, as the University of Toronto investigators always have been engaged only in summer and have made no particular efforts to study the habits of herring. Sets of nets were made during the summer, however, at all depths to 65 fathoms, and it is interesting to note in Table 75 that between July 16 and September 11 in several seasons no numbers of individuals were taken in the netting at depths of more than 15 fathoms. The deepest set that showed herring was made by me off Macdiarmid in 30 fathoms on July 28, 1922, and only one individual was present among dozens of other Leucichthys (record 1). It is probable, then, that the species at no time frequents great depths and during the summer either traverses the surface waters of the open lake, as in Lake Superior, or sinks to depths of 15 fathoms or less. The schools, in that case, without doubt come ashore in fall to spawn.

BREEDING HABITS

Nothing is known of the time of spawning, but none of the individuals collected as late as September showed well-developed sex organs, and the two specimens taken on October 26, 1922 (record 21), were not yet ripe. The spawning season is probably in late November, as in Lake Superior, and the spawning grounds are probably in shallow water, as is usual for the species.

Leucichthys artedi artedi and artedi albus of Lake Ontario

The *artedi* of Ontario are variable, as in Lake Erie, and the same two types are represented, namely the terete blueback and the deep, more compressed form. The latter, however, is usually always elliptical in side view in Lake Ontario. The difference between the two types in Lake Ontario is largely in this aforementioned body shape and color, and as these characters, excepting the length-depth ratio (L/D), do not lend themselves to numerical expression, the characters that can be expressed thus may be combined for both types for comparison with the combined types for Lake Erie. The races may be compared better and in more detail in Tables 67 and 78, where 20 large *albus* and 10 large *artedi* for Lake Erie and 10 large specimens nearest the *artedi* type and 10 nearest the *albus* type for Lake Ontario are analyzed. The two types of Ontario are discussed further under the section "Variations." The various characters of systematic value are compared below:

Gill rakers on the first branchial arch:
- Erie, (41) 44–48 (53).[61]
- Ontario, (41) 46–50 (54).[62]

Scales in the lateral line:
- Erie, (64) 71–81 (89).
- Ontario, (66) 73–82 (89).

L/H:
- Erie, (4.1) 4.3–4.7 (5.2).
- Ontario, (3.7) 4.3–4.7 (5).

H/E:
- Erie, (3.8) 4.2–4.5 (4.9).
- Ontario, (3.9) 4.1–4.4 (4.9).

H/M:
- Erie, (2.5) 2.7–2.9 (3.3).
- Ontario, (2.5) 2.7–2.9 (3.3).

H/S:
- Erie, (3.6) 3.8–4 (4.5).
- Ontario, (3.4) 3.7–4 (4.5).

Pv/P:
- Erie, (1.6) 1.9–2.1 (2.5).
- Ontario, (1.7) 1.9–2.1 (2.5).

Av/V:
- Erie, (1.4) 1.6–1.8 (2.1).
- Ontario, (1.3) 1.5–1.8 (2).

L/D:
- Erie, (2.8) 3.3–3.7 (4.8).
- Ontario, (2.9) 3.6–4.3 (5).

It appears from the foregoing that the composite collections have similar characters. Only the body-depth ratio appears to be different in the two forms, Erie fish averaging deeper.

The color in life is, in general, like that of the Erie form. The deep-water individuals average paler than those from shallow water, even though they may, in other respects, be exactly like them, and often show pinkish bases to the fins, especially the abdominal ones. It is possible that the presence of the pinkish color is due to congestion caused by the constriction of the net threads. The shoal form is colored about like the Erie blueback.

The males and at least some females develop pearl organs in the breeding season. Specimens collected off Bronte, Ontario, on November 23, 1917, show pearls that differ in development in no material way from those described for the typical form.

VARIATIONS

Racial variations.—There are two more or less distinct types of herring in Lake Ontario, as in Lake Erie. While in Lake Erie the slender blue-backed type is comparatively rare and the herring population is constituted primarily of deep, somewhat compressed individuals, the reverse is the case in Lake Ontario, except that the deep form is much more abundant, relatively, than the Erie blueback. The most typical specimens of this deep-water variety have been taken on the spawning grounds of the west shore of the lake (records 1 and 2). The most typical specimens of the shoal type are those from Wellers Bay and South Bay (records 5 and 7). The rest are more or less intermediate. This deep-water form has a deeper, somewhat more compressed body and averages paler in color than the herring from the shoals, but a comparison of other characters shows no important differences. Its appearance, therefore, is quite like that of the typical *albus* of Erie. The other herring of the lake are about

[61] These figures for Lake Erie are based on an examination of 313 specimens ranging in length from 128 to 402 millimeters. Those for scales are based on 750 specimens of the same size range, but figures for proportions are based only on 163 of the specimens 225 millimeters or more long.

[62] These figures for Lake Ontario are based on an examination of 254 specimens ranging in length from 155 to 366 millimeters. Those for scales are given for 266 specimens of the same size range. All other figures are based on an examination of 205 individuals ranging in length from 225 to 366 millimeters.

like the Erie bluebacks, except that, on the average, they probably have somewhat longer paired fins.

Size variations.—Very few small herring have been examined, and these are from varied situations in the lake, so that nothing can be stated conclusively about the changes with growth; but a comparison of the characters in Tables 8 to 11 for large and small individuals indicates, as is to be expected, that the head and eye are larger, relatively, and the paired fins longer in the small individuals. Other data indicate that the maxillary and snout are relatively somewhat longer in small fish and the body depth less. Ranges of values for the characters follow:

L/H:
- Large fish, (3.7) 4.3–4.7 (5).
- Small fish, (3.9) 4.1–4.4 (4.6).

H/E:
- Large fish, (3.9) 4.1–4.4 (4.9).
- Small fish, (3.8) 4–4.2 (4.4).

H/M:
- Large fish, (2.5) 2.7–2.9 (3.3).
- Small fish, (2.5) 2.6–2.8 (3).

H/S:
- Large fish, (3.4) 3.7–4 (4.5).
- Small fish, (3.6) 3.8–3.9 (4.2).

Pv/P:
- Large fish, (1.7) 1.9–2.1 (2.5).
- Small fish, (1.6) 1.8–2 (2.2).

Av/V:
- Large fish, (1.3) 1.5–1.8 (2).
- Small fish, (1.2) 1.4–1.6 (1.7).

L/D:
- Large fish, (2.9) 3.6–4.3 (5).
- Small fish, (3.4) 3.7–4.4 (4.8).

All the specimens collected, even the smallest one of 155 millimeters, were sexually mature.

COMPARISONS

A discussion of the differences between *artedi* and the other species of Leucichthys, except *nigripinnis*, occurring in Lake Ontario is given under the heading "Comparisons" in the accounts of these species.

From *nigripinnis* the species probably was distinguished chiefly by the more elliptical outline of the body, as seen from the side, by its firmer and drier flesh, and by its shorter maxillary, snout, and paired fins. *Nigripinnis* spawned a month later, also.

GEOGRAPHICAL DISTRIBUTION

Herring occur throughout the lake, though only in a few localities are they abundant enough to be commercially important. The largest catches are made in the deep water at the western end of the lake and in shallow water at the east end, from the Bay of Quinte region to as far west as Sodus Point on the New York shore. They occur in the eastern waters in relatively deep water during the summer and are fished for to some extent. Specimens have been collected at many ports. The data for these are given in Table 77 and are shown platted on the chart in Figure 7.

METHODS OF CAPTURE

Virtually all of the herring in the Canadian waters are taken with gill nets. These nets have been of 2½-inch mesh in the western waters and of 3-inch mesh elsewhere. In New York waters gill nets, which must be of 3-inch mesh, are employed widely, exclusively when the fish are off the shore; but when the fish come ashore to spawn, especially in Chaumont Bay and Sodus Bay, they are taken largely by trap nets. These nets may be floated even at that season.

SEASONAL MOVEMENTS

As in the other lakes, the schools of herring in Lake Ontario move inshore in spring and fall. There is no evidence to indicate that they remain inshore during the winter, and on account of the violence of currents in the lake to depths of 30 fathoms and more, even in summer, it is not likely that any numbers of herring brave the turbulent conditions that must obtain often on the shores in winter.

Data on occurrence in the herring nets in spring and fall.—In the western waters of the lake, off the ports from Niagara, N. Y., to Bronte, Ontario, and also somewhat farther eastward, the principal herring is the deep-water form. These fish, according to the testimony of many fishermen, replaced the "cisco" (probably *Leucichthys hoyi* and *nigripinnis*) which supported a fishery since about 1860. These ciscoes declined in abundance toward the end of the century, and the fishermen are of the opinion that the territory formerly occupied by them has been taken over by the blue-backed or shore herring. The deep-water fish are little different from their shore relatives except that they are fatter (see p. 508), and the fishermen may be right in their postulate that they are descendants from them. At any rate, shore herring are not common along the west end, but some do occur along the shores and in Burlington Bay in October and November, and some few again in April and May. The deep-water form is now taken most abundantly in fall, when it settles to the bottom to spawn. The schools move within a few miles of shore in 15 to 30 fathoms of water about October 1 and are densest in November. The catch usually drops off abruptly after early December, but sometimes enough fish remain on the grounds to permit the continuation of fishing operations through the winter.

Latterly the herring catches have dropped off and winter fishing has been discontinued for the most part. These fish are not taken in summer. The fishermen have suggested that they swim off the bottom at that season, and, as will be seen later, this explanation is probably sound. At Brighton, Ontario, according to Harry and W. A. Quick, the herring come onto the shoals around October 1 and by November 1 enter the Wellers and Presque Isle Bays and also the Bay of Quinte. They are said to remain until the bays freeze. In the spring they are again present on the shoals during the month of May but do not enter the bays at this time. At Sandy Pond, N. Y., according to Perry Bartlett, the fish come onto the lake's shores in early October and enter the Sandy Ponds in early November. They return to the lake after spawning, in early December, and do not come ashore again in spring. At Sodus Point, N. Y., Hurd Doville says the herring schools come ashore around October 1 and move into Sodus Bay and onto the beaches about November 1. The fish leave the bay abruptly after spawning, and Mr. Doville says that from 1914 to 1920, seven years for which he has records, the date of departure was between December 3 and 5, regardless of weather conditions. A few enter the bay again in spring when the ice leaves, but they are more numerous on the beaches in water as shallow as 20 feet. They remain only about three weeks and are gone by the middle of May into deep water, where they may be taken occasionally during July. In and about Chaumont Bay many herring come ashore to spawn, as in Sodus Bay. At Wilson, N. Y., herring formerly were at 15 to 20 fathoms in October and November, according to Timothy Wilson, but commercial fishing has been abandoned practically at this port in the last 25 years, and now very few are taken.

Data on summer occurrence.—The herring are not followed in the spring because other fish can be taken in greater quantity at that time, and the only data we have on the location of the herring schools in summer are from the east end of the lake. On Lake Ontario few fishermen claim ever to have seen herring swimming at the surface in the open lake, a phenomenon not uncommonly witnessed in the upper lakes where the water is cooler, and the belief is held generally that these fish sink to the bottom and remain there during the warm months. On the eastern New York shores, off Sandy Pond, Selkirk, and Port Ontario, within the last 10 years, and within the last two years off Oswego, the fishermen have taken to herring fishing when the whitefish fell off or they employed herring nets along with the whitefish nets. The herring are found, according to Perry Bartlett, Garry Tifft, and Jacob Fickeis, fishermen at the aforementioned ports, from May, when the nets are put in, to about September in 20 to 30 fathoms of water and even deeper. The lifts during July and August are best, and the herring run large, as nets of 3-inch mesh are used exclusively. Lifts examined by me off Selkirk on July 11, 1921, in about 30 fathoms, and off Sandy Pond on August 24, 1923, at about the same depth, showed herring to occur in these waters in abundance. A lift witnessed on September 1, 1923, off Oswego in 30 fathoms had few fish, although Mr. Fickeis said that in August the lifts had been so heavy that it had been impossible to dispose of the fish caught. About September the lifts drop off in the deep water, and the fish apparently rise above the bottom at that season. Mr. Fickeis used a number of deep bull nets employed on Lake Erie, which fish up to 25 feet above the bottom, and on September 1 it was only in these nets that any quantity of herring was taken.

The occurrence of herring in abundance at depths of 30 fathoms is unknown in any other lake except Erie, where it is known that they occupy the maximum depths of 30 to 35 fathoms in December; but this situation may be accounted for by the peculiar limnological conditions in Lake Ontario. In none of the other lakes are nets in danger during a blow in 30 fathoms, and except in the colder months such nets usually would show no influence of the wind. In Lake Ontario, on the other hand, summer breezes may demolish netting by the induced currents at depths of 30 fathoms. Nets lifted on August 24, 1923, off Sandy Pond from 30 fathoms, after one of the breezes usually experienced in late summer, were practically destroyed by the débris that the currents swept into them. Tree trunks 10 feet long and 4 inches and more in diameter were among the detritus. The force of the currents is greatest in the shallow water and no doubt diminishes toward the deeper water, so that to escape these unsettled conditions the herring may seek refuge in water deeper than in the other lakes. Unfortunately, no temperature readings were taken anywhere on Lake Ontario, so that it is not known whether temperature is a factor in this depth migration of the herring. The maximum depth to which individuals migrate is not known, but a few specimens were taken in 3 to 3½ inch gill nets lifted on August 30, 1923, off Sandy Pond, N. Y., from 60 fathoms, and on September 4, 1923, off Oswego, N. Y., from 70 to 75 fathoms (records 9 and 12).

The records of the fishermen covering commercial-fishing operations for the herring thus show that they begin to move ashore in commercial quantities in early October and that they continue on these grounds until the ice forms in early December. The deep-water form at the western end of the lake comes no nearer shore than 15 to 30 fathoms in the fall, but elsewhere the migration is onto the shoals and into the bays. None of the fish are known to remain in shallow water during the winter, and only at a few ports are they known to return to shallow water again in the spring, though it is probable that the onshore movement at that season is general. At Bronte and Brighton, Ontario, and at Sodus Point, N. Y., some fish are present on the shoals in May. In summer the herring at the west end are said to swim off the bottom and are not fished for, while those at the east end congregate at depths of 20 to 30 fathoms and even to 75 fathoms from May to September, where they are taken at times when market conditions are favorable or when no other species of fish is to be had in marketable quantities. There are no fishing operations of any consequence on the American shore except at the eastern end of the lake, and on the Canadian shore fish other than herring occupy the attention of the fishermen except in the fall.

BREEDING HABITS

The inshore migration in the fall is for the purpose of spawning. Except for the deep-water form at the western end of the lake, which spawns at depths of 15 to 30 fathoms presumably on clay bottom, the herring elsewhere spawn on the shoals and in the bays as shallow as 10 feet. The bottom selected is sand, as a rule, though in the bays pond conditions obtain and the bottom is usually carpeted with the last previous summer's growth of Myriaphyllum, Ceratophyllum, and Utricularia. The time of spawning is usually from the middle to the last of November, and the season, according to the fishermen, lasts about 10 days.

Hurd Doville, who has fished herring in Sodus Bay for the last 15 years, says that the larger males appear first on the grounds, and after spawning is nearly finished there is a run of small males. The fish are caught best in gill nets when spawning, and Perry Bartlett says usually they are taken at the bottom of the netting at this time, which indicates that they spawn near the ground. After spawning, the fish leave abruptly. It is not known definitely when the young, which are hatched in the bays, enter the lake.

VALUE AS FOOD

The western deep-water herring are of the same quality as those of Lake Erie and often are prepared smoked on account of their oily flesh. Other herring are less fat and are not esteemed generally, but there is some demand for them locally, and at certain seasons they can be disposed of to advantage in the New York markets.

RELATIVE ABUNDANCE

Herring have been fished for on Lake Ontario for more than 50 years. In the western waters there has been a decrease in their numbers, according to statistics and according to the testimony of fishermen. The herring fisheries now exploited in the Bay of Quinte region and in the eastern American waters are of relatively recent origin, and in the last decade they have become of great importance in the fisheries of the lake. Perry Bartlett is of the opinion that there has been a decline in the number of herring at Sandy Pond. Hurd Doville, who has fished them at Sodus Bay for the last 15 years, says the runs have not been good for the last five falls.

George Jones, a fisherman at Sodus, says that at one time the herring disappeared entirely for a number of years from Sodus and returned later in abundance, and the fishermen are now expecting them to disappear once more.

LEUCICHTHYS NIPIGON Koelz

Leucichthys nipigon, Koelz, 1925, pp. 1–3, Lake Nipigon; Dymond, 1926, pp. 61–62, Pl. II, Lake Nipigon.

This species is not known to occur in any of the Great Lakes proper, but specimens have been seen from Lake Winnipeg and from Black Sturgeon Lake near Lake Nipigon. (Fig. 28.)

The type is a male specimen (catalogue No. 87092, U. S. National Museum) 282 millimeters in length to the base of the caudal, collected in Lake Nipigon off Macdiarmid at a depth of 30 fathoms on July 28, 1922.

The fish grows to a larger size than any species of Leucichthys seen from the Great Lakes, though it is possible that when these waters were virgin, as Lake Nipigon now is, some individuals of the larger species in the Great Lakes equaled those of this form in this respect. The largest specimen I have seen is from the University of Toronto collection and measures 447 millimeters. Examples longer than 300 millimeters are common. The flesh appears to be dry, like that of lake herring (*artedi*), and the shape of the body is very close to that of the deep-bodied, compressed, tullibee type of this form; namely, it is elliptical in outline as seen from the side. In the case of the largest examples, however, the anterior dorsal contour may rise rather sharply at the occiput over two-thirds its course and then continue to the dorsal insertion with little further elevation. The body is relatively very deep, especially in the larger individuals, and is moderately compressed; the depth is contained in the total length 3.5 [(3) 3.3–3.8 (4.1)] [63] times. The body width has been so altered by artificial compression that in the preserved material at hand it does not appear worth while to record the proportional relations of this character. The head is moderately elongated and is contained 4 [(3.8) 3.9–4.1 (4.5)] times in the total length. Its dorsal profile is nearly straight usually. The premaxillaries are directed forward and make an angle of about 55° with the horizontal axis of the head. The snout is contained 3.8 [(3.3) 3.5–3.8 (4)] times in the head length; the eye 4.4 [(3.8) 4.4–4.6 (5.2)] times; and the maxillary 2.7 [(2.5–2.7 (3.1)] times. The mandible in the type is equal in length to the upper jaw, but in the paratypes it is often somewhat longer or shorter. The gill rakers on the first branchial arch number 19+37 [19–21 (24)+35–37 (43)=(54) 56–59 (66)]. The scales in the lateral lines are 75 [(68) 72–77 (82)] in number. Scale rows [64] around the body just in front of the dorsal and ventrals number 42 [(41) 43–45]; just in front of the adipose and anus, 33 [(32) 33–34 (35)]; around the caudal peduncle at its commencement, 23 [(23) 24–25 (27)]. The pectorals are very long, being contained in the distance from their insertion to the ventrals 1.8 [(1.4) 1.5–1.7 (1.9)] times. The ventrals also are long. Their length divided into the distance from their origin to the insertion of the anal equals 1.6 [(1.3) 1.4–1.5 (1.7)]. There are 10 [10–11] [64] dorsal rays,

[63] These and unmarked figures are based on measurements of 43 paratypes ranging in length from 220 to 447 millimeters.
[64] Ten specimens.

12 [11–12 (13)] [64] anal rays, 12 [12 (13)] [64] ventral rays, 15 [(15) 16–17 (18)] [64] pectoral rays, and 8 [8–9 (10)] [64] branchiostegal rays.

The appearance of the species in life is silvery, with the underlying tints of green and the superficial iridescence that characterize all the Great Lakes forms of Leucichthys. Preserved specimens show moderate pigmentation on the back but heavier pigment on the cranium. The prenarial region is often nearly black, as is the tip of the mandible. The preorbital area and the maxillary also are always pigmented. The dorsal and caudal fins are widely margined with smoky, the hue being deepest on the short rays of the caudal. The paired fins and the anal always show more or less of pigment.

No breeding fish have been seen, and it is not known that pearl organs are developed in the breeding season, but it is likely that they are.

VARIATIONS

Racial variations.—Very few specimens have been examined, and it is not possible to state from the material at hand whether there are races within the species.

Size variations.—Sixteen of the forty-four specimens are less than 300 millimeters in length. A comparison of these with the larger fish indicates that the head, eye, maxillary, and paired fins become proportionally smaller with growth and the body depth increases proportionally. The figures follow:

L/H:
- Large fish, (3.9) 4–4.1 (4.5).
- Small fish, (3.8) 3.9–4 (4.1).

H/E:
- Large fish, (4.4) 4.6–4.8 (5.2).
- Small fish, (3.8) 4.2–4.4 (4.5).

H/S:
- Large fish, (3.3) 3.5–3.8 (4).
- Small fish, (3.5) 3.7–3.8 (4).

H/M:
- Large fish, (2.5) 2.7–2.8 (3.1).
- Small fish, 2.5–2.8.

Pv/P:
- Large fish, (1.5) 1.7–1.8 (1.9).
- Small fish, (1.4) 1.5–1.6 (1.8).

Av/V:
- Large fish, 1.4–1.6 (1.7).
- Small fish, (1.2) 1.4–1.5 (1.6).

L/D:
- Large fish, (3) 3.3–3.6 (3.7).
- Small fish, (3.5) 3.8–4 (4.1).

All but one of the specimens under 300 millimeters have been found sexually immature.

COMPARISONS

A discussion of the differences between *nipigon* and the other species of Leucichthys occurring in Lake Nipigon is given under the heading "Comparisons" in the accounts of these species.

GEOGRAPHICAL DISTRIBUTION

The data from my nets and those of the University of Toronto investigators set during the summers of 1921, 1922, 1923, and 1924 are given in Table 79 and platted on the lake chart in Figure 2 and indicate that this species is found throughout Lake Nipigon.

BATHYMETRIC DISTRIBUTION

Very little is known about the depth preferences of *nipigon*. The data that we have are obtained, for the most part, from the use of nets that were of too large

[64] Ten specimens.

mesh to gill any but extreme examples—namely, the 4½-inch whitefish nets. Some nets of 2½ and 2¾ inch mesh were set by me on July 26, 1922, off the source of the Nipigon River in 10 to 15 fathoms (record 10) and took 11 individuals along with 129 other Leucichthys, and a set made on July 28, 1922, off Macdiarmid in 30 fathoms (record 1) took only 3 out of 251. The same nets set on July 28, 1922, off Livingston Point in 56 fathoms took no individuals of the species. What data we have, therefore, indicate that the species is found in shallow water during the summer, at least. Dymond (1926) also suggests that it is a shallow-water form.

BREEDING HABITS

Nothing is known about the breeding habits of the species. None of the specimens taken from July to October showed sexual glands either ripe or recently spent, so that the spawning season must fall later than October and earlier than July.

Genus COREGONUS Linnaeus

The Great Lakes fish of the genus are relatively large. They are usually immature under 2 pounds and attain a weight of more than 20 pounds. The body is compressed laterally; its width is equal to about 50 per cent of its depth. The premaxillaries are wider (dorsal-ventral measurement) than long and retrorse in position.

A B

FIG. 27.—Openings of a nostril in Prosopium (A) and in Coregonus (b)

The two openings of each nostril are separated by two flaps. (Fig. 27.) The exposed area of the scales of the lateral line is not conspicuously smaller than that of those of the adjacent rows. The gill rakers on the first branchial arch are usually less than 32 and more than 20. Vestigial teeth are usually present on the premaxillaries, palatines, mandible, and tongue. The prefrontal bone is moderately developed, more than in Prosopium but less than in Leucichthys. The carina of the frontals extends to the frontal-parietal suture.

COREGONUS CLUPEAFORMIS Mitchill

THE WHITEFISH (FIG. 29)

Salmo clupeaformis Mitchill, 1818, p. 321, Sault Ste. Marie.
Coregonus clupeiformis Evermann and Smith, 1896, pp. 297–301, pl. 17, Great Lakes.
Coregonus clupeaformis Jordan and Evermann, 1911, pp. 35–37, fig. 19, Pl. VI, Great Lakes, except Erie; Dymond, 1926, pp. 55–57, Lake Nipigon.
Salmo otsego Clinton, 1822, pp. 1–6, fig., Otsego Lake.
Coregonus labradoricus Richardson, Evermann and Smith, 1896, pp. 302–305, pl. 19, Great Lakes; probably also Richardson, 1836, Labrador.
Coregonus sapidissimus Agassiz, 1850, pp. 344–348, Lake Superior.
Coregonus latior Agassiz, 1850, pp. 348–351, Lake Superior.
Coregonus neo-Hantoniensis Prescott, 1851, p. 343, Lake Winnepesaukee.
Coregonus albus LeSueur, Jordan and Evermann, 1911, pp. 37–38, Pl. VI, Lakes Erie and St. Clair; not of LeSueur, 1818.

The whitefish was described originally from a specimen taken in St. Marys River below the falls. The type is not known to exist.

The whitefish is distributed generally throughout the Great Lakes. It is the largest and most valuable of the coregonids. The maximum size attained varies with the locality, but from the most favorable areas individuals have been reported weighing 26 pounds or more. Such large fish are now rare everywhere. In most of the lakes the largest fish now caught weigh 8 or 10 pounds, and but few examples so large are obtained annually. The species inhabits by preference the shallower water and spawns in late fall. In all of the bodies of water except Erie and Ontario the whitefish races are quite similar in appearance. Those from Lakes Erie and Ontario tend to have proportionally deeper bodies, and the Erie race is distinguished further by having, on the average, fewer lateral-line scales and probably fewer pectoral rays and scale rows.

A description of the Lake Michigan form is given as typical for the sake of uniformity of arrangement of the various sections of the text, most of the other types of Great Lakes coregonids having originated in that lake. The whitefish of Lake Huron, which the St. Marys River fish probably most nearly resembles, is, moreover, virtually identical in its characters with the whitefish of Lake Michigan.

Coregonus clupeaformis of Lake Michigan

The body is compressed, fusiform, and rather elongate, with its greatest depth through a point just in front of the dorsal. This dimension varies considerably, but for specimens under 40 centimeters in length it is contained (3.3) 3.9–4.3 (4.8) [65] times in the total length. Larger fish, especially the females, certainly would average deeper. From the occiput the dorsal profile curves upward to the insertion of the dorsal fin. In specimens up to about 2½ pounds in weight (about 420 millimeters long) the rise of this curve is even and gradual, but in larger specimens its cranial half rises more rapidly than the caudal, while the caudal half continues with little further elevation. Thus, the predorsal profile becomes more convex in large fish, wherefore the fishermen often call them "bowbacks." The base of the dorsal usually is somewhat inclined caudally toward the lateral line. It often lies below the general level of the back. The contour line between the dorsal and the adipose is nearly straight. The ventral profile descends in a gentle curve from the tip of the mandible to the ventrals and then rises in a sharper curve to the caudal peduncle. The head, viewed from the side, is relatively small and of little depth and varies in shape from obtuse triangular to acute, according to the shape of the snout. Its length is contained (4.2) 4.4–4.8 (5.3) times in the length of the fish. Its dorsal profile varies from a nearly straight line to a faint double curve. In the latter case the curve is convex from the tip of the snout to a point above the caudal margin of the eye and concave from the latter point to the occiput. The convexity of the anterior dorsal contour is often very pronounced in large individuals. The ventral

[65] These and succeeding figures (unless otherwise marked) are based on an examination of 126 specimens ranging in length from 179 to 483 millimeters. All but two of these are less than 2 pounds in weight, such specimens having been selected for reasons of economy and convenience. In the proportional values given for these specimens, therefore, it should be borne in mind that larger specimens may regularly have values, particularly for L/H and H/E, that will not fit in the usual range of these values given for the smaller fish, and which may even fall outside the extremes here recorded. The changes accompanying growth are considered in a succeeding paragraph.

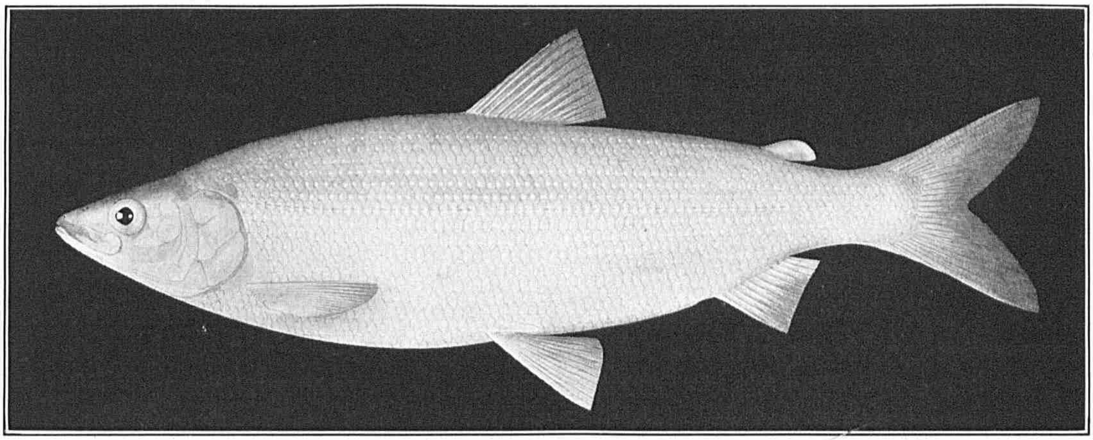

FIG. 28.—*Leucichthys nipigon* Koelz, the tullibee. Male (type), 282 millimeters long, taken in Lake Nipigon in Orient Bay in 30 fathoms on July 28, 1922

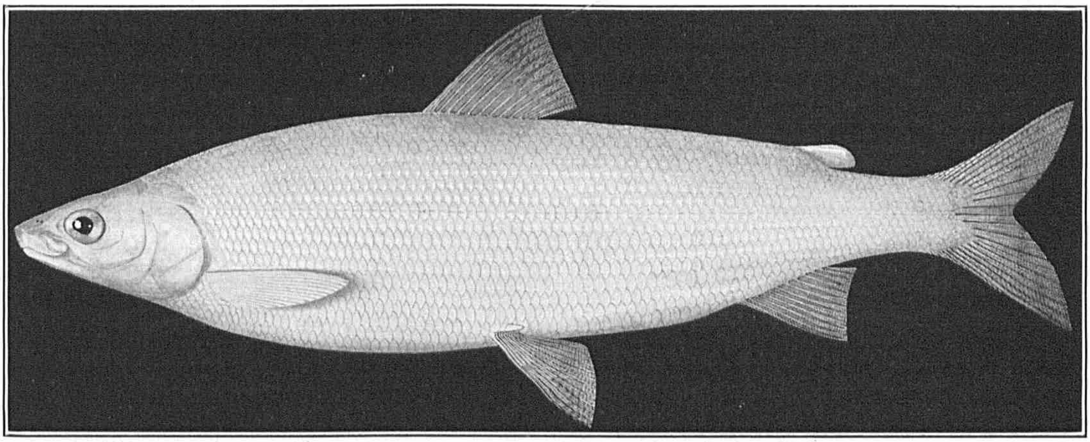

FIG. 29.—*Coregonus clupeaformis* Mitchill, the whitefish. Immature fish, 305 millimeters long, taken in Lake Huron in Thunder Bay in 8 to 10 fathoms on September 24, 1917

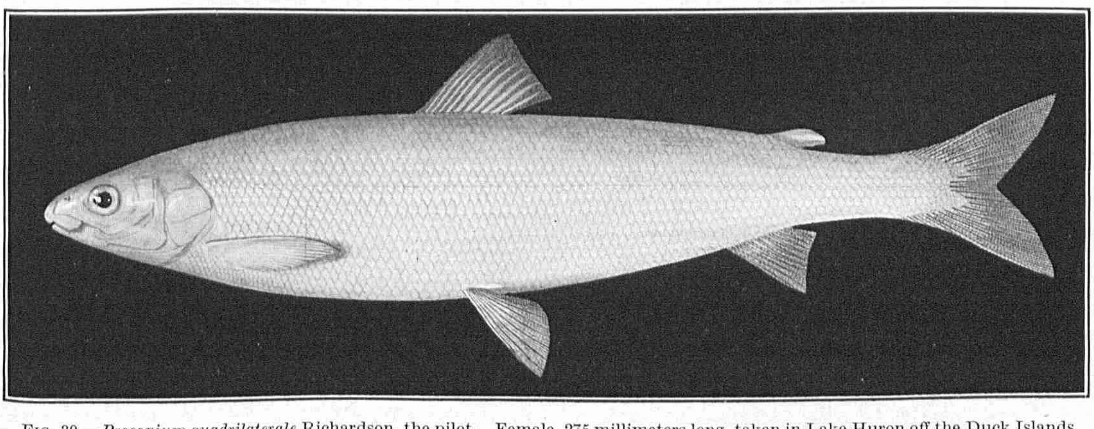

FIG. 30.—*Prosopium quadrilaterale* Richardson, the pilot. Female, 275 millimeters long, taken in Lake Huron off the Duck Islands in 2 fathoms on October 22, 1919

profile of the head is straight. The cheeks are nearly flat, converging slightly in a downward direction. The dorsal surface is triangular. The sides of the triangle converge gradually from its base at the occiput, so that the snout is not sharply compressed and its apex is rounded in front by the retrorse premaxillaries. The width of the head through the nares is about 22 to 23 per cent of its length. A heavy median keel, becoming heaviest in the center of its course, runs from the occiput to the premaxillaries; as a result, the cranial surface is distinctly convex from side to side. The ventral surface is like the dorsal, but nearly flat from side to side. The branchiostegal membrane is supported by (8) 9–10 rays. Their proximal margins run in a nearly smooth line with the outer lateral margin of the longest ray, so that the entire figure is saber shaped. The borders of the isthmus are only slightly convergent and join the mandible without uniting. The mandible is not conspicuously compressed. The premaxillaries are wider (dorso-ventral measurement) than long and are retrorse in position, making the mouth inferior. The extent of their backward slant determines the shape of the snout, which may be elongate and tapering or nearly truncate. Its length is contained in the head length (3.2) 3.4–3.7 (4.1) times and is nearly equal to the short maxillary, which is contained (3) 3.2–3.4 (3.8) times. The maxillary is always pigmented and seldom extends beyond the anterior edge of the pupil. The eye is relatively small, decreasing conspicuously in relative size with age, and is contained between 3.8 and 5 times in the head in the specimens examined. For specimens under 250 millimeters in length the value is usually 3.9–4.3; in specimens 250 to 350 millimeters long 4.4–4.8, and in larger fish more than 4.8. The pupil is roundish, with usually a conspicuous angle in front, from which characteristic the name Coregonus has been applied to such fishes. The gill rakers on the first branchial arch are (9) 10–11 (12) + (14) 16–17 (19) = (24) 26–28 (30).[66]

The scales in the lateral line number (74) 81–88 (93).[67] Scale rows[68] around the body just in front of the dorsal and ventrals number (46) 48–50 (52); in front of the adipose and anus, (36) 37–39 (40); around the caudal peduncle at its commencement, 25–27 (28). The length of the pectorals in contained (1.5) 1.7–2 (2.3) times in the distance from their origin to that of the ventrals. The ventral length is contained (1.3) 1.5–1.8 (2) times in the distance between their origin and that of the anal. The adipose is scaled often to one-third its extent and is variable in size. There are (10) 11 (12)[68] dorsal, ventral, and anal rays and (14) 15–16 (17)[68] pectoral rays. (See also fig. 12.)

The color in life has been recorded incompletely but is not different from that given under this heading for the Lake Superior form.

COLOR IN ALCOHOL

Most of the specimens preserved show the entire dorsal surface suffused with a more or less smoky, sometimes nearly black, hue, which diminishes in intensity to the lateral line and is absent below it, though pigment dots are present to the belly. The hue on the back is often darkest in front of the nares, descending onto the retrorse premaxillaries but usually stopping abruptly before reaching their

[66] One hundred and fifty-one specimens.
[67] One hundred and ninety-one specimens.
[68] Twenty specimens.

cutting edge. Pigment dots usually are grouped in bands around the free margins of the scales, the bands showing best below the lateral line where the dusky hue is absent. Above the lateral line and on the back there are often, especially in fish over 300 millimeters in length, one or two or more well-defined dots of pigment lying below each scale near the center of its exposed surface. There is no pigment on the belly. The sides of the head are pigmented throughout, most heavily in the preorbital area. The mandible is white. All fins are more or less smoky in color throughout, but the ventrals are usually darkest and the pectorals are possibly the palest. The fish caught off Port Washington, Milwaukee, and Michigan City show comparatively very little pigment. The back is not smoky, there are no bands around the free margins of the scales below the lateral line, and the abdominal fins are usually immaculate. These unpigmented fish are among the smallest specimens in the collection, and it is possible that pigmentation increases with age. Specimens equally small, however, and which show decided pigmentation, were taken in Grand Traverse Bay and around the South Manitou Island.

Pearl organs very likely are developed in the breeding season by sexually mature individuals, as in other lakes. Few specimens taken at that time have been examined, but it is probable that the development of the pearls is not different from that recorded for Lake Huron specimens.

VARIATIONS

Racial variations.—So few specimens have been collected from any one port that nothing can be said of race differentiation. No conspicuous features are exhibited by any of the fish collected from various localities, except that pointed out in the preceding paragraph, namely, that specimens south of the island region are less pigmented.

Size variations.—In Table 82, 10 specimens of various sizes are compared in detail. The collected specimens, divided into two size groups at 300 millimeters, show, like specimens of the table, that changes with growth evidently concern principally the relative size of the eye and to less extent that of the head.

GEOGRAPHICAL DISTRIBUTION

All records indicate that originally the whitefish occurred in abundance all along the shores of Lake Michigan and around the islands to the north. At present it has been so reduced in numbers that over most of the shore line it is commercially insignificant, and only in the northern sector of the lake is it still the object of special fisheries.

Specimens have been collected by me from several ports. Complete data for these are given in Table 81 and are platted on the chart in Figure 4.

METHODS OF CAPTURE

The principal methods of capturing whitefish are by means of pound nets and gill nets, the latter of about 4½-inch mesh. In the northern sector of the lake, north of a line drawn through Frankfort and Escanaba, both pound and gill nets are used, the latter chiefly on grounds in more than 10 fathoms and on the spawning grounds in the spawning season. The catches during the spawning season are the heaviest, though at other seasons some quantities of whitefish are taken also; but the catches at other times are mixed with trout usually, and few fishermen could operate large-meshed gill nets if they were dependent on their catches of whitefish. Elsewhere in the lake there are now virtually no spawning grounds where numbers of whitefish can be gilled, and the whitefish thus taken are stragglers among the trout. The pound nets in the north depend for their success largely on the whitefish, though in Grand Traverse Bay rough fish, trout, etc., are a considerable factor in the profit of the fishermen. In other parts of the lake whitefish are chiefly of lesser importance because of their relative and absolute scarcity, and the pound nets are found profitable on account of the variety of fish taken and the better price that can be realized for the rough fish, due to proximity to the markets.

There is a notion widely current over the Great Lakes, based on the observation that gill nets do not take whitefish successfully in shallow water; that there are two kinds of whitefish, one of which will lead into the pound net and one that will gill only. An exposition of the principle on which the two types of apparatus depend for effectiveness affords an explanation for this belief. In Lake Michigan pound nets are fished only from shore to depths of about 50 feet, due to the expense of splicing the stakes used in holding the pots in deeper water. In Lake Huron nets sometimes are set to 90 feet, but for the most part all pounds everywhere on the Great Lakes are set within the first-named limit. In this shallow water, in the daytime at least, the netting is probably always visible to the fish, and the success of the pound net is due to the ability of the fish to detect the presence of the netting and to avoid it. Thus, when the fish encounter the leads of the pounds (which, by the way, are usually coarse enough to permit them to swim through them), some, at least, follow them and thus eventually find themselves in the pot, from which there is little chance of escape. If they did not sense the presence of the lead they would swim through it. The hordes of herring and other small fish that often fill the pots in summer and that remain in the pot until, on lifting, they are frightened through its meshes, illustrate the tendency of fish to keep free from contact with the netting. The success of the gill net, on the other hand, depends on its being unobserved by the fish, else the fish would follow along the meshes and not become gilled. Thus, the effectiveness of the gill nets probably declines directly as that of the pounds increases, and therefore gill nets are not successful in shallow water. Even in deeper water many of the gill-net fishermen believe that their lifts are heavier in the dark of the moon, while many pound netters expect better catches in the light of the moon. At times when gill nets make good catches in shallow water (namely, during the spawning season) the fish may enter the nets in the excitement of the mating act.

SEASONAL MOVEMENTS

Like the rest of the coregonids, the whitefish travel in schools, as shown by the fact that a gang of gill nets may catch all its whitefish in one or two boxes of nets, or by the fact that only one pound of half a dozen in the same neighborhood may take the fish. Many fishermen claim, also, to have seen these schools along the shores. The schools, it appears, are local in their habits and do not wander over wide stretches of the lake. Evidence of this habit is derived from the facts that often the individuals from certain localities exhibit characteristics different from those possessed by individuals of a neighboring locality, and that when certain grounds are exhausted the abundance of the fish on grounds a few miles distant is undiminished. Earlier authors (Milner, 1874; Rathbun and Wakeham, 1897) made observations of the same sort and arrived at the same conclusion.

In the main, the movements of the fish are the same all over the lake. The schools move onshore and offshore like the other shallow-water coregonids, and the causes of the migrations are as little understood for the whitefish as they are for the others. The fishermen believe that temperature plays an important rôle in determining these movements, and the data presented appear to confirm this belief. Milner (1874a) mentions as a probable cause of the inshore movements in summer the presence of more oxygen in the shallower waters. Other writers have suggested that food may be more abundant on the shoals. Probably several factors work together to determine the movement of the fish, all of which are affected by the temperature.

I have collected data from the fishermen on the movements of the whitefish from most of the ports into which they are commonly brought. In Table 83 are given these data so far as they concern the pound nets.

Data from the pound nets.—The pound nets once set remain until pulled out at the end of the season or until blown out by storms, while gill nets are moved in and out at the option of the fishermen. Hence the data from the pounds show the occurrence of the fish at a given location during a fishing season, and the data for one location may be compared with those for another. The depth given in the third column is the depth in which the pot of the net is located. The leads of the pound run shoreward and often extend to the shore. Thus, the catch of any net presumably is a fraction of the fish that occur in the area between the shore and the pot.

The data in the table indicate that the fish do not enter the nets at the various points along the shore at the same season. In some areas they are on the shoals as soon as the nets are set in May (Traverse City, Beaver Island), and in others they may not appear until early July (South Manitou and Fox Islands), or not at all until September (Northport). In the extreme southern end of the lake they are most abundant in late May and early June (Michigan City), but at other points July seems to be the best month. Off Michigan City the schools are gone about the middle of June, off Traverse City about the first of July, and elsewhere about the first of August. Their return in the fall varies from early September to early October.

The catches of the pound nets are determined closely, all the fishermen agree, by the character of the weather. Meteorological conditions determine the time of their appearance on and disappearance from the shoals. Thus, the dates given in the table are only averages, and a variation of a week or more may be looked for from year to year, according as the summer is early or late, long or short. Even when the season is at its height, unfavorable water currents may drive the fish from the shoals temporarily. The currents, to be favorable, must be of moderate intensity and of low temperature.

Data from the gill nets.—Gill nets now are set for whitefish only in the northern part of the lake, but during most of the season the profits from these nets are determined as much by the trout that they take along with the whitefish. In the southern part of the lake the trout outnumber by far the whitefish, and as the trout here frequent deeper water than in the north, such few whitefish as still occur along the shores are not taken often in the gill nets. Out of most of the ports (Manistee, Frankfort, Northport, St. James, Traverse City) the nets find the whitefish in 20 to 30 fathoms when the ice leaves in April. By the middle of June the nets are, on an average, 10 fathoms shallower, and they are left at this depth for the summer. The gangs usually are moved in and out, according as the fish are found best at the deep or shallow ends of the gangs. During the last of August and early in September few whitefish are found anywhere, and it is not known whether they swim off the bottom at this season or avoid the nets. When the water begins to cool they are found again, and from late October until the spawning season is over they may be taken still nearer the beaches. In the fall the fish move in and out from day to day. Some whitefish are taken through the ice at depths of 10 to 20 fathoms.

The data from the two types of apparatus show the same habits for the whitefish. As soon as the ice leaves the fish are driven to the deepest water in which they ever are taken abundantly, namely, 20 to 30 fathoms. Individuals stray into deeper water occasionally during any season, and specimens have been caught in 60 fathoms or even deeper. One such is recorded from off Charlevoix, Mich., in Table 81. When the water begins to warm they approach the shores, and in July, in most localities, they are taken most abundantly in the pounds at depths of 16 to 65 feet (3 to 11 fathoms). In July and August the gill nets take them best at 10 to 20 fathoms. In fall they come ashore again and are taken best first by the pound nets and later, when they are spawning, by the gill nets. During the winter they probably remain near shore under the ice, but when the ice breaks they are driven to deeper water, possibly by the heavy shore currents at this time or in quest of food.

BREEDING HABITS

The time of spawning varies from year to year, but almost everywhere it begins sometime between November 15 and December 15. The season continues for about two weeks. The fishermen believe that the water must cool before the fish will spawn, and as some seasons are warmer than others, a variation in dates is to be expected. All the fish that gather on the various grounds do not spawn at the same time, in a given season, even in the same general area. Some of the interesting variations in the time of spawning for the vicinity of Grand Traverse Bay have been reported to me by John Greilick, of Traverse City, Mich., and B. Peter Anderson, of Northport, Mich., and for the northern islands by James and W. J. Gallagher and Dennis and Hugh Boyle, of St. James, Mich. Their observations have been confirmed by other fishermen. The spawning season of the whitefish in Grand Traverse Bay, at Mission Point, is two weeks later than at the Grand Traverse Lighthouse Point. Those at Tucker Point spawn still later than the Mission Point fish. Off Hog Island the whitefish may spawn in late October, while on Boulder Reef and off the Fox Islands the season will be a month later. The trout schools also are known to have varied spawning times in this area.

Spawning grounds are scattered all along the shores of the lake, but the most important are at the northern end of the lake on the reefs around the islands. Boulder

Reef and the Fox Island Reef are among the largest areas frequented by spawning whitefish. The bottom varies with the locality and may be gravel, honeycomb rock, or small stones. Sand or clay appear in general to be avoided now, though when the species was commoner some individuals may have been forced to spawn in such locations. The depth at which spawning takes place is from 1 to 10 fathoms, according to the fishermen. Earlier in the season some of these grounds are used as spawning places by the lake trout, but the whitefish do not spawn on all the trout-spawning grounds. Possibly some have unsuitable bottoms, though the fishermen do not know that there are differences between the trout grounds they visit and those that they do not.

Nothing definite is known of the spawning behavior of the whitefish, but several fishermen from different localities say that during the breeding season they have seen areas of the bottom on the spawning grounds cleaned of silt, such areas often being a square foot in extent. Whether these spaces actually are cleaned as sites for the eggs or whether they are the result of the body movement of the fish while spawning is not known. That the fish spawn by jumping out of the water, as has been described for pen fish, has been observed by no one anywhere on the lakes to my knowledge; and it is likely that these fish were trying only to escape from their pens, and, being ripe, their violent movements forced the eggs out.

The size of the whitefish at spawning varies with the locality. Among the largest spawning fish are said to be those of Jo Smiths Reef northwest of Hog Island, while those on the Fox Island Reef are among the smallest. It appears that the whitefish in Lake Michigan begin to spawn while still small, and most fishermen have seen individuals that were sexually mature at 1¼ to 1½ pounds in the round. Two male specimens weighing 10 and 13 ounces, taken off Algoma, Wis., and South Manitou Island late in July, were sexually mature. Scale examinations show, however, that these fish are in their fifth year and therefore are dwarfs. Study probably will show that maturity is a question of age rather than of size.

VALUE AS FOOD

The flesh of the whitefish brings a price, on the market, greater than that of any other lake fish except the sturgeon. Its value as food has been recognized fully since its existence in the lakes has been known.

ABUNDANCE

In consequence of its food value, the whitefish, in the earlier days, was sought for the markets with the aid of every device that human ingenuity could invent. At no season was the pursuit relented, and no fish were too small to be taken. The smallest, together with the herring and the sturgeon, often were carried out onto the beach because they were so numerous that they interfered with the capture of the larger whitefish. Though originally whitefish were found in incredible abundance all along the shores of the lakes (in fact, it is said that the species was the predominant one on the shoals), they could not endure long such drains on their numbers. Where for 1880 the Federal statistics show a production in Lake Michigan of over 12,000,000 pounds of whitefish, the catch for 1922 is given as a little over 1,500,000 pounds, despite the great increase in quantity and effectiveness of the fishing apparatus and increase in value of the fish taken. It is noteworthy, also, that the areas that produced the whitefish of 1880 are not those that yielded the bulk of the 1922 catch. Many millions of fry have been planted in the lake since 1880 and the fish have been protected more carefully, but the effectiveness of propagation and protection has been reduced by the pollution of the lake from the industrial cities that have sprung up along its shores and by other abuses. It may be pointed out here that the success of propagation of the species in the Great Lakes has not yet been demonstrated. It is true that there has been reported from time to time in various areas increases in abundance, which have been ascribed to artificial propagation; but there may have been other causes for these phenomena, among which may be mentioned the indisputable decrease of suckers (which possibly compete with the whitefish, as Clemens has found in Lake Nipigon) and of predatory species that may feed on the young. Certainly if the increase could be credited positively to propagation acitvities, it is a result of chance and not of careful and intelligent disposition of the fry. Hatching methods reached the climax of perfection many years ago, and despite the fact that it has been apparent that by far the greatest percentage of the fry planted never were heard from, no investigations have been made to determine why plants were not more successful. Almost nothing is known of the life of the whitefish up to the time it is taken in the commercial nets.

Coregonus clupeaformis of Lake Huron

The Lake Huron whitefish has the general appearance of the Michigan form. The systematic characters capable of numerical expression are given below:

Gill rakers on the first branchial arch:
- Michigan, (24) 26–28 (30).[69]
- Huron, (24) 26–28 (31).[70]

Lateral-line scales:
- Michigan, (74) 81–88 (93).
- Huron, (73) 80–88 (91).

L/H:
- Michigan, (4.2) 4.4–4.8 (5.3).
- Huron, (4) 4.5–5 (5.1).

H/E:
- Michigan, (3.8) 4–4.4 (4.8).
- Huron, (3.8) 4.1–4.5 (4.6).

H/M:
- Michigan, (3) 3.2–3.4 (3.8).
- Huron, (2.9) 3.1–3.5 (3.8).

H/S:
- Michigan, (3.2) 3.4–3.7 (4.1).
- Huron, (3.2) 3.4–4 (4.4).

Pv/P:
- Michigan, (1.5) 1.7–2 (2.3).
- Huron, (1.5) 1.7–2 (2.2).

Av/V:
- Michigan, (1.3) 1.5–1.8 (2).
- Huron, (1.4) 1.5–1.8 (2).

L/D:
- Michigan, (3.3) 3.9–4.3 (4.8).
- Huron, (3.3) 3.7–4.3 (4.9).

The figures show no conspicuous differences between the two forms. The indication of a tendency on the part of Huron specimens to have deeper bodies and shorter snouts may well be due to the preponderance in the Huron collection of local races exhibiting these tendencies.

[69] Figures for Lake Michigan, except those for gill rakers, lateral-line scales, and H/E, are based on an examination of 126 specimens ranging in length from 179 to 483 millimeters. The H/E figures are given for 74 specimens 300 millimeters or less in length, those for gill rakers for 151 specimens, and those for scales for 191.

[70] These and succeeding figures for Lake Huron, except those for H/E, are based on an examination of 195 specimens ranging in length from 192 to 512 millimeters. The H/E figures are given for 80 specimens 300 millimeters or less in length.

The color in life and in spirits is not essentially different from that described for the northern Lake Michigan specimens. The intensity of pigment varies with the individual; possibly also with locality. All the specimens collected tend to be darker than those that were obtained in the southern waters of Lake Michigan. Only an occasional individual from Saginaw Bay has been found with the pigment inconspicuous on the abdominal fins, and such pale fish have been among the smallest in the collection.

Pearls are always present during the breeding season on all males and on the majority of females. They occur conspicuously on the body, the head, and faintly on all the fins. On the males they are developed best on the first row of scales above and below the lateral line. They are slightly smaller on the next row dorsad and ventrad and continue to diminish in size to the third or fourth rows above and the fourth or fifth rows below the lateral line. On the surface of the body, dorsad to the third or fourth rows above and ventrad to the fourth or fifth rows below, they are faint and irregularly distributed, often two, three, or more on one scale. On the first four rows above and below the lateral line there is usually only one large pearl on each scale. This is rounded oblong in shape at its base, longer than wide, and is situated in the center, occupying in its extreme development from one-fourth to one-sixth of the exposed scale surface. The pearl is not of uniform thickness. Its two lateral surfaces rise to meet in a line that is distinctly elevated above the remainder of the button and runs lengthwise through its center. Often a much smaller and similarly shaped pearl occurs on one or both sides of the larger one, slightly caudad to its center. Along the cranial half of the lateral line there are often two pearls on each scale, each about one-half the size of those in the first row above and below, or there may be two or three small and unequal pearls. These decrease usually to one small pearl on each scale on the caudal half of the line but remain virtually the same size as on the cranial half. The pearls on the head are well developed and numerous but small and irregularly distributed. They are most numerous on the dorsal surface and on the lateral surface craniad of the operculum. On the suboperculum, interoperculum, and operculum they are fewer, and on the branchiostegal membrane a single row is present on each ray. The premaxillaries and the free edge of the mandible alone are free from pearls. On the pectoral fins they are present in a row running on both sides of the longest ray, being fainter on the inside surface. There are other rows, chiefly on the distal halves of the other pectoral rays. On each side of the longest ventral ray there is a row, and there are often broken rows on the outside of some of the other rays. Besides these, there is a row on the first rays of the dorsal, on the longest rays of the caudal, and on the scales of the adipose fin. The occurrence of pearls in females is approximately the same as in the males, though the maximum development attained is greater in the latter.

VARIATIONS

Racial variations.—There is reason to believe that the whitefish are local in their habits, and therefore races with more or less definite characteristics might be looked for. The existence of no races with distinctive taxonomic characters is disclosed by my analysis of the specimens in my collection, but the material is not sufficiently complete to warrant a positive statement. In certain localities the fish have seemed, from cursory examination in the field, to have more pointed snouts, but no data on this subject were collected in the field, and in preserved specimens the snout is inclined to be mechanically distorted. However, races may be quite as well marked by physiological differences. Additional discussion on this subject will be found under "Breeding habits."

Size variations.—In Table 85, 10 specimens of various sizes are compared in their chief characters. Separating collected specimens into two size groups, with the dividing line at 300 millimeters, the range of certain proportional characters for the two groups varies more or less. These averages, where they tend to be different, are abstracted below:

L/H:
- Small fish, (4.3) 4.5–4.8 (5).
- Large fish, (4) 4.7–5.

H/E:
- Small fish, (3.8) 4.1–4.5 (4.6).
- Large fish, (4.2) 4.6–5 (5.3).

H/S:
- Small fish, (3.4) 3.6–4 (4.4).
- Large fish, (3.2) 3.4–3.7 (4.2).

L/D:
- Small fish, (3.4) 3.8–4.3 (4.9).
- Large fish, (3.3) 3.7–4.1 (4.7).

The most conspicuous changes involve the head-eye relation, which shows the eye to decrease in relative size with growth. The head and depth appear to be altered but little relative to the body length. From the figures the snout appears to be proportionally shorter in small specimens, but these results are not conclusive, as the snout in large individuals often is deformed in preservation, and slight distortions, even to the extent of a millimeter, would affect the proportions seriously.

METHOD OF CAPTURE

The same methods of capture are employed on Lake Huron as on Lake Michigan and the other lakes. Pound nets in the North Channel and in Georgian Bay yield the greatest production, while on the American shore trap nets figure more extensively as an effective apparatus than on Lake Michigan. Gill nets in the lake are of 4½-inch or larger mesh and depend for profitable use on their catches of whitefish and trout. They may, however, take whitefish on their spawning grounds only, or their catches may be predominantly of whitefish out of a few ports for a short period at other seasons.

GEOGRAPHICAL DISTRIBUTION

We have the assurance of the fishermen that the whitefish formerly occurred all along the shores of Lake Huron, the North Channel, and Georgian Bay. To-day it is virtually unknown from long stretches of the shore line, and in only a few areas does it still remain in numbers. There are two such areas where the fish are fairly abundant on the American shore—in Saginaw Bay and off Alpena—and one of greater extent on the Canadian shore, in the northern and eastern portions of Georgian Bay.

I have collected specimens from most of the ports visited. The data for these are given in Table 84.

SEASONAL MOVEMENTS

The schools of whitefish in Lake Huron, as in the other lakes, engage in migrations toward and away from the shores during the season. From the users of the various types of fishing apparatus I have collected data on these movements.

Data from the pound nets.—In Table 86 are assembled statements on the occurrence of the whitefish in the pound nets set out of various ports on Lake Huron. As might be expected over so wide an area, the movements of the fish vary from port to port. It appears that the fish are often on the grounds in shallow water as soon as the nets are put in in the spring (Point Au Gres, Port Huron, Blind River, Thessalon, Gore Bay, and Cockburn Island). At Killarney the fish are said to be on the shoals when the ice leaves. At a depth of 65 to 75 feet the nets get them only as they move out toward the last of May. The heaviest runs usually are over by the first part of July in the nets set in less than 45 feet (East Tawas, Point Au Gres, Port Huron, Blind River, Thessalon, Gore Bay, Kagawong, and Wiarton). In the nets at 45 to 75 feet off Providence Bay and Killarney and in the 30 to 45 foot nets off Cockburn Island and the Duck Islands the heaviest runs appear from June and July (for Killarney) to August and September (for Providence Bay and Cockburn). The fish are absent entirely in all the nets in 25 to 45 feet of water during August and in some localities earlier (Alpena, East Tawas, Point Au Gres, Port Huron, Blind River, Thessalon, Gore Bay, Kagawong, and Wiarton). At Cockburn Island, the Duck Islands, and Killarney the fish may remain all the summer. The schools return in the fall between the first part of September and the last of October.

Data from gill nets.—The number of whitefish caught in gill nets has decreased to such an extent that few fishermen could operate if they were dependent on their catches of whitefish. Almost every port, however, takes some whitefish in gill nets during the year. The most successful catches, the fishermen say, are those made on mud or gravel bottom. The nets usually are set in the early spring at 10 to 15 fathoms, except off Alpena, where the whitefish are found in April in 30 fathoms, the maximum depth from which the species is known in the lake. The biggest catches are made in 15 to 20 fathoms during July and August. In September the nets are moved into shallower water again, and in October and November the spawning run is taken on the shoals. A few whitefish are taken through the ice in 10 to 20 fathoms off Thessalon and Gore Bay.

The fish caught in the gill nets are smaller, as a rule, than the pound-net fish. Certainly few jumbos (fish over 4 pounds) are caught in the gill nets in summer, while they may be common in the pounds. This fact and the fact that gill nets set in shallow water take few fish have led some fishermen to assert that there are two kinds of whitefish. Neither statement can be disproved. An explanation for absence of fish in gill nets in shallow water has been suggested already. As for the former, it is probable that the 4½-inch mesh is too small for the larger fish.

The data from the gill nets on the movements of the whitefish agree with those from the pound nets. In spring and summer the fish are found by the gill nets in 10 to 15 fathoms when the main schools are in 45 feet (about 8 fathoms) or less. Then when the fish move to deeper water in July and August the pound nets in 45 to 75 feet get them best and the gill nets make their biggest chatches in 15 to 20 fathoms. In the early fall the fish move inshore again and are taken first by the pound nets and later, when they are spawning, by the gill nets. In most localities they probably remain on the shoals under the ice. There are several facts that support this statement: (1) Some fish are caught under the ice in the North Channel; (2) the nets at Point Lookout in Saginaw Bay get the fish as soon as the ice leaves, while the nets at East Tawas at the entrance of the bay get them as they move out; (3) at Killarney and Port Huron the fish are taken on the shoals when the ice leaves, and at Blind River and Thessalon they are taken in 25 feet of water as soon as the nets are put in in May. Where ice does not form regularly, the heavy winter winds probably drive the fish to deeper water, as off Alpena.

BREEDING HABITS

The size of spawning fish varies with the locality. In general males are smaller than females and mature at less size. One of the largest races in the lake is found off Alpena. Here, on November 16, 1917, males were found on the spawning grounds as small as 2½ pounds in the round, occasionally even 2 pounds, while no females were seen smaller than 3 pounds. Individuals of both sexes occurred as large as 14 pounds, but only females over 5 pounds were relatively common. An examination of the sexual condition of two lifts of whitefish taken in 4½-inch nets, numbering 419 individuals, off Alpena on July 3 and 10, 1923, confirmed these findings, making allowance for increased weight due to growth and to development of the sex glands in the four or five months' period preceding the spawning season. At that season males under 2 pounds in the round usually showed no indication of spawning in the fall, while females usually were not maturing under 2½ pounds. The data for all these specimens of July, 1923, are given below:

Weight in the round	Males		Females		Weight in the round	Males		Females	
	Immature	Maturing	Immature	Maturing		Immature	Maturing	Immature	Maturing
1 pound 8 ounces	2		2		3 pounds 12 ounces		4		6
1 pound 12 ounces	4	3	8		4 pounds		0		5
2 pounds	4	31	24	1	4 pounds 4 ounces		1		1
2 pounds 4 ounces	4	52	40	8	4 pounds 8 ounces		1		5
2 pounds 8 ounces	1	45	32	23	4 pounds 12 ounces				2
2 pounds 12 ounces		37	11	16	5 pounds				1
3 pounds		15	2	16	5 pounds 4 ounces		1		1
3 pounds 4 ounces		10		10	5 pounds 8 ounces				1
3 pounds 8 ounces		7		10					

The fish in Hammond Bay are said to be large also.

The smallest breeding fish were observed in the North Channel. Whitefish taken by J. H. Young off Barrie Island, on September 27, 1919, ranged from 2 to 4 pounds, and virtually all were mature males or females. Mr. Young assured me that this catch was average and that he seldom gets fish larger than 4 pounds. At Kagawong, on November 10, 1917, and in 1919, the fish were no larger than at Gore Bay. Here pearled males less than 1½ pounds in the round were taken occasionally. Alfred Rocque and Charles Lowe, of Killarney, tell me that there is a run of these small fish toward the last of November around the Cloche Islands at the eastern end of the channel. They congregate around these islands to spawn and are so small that many pass through the 4½-inch gill nets that are used to catch them. In Kagawong and Manitou Lakes on Manitoulin Island also the fish are said to run very small.

The time of spawning varies with the locality. In Saginaw Bay, on October 25 1917, I found many of the fish ripe; some of the females were even nearly spent. In the North Channel at Blind River, on November 8, 1917, Mr. Baxter told me, the fish were beginning to spawn. Off Barrie Island, Mr. Merrylees, of Gore Bay, told me, they were beginning to spawn on November 10, 1917. Some males of the catches examined here in 1919 as early as September 27 showed pearl organs well developed. At Kagawong, on November 10, 1917, the fish taken were not yet ripe. In Lake Huron, at Alpena, Mich., the spawning season was just beginning on November 16, 1917, according to the spawn takers. The males, they said, had been on the grounds earlier. Furthermore, the time of spawning varies from year to year. What factors influence the ripening of the fish is not known. Some fishermen claim that the moon has something to do with it, but exactly what influence the moon exerts is not clear. It need hardly be said that a closed season for the purpose of protecting the spawning fish, the dates of which are fixed once for all and which holds for every port on the lake, can not accomplish its purpose effectively.

The bottom preferred by the spawning fish is the limestone formation known as honeycomb rock and gravel. Bower (1897) mentions the honeycomb and adds "sometimes on a solidly paved cobblestone bottom, the latter sometimes interspersed with bowlders." Rathbun and Wakeham (1897) say, for Lake Huron, "spawning grounds are found at intervals on rocky or sandy bottom." Milner (1874a) says of the whitefish in the Great Lakes, "the bottoms on the spawning grounds vary in character in different localities, rock, sand, clay, and mud being used indifferently for the spawning beds." Leathers (1911) tells of their spawning on the broad sand flats in Huron County, Mich.

The depth at which the fish spawn varies. Some fishermen say the fish will spawn in as little as 4 feet of water, while others insist that the fish run into this shallow water previous to the spawning season (as do the trout) and that they then repair to 6 to 8 fathoms to spawn. One of the best spawning grounds in the lake lies off Alpena, 6 miles NNE. of Thunder Bay Island, in 8 fathoms of water.

ABUNDANCE

The whitefish in Lake Huron is now much less abundant than formerly. It occurs commonly in relatively few localities. In the vicinity of Alpena and Saginaw Bay on the American side and along certain sections of the North Channel and of the north and east shores of Georgian Bay on the Canadian side it is still the object of special fisheries, but here, as elsewhere, the increased importance of other kinds of fish that are taken incidentally has sustained the fishery in late years.

FOOD

Doctor Hubbs finds, from an examination of the stomach contents of 160 specimens collected off Alpena, Mich., from September 17 to November 2, 1917, and 1919, that Pontoporeia constitued the bulk of the food, supplemented in almost every case by small bivalved and univalved mollusks (Sphærium, Amnicola, etc.). Sand, gravel, cinders, wood fragments, seeds, etc., were present as accidental inclusions in most stomachs, and Chironomidæ larvæ also were of frequent occurrence. Articles occasionally ingested include bryozoan statoblasts, adult land insects, Trichoptera larvæ, Corixidæ, and fish (*Cottus franklinii*). One specimen collected on October 22, 1917, off East Tawas, Mich., had eaten chiefly Sphærium and small gastropods, with some sand and cinders included. Fifteen individuals collected on October

23, 1917, off Bay City in Saginaw Bay were subsisting almost exclusively on the larvæ of the burrowing Mayfly Hexagenia. Sphærium and detritus were present occasionally.

Coregonus clupeaformis of Lake Superior

The whitefish of Lake Superior resembles closely, in body form and other characters, the whitefish of Lake Michigan. The principal systematic characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
Michigan, (24) 26–28 (30).[71]
Superior, (25) 26–28 (30).[72]
Lateral-line scales:
Michigan, (74) 81–88 (93).
Superior, (77) 81–86 (94).
L/H:
Michigan, (4.2) 4.4–4.8 (5.3).
Superior, (4.4) 4.6–4.8 (5).
H/E:
Michigan, (4.4) 4.6–4.9 (5).
Superior, (4.1) 4.4–4.7 (5).
H/M:
Michigan, (3) 3.2–3.4 (3.8).
Superior, (2.9) 3.2–3.4 (3.8).
H/S:
Michigan, (3.2) 3.4–3.7 (4.1).
Superior, (3.2) 3.4–3.8 (4.2).
Pv/P:
Michigan, (1.5) 1.7–2 (2.3).
Superior, (1.4) 1.6–1.9 (2.3).
Av/V:
Michigan, (1.3) 1.5–1.8 (2).
Superior, (1.3) 1.5–1.8 (1.9).
L/D:
Michigan, (3.3) 3.9–4.3 (4.8).
Superior, (3) 3.7–4.3 (4.7).

The most important differences that the figures show are a proportionally larger eye for Superior fish, but this character is known to decrease in proportion with growth, and as the Superior specimens average smaller and therefore might be expected to differ in this way from the Michigan fish, the data can not be regarded as establishing differences between the two forms.

The general appearance in life is essentially silvery, though less so, perhaps, than in most Leucichthys. The back, as a rule, is pale pea green, palest behind the dorsal, fading toward the tail, and obscured by wide bands of pigment around the free edges of the scales and fins and fine scattered pigment over the entire surface. The color extends on the sides to about the fourth or fifth row of scales above the lateral line and begins then to change to a blue, which is strongest below the line and fades toward the colorless belly. The silvery layer begins to become conspicuous on the ninth row above and reflects on the sides a superficial brassy to purplish iridescence, which is most conspicuous above the lateral line. The top of the head is cartilaginous white, frequently with a flesh tone, but it is often so heavily dotted with pigment as to have an almost black cast and to conceal the green patches lying in the cranial cartilages. There is a more or less evident trace of green in the preorbital area. The premaxillaries, maxillary, and mandible also show flesh tones. Otherwise the head is silvery with the reflections of the sides. The fins are whitish, more or less pigmented, sometimes tinted a flesh color at the base, especially the pectorals.

The color in alcohol is dark, like that recorded for Michigan specimens, except that the specimens from Ontonagon, Mich., the smallest ones in the collection, show

[71] Figures for Lake Michigan, except those for gill rakers, lateral-line scales, and H/E are based on an examination of 126 specimens ranging in length from 179 to 483 millimeters. The H/E figures are given for 52 specimens between the lengths of 300 and 483 millimeters; those for gill rakers for 151 specimens, and those for scales for 191.

[72] These and other figures for Lake Superior, except those for H/E are given for 109 specimens ranging in length from 180 to 382 millimeters. The H/E figures are given for 55 specimens from 300 to 382 millimeters long.

little or no pigment on the abdominal fins and reduced pigmentation elsewhere, as in the case of the small fish of southern Lake Michigan. The only other small fish (two taken off Marquette, Mich.) are as heavily pigmented as the largest specimens taken from the same locality, so that it is not certain that these small fish from Ontonagon would become darker with age, nor is it certain that all small fish from Marquette would also be dark.

Pearl organs no doubt are developed by both sexes when spawning, but no spawning fish were collected. It is probable that the descriptions of these excrescences given for Lake Huron specimens will fit those from Superior.

VARIATIONS

Racial variations.—Relatively few specimens have been obtained from any locality, as may be seen from Table 87, and the collected specimens indicate that in only one area (Black Bay, a long, rather inclosed bay on the north shore) do the fish seem to have developed any peculiarity of structure that distinguishes them from their relatives in other parts of the lake. The pale fish from Ontonagon are not considered further, as it is not known definitely that pigmentation may not increase with age. The Black Bay whitefish appear to be notably deeper bodied, on the whole, than those from the open lake. The meager data on hand also indicate that the bay fish tend to have fewer lateral-line scales, as in the case of the Lake Erie race, which is also deeper bodied. L/D values for Black Bay specimens and for those from other parts of the lake are compared below:

	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7
Black Bay	1	0	2	3	3	6	3	5	4	0	2	1	1	1	1	----	----	----
Lake Superior	----	----	----	----	----	1	1	4	2	6	13	8	7	5	7	5	2	1

The *artedi* in Black Bay are known also to be deeper bodied (see p. 500), and both the whitefish and the herring show the same general characters that these species exhibit in Lake Erie. It is probable that in each case the peculiar characteristics are a response to the environment. While there are no data to indicate exactly what the environmental conditions are, it is known that Black Bay is conspicuously shallower and warmer than Lake Superior and even than other much smaller but more open bays near it; and it is assumed that Lake Erie, on account of its shallowness and southerly location is the warmest of the Great Lakes. I have no temperature readings for Lake Erie, but records 9 to 25 in Table 13 show the greater warmth of Black Bay as compared with Lake Superior a few miles outside of the bay and with the more open channels and bays of the north shore. Temperature readings for other parts of Lake Superior, given in the same table, all indicate that the main lake is warmed but slowly and that even at the end of the summer its heat budget is not large. In the figures above it is of particular interest to observe that while the surface temperature in Black Bay was not as high on July 20, 1922, as in Simpson Channel, Moffat Strait, or Armour Harbor on August 5 and 10, 1922, yet the temperature at 8 fathoms was from 3.1° to 6.3° warmer than that recorded at only 4 to 5 fathoms below the surface at these points, and at 8 fathoms was 4.4° warmer than the surface water a few miles outside the bay off Thunder Cape Light on the same day. It is noteworthy also in this connection that the whitefish and herring of Lake Winnipeg and certain other shallow lakes, which must become fairly warm in summer, show the same peculiar features.

Size variations.—The same kind of variation of proportions with size is exhibited by Superior specimens as has been recorded for those of Michigan. In Table 88 are compared in detail 10 individuals of varied sizes. Separating the specimens of the collection into two groups, according as they are more or less than 300 millimeters in length, the only character that appears to be different in the two groups is the H/E ratio. The figures for the smaller fish are (3.8) 4.2–4.4 (4.7); for the larger ones (4.1) 4.4–4.6 (5), indicating that the eye becomes smaller with growth, relative to the head. Of course, all the fish in the collection are fairly uniform as to size, the length of most of them falling within 50 millimeters of the dividing point of the two groups; and if there were greater disparity in size between the groups compared, the differences in this ratio would become much more conspicuous and other ratios also might be found to differ.

METHOD OF CAPTURE

Whitefish are taken chiefly by means of pounds and gill nets, as in Lake Michigan, but a few are taken by other apparatus. The pound nets are located chiefly on the north shore, but there are a few on the southern and eastern shores, most of which yield whitefish. Gill nets, too, are used for whitefish in these areas, but the catches are mixed with trout, for the most part, and here, as in the other lakes, the gill-net industry would long since have perished if it had been dependent on the whitefish alone.

GEOGRAPHICAL DISTRIBUTION

Table 87 shows data for specimens collected from various points along the north, east, and south shores. The records are shown platted on the lake chart in Figure 3. Whitefish are known to exist at all ports on the lake, but they are rare in many sections, particularly on the west shore, where only occasional specimens are taken. They occur around Isle Royale and Michipicoten Island, also, and Will Parker says he has taken stray specimens on Stannard Rock Reef (separated from the mainland by a 30-mile stretch of water, which in most places is from 50 to 100 fathoms in depth).

Lake Superior does not offer particularly favorable conditions for littoral fishes, and the whitefish, therefore, has never been more than locally common. Excepting the bays and the south shore, there is elsewhere only a narrow zone along shore, in many sectors barely a mile wide, in which bathymetric conditions are favorable, to say nothing of bottom conditions. Many of the bays even are too deep over most of their extent, and along the south shore there is only a strip not more than 5 miles wide over which there is water of suitable depth. The bottom, except on the south shore and in the bays, is largely rocky, where the whitefish probably find little food; and the low temperature of the lake's waters also probably retards the development of food organisms, even where conditions are otherwise favorable.

SEASONAL MOVEMENTS

The whitefish behave in Lake Superior as in the other lakes, moving to and away from the shoals during the season.

Data from the pound nets.—Lake Superior often is still covered with ice by May 1, so that the driving of the pound nets may not be completed before the 1st of June.

(See Table 89.) The whitefish are found inshore as soon as or shortly after the nets are set and are at their best in June and July—earlier in those nets to the south or in shallow bays (Whitefish Point, Marquette, Black Bay and Nipigon Bay), and later in other places (Gargantua and Batchawanna). In the shallowest nets the fish are practically absent after the middle of July, and after early August they are taken only in the deepest nets. At Whitefish Point some are said to have been caught in the 90-foot nets throughout the summer. The runs return in the fall (if the nets are not blown out before), from mid-September to late October, depending on the locality.

Data from the gill nets.—Gill nets are set for whitefish in most of the areas where they are caught in pounds. As soon as the ice breaks the whitefish are found along the banks in from 20 to 35 fathoms. When the water temperature rises in June and July the nets are moved shallower. When the water is warmest (in August) the fish leave the shoals, and then the catches, as a rule, decrease. The inshore run in the fall is again a favorable time for the gill netters, though often the weather is too inclement to risk the netting in the shallow water.

John MacMillan, of Sault Ste. Marie, Ontario, informs me that in the summer whitefish can be taken in commercial quantities in the 60 to 70 fathom holes off the Lizard Islands. Other fishermen have found stray individuals in water as deep outside the main banks, and originally when the species was more abundant captures at that depth along the shores were still more common, probably due to the overcrowding of the more favorable shoal areas.

Thus, all the data we possess on the movements of the whitefish indicate that for the most part they are to be found in early spring at depths of 20 to 35 fathoms, probably in those localities where shallower water is too disturbed by currents to offer suitable conditions. As the season advances they move onto the shoals, leaving these again when the waters become warmest, and then occurring rather sparingly anywhere until the schools come ashore again in the fall to spawn. While they prefer relatively shallow water at all times, as in other lakes, there is evidence that at times they occur at 60 or 70 fathoms, where such depths are near shallow areas.

The fingerlings probably live along the beaches during most of the year (Hankinson, 1914).

BREEDING HABITS

The average time of spawning for the species is during the month of November, though here, as elsewhere, the spawning season is not uniform for every locality on the lake. It appears that, as a rule, the northshore whitefish spawn earlier than those in other sectors. If it is a question of lowered temperature that induces spawning, the phenomenon probably can be explained, inasmuch as the bays, which are shallower and more northerly, probably cool more rapidly than the main lake.

No extensive spawning grounds are known, but areas suitable for spawning are scattered along most of the shore stretch where whitefish are found in the summer. The bottom selected is sand, gravel, or small stones at depths from 1 to 12 fathoms.

Nothing is known of the breeding behavior of the species in Lake Superior.

The size of the whitefish at maturity varies with the locality, as in the other lakes. The whitefish from Rossport and in Black Bay are notably small, according to the fishermen, not often exceeding 4 pounds in weight. I have collected specimens with maturing gonads less than 300 millimeters in length from these localities, though individuals of either sex were not often seen maturing under 320 millimeters in length. These fish weigh about 1 pound in the round. Maturing of the sex organs in small fish was observed in Batchawanna specimens, though Frank La Pointe, who fishes there, says the fish run large and seldom spawn under 3 pounds. Specimens from Marquette, Mich., between the lengths of 300 and 348 millimeters, were not approaching maturity. Nothing is known of the size at maturity at other places.

ABUNDANCE

What has been said about the abundance of the whitefish in Lake Michigan applies with equal force to Lake Superior and the other Great Lakes. Whitefish are now common nowhere, and the lake's entire production for 1922, the last year for which complete census figures are available, amounted to about 680,000 pounds, as compared with 4,191,000 pounds reported in 1890. The bays and shoals around the various islands are the last strongholds of the species, and the quantity of the production in these areas fluctuates from year to year. In some such areas, when the species has been so reduced that commercial operations are no longer profitable, the economically enforced respite from persecution probably enables the species to increase in numbers again. The Whitefish Point grounds, the most famous on the lake, now, however, are believed to have been entirely depleted for many years.

Coregonus clupeaformis of Lake Nipigon

The whitefish of Lake Nipigon closely resembles that of Lake Michigan. There are a few differences, which are apparent from a comparison of the main systematic characters capable of numerical expression listed below:

Gill rakers on the first branchial arch:
- Michigan, (24) 26–28 (30).[73]
- Nipigon, (26) 27–29 (30).[74]

Lateral-line scales:
- Michigan, (74) 81–88 (93).[75]
- Nipigon (76) 78–85 (89).

L/H:
- Michigan, (4.2) 4.4–4.8 (5.3).[76]
- Nipigon, (4.1) 4.3–4.5 (4.8).

H/E:
- Michigan, (3.8) 4–4.4 (4.8).
- Nipigon, 3.9–4.3 (4.7).

H/S:
- Michigan, (3.2) 3.4–3.7 (4.1).
- Nipigon, (3.2) 3.4–3.7 (4.1).

H/M:
- Michigan, (3) 3.2–3.4 (3.8).
- Nipigon, (2.8) 3–3.3 (3.6).

Pv/P:
- Michigan, (1.5) 1.7–2 (2.3).
- Nipigon, (1.5) 1.6–1.8 (2).

Av/V:
- Michigan, (1.3) 1.5–1.8 (2).
- Nipigon, (1.2) 1.5–1.6 (1.7).

L/D:
- Michigan, (3.3) 3.9–4.3 (4.8).
- Nipigon, (3.1) 3.5–4 (4.2).

The figures show no conspicuous differences between the two forms, and it is likely that, if more specimens of comparable size were studied, the apparent ones might disappear. There is a possibility that the maxillary may be found to be proportionally longer in the Nipigon form.

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[73] One hundred and fifty-one specimens.

[74] These and succeeding figures for Lake Nipigon, except those for H/E, are based on an examination of 34 specimens ranging in length from 203 to 409 millimeters. The H/E figures are given for 25 specimens 300 millimeters or less in length.

[75] One hundred and ninety-one specimens.

[76] These and succeeding figures for Lake Michigan, except those for H/E, are based on an examination of 126 specimens ranging in length from 179 to 483 millimeters. The H/E figures are given for 74 specimens 300 millimeters or less in length.

The color in life has not been recorded carefully, but it is paler than that of the Michigan form. Most of the preserved specimens have notably less pigment than those from the northern waters of Lake Michigan, though it is distributed over the same areas. They lack the dusky hue of the back, for the most part. One specimen, however, taken off the Blackwater River (a muskeg stream), is as dark colored as any specimen collected anywhere in the Great Lakes.

PEARL ORGANS

No fish were collected by me during the spawning season, but the fishermen all agree that the spawning fish develop pearls. These probably are more or less similar to those exhibited by breeding fish in the other lakes.

VARIATIONS

Racial variations.—Specimens have not been obtained in sufficient numbers to study local variation, and from the material at hand, which originated from various sectors of the lake (see fig. 2), there are no indications (except for the muskeg color of the specimen referred to in a previous paragraph) that local races, if they do exist, are characterized by conspicuous external features.

Size variations.—In Table 91 the five largest and the five smallest fish of my collection are compared extensively in certain systematic characters. The chief differences between the two size groups appear to be the usual ones, namely, a relatively larger head and eye in the smaller fish. Possibly a study of more specimens would reveal other changes with growth.

METHODS OF CAPTURE

Gill nets of 4½-inch mesh and pound nets are the only apparatus employed in the whitefish fisheries on Lake Nipigon. The gill netting is usually spun of sea-island cotton on account of the large quantities of suckers and other rough fish that are taken. The latter are very destructive to the more expensive linen netting generally used in the Great Lakes.

GEOGRAPHICAL DISTRIBUTION

While the data given in Table 90 and platted on the lake chart in Figure 2 for the specimens I have collected do not show a wide distribution of the whitefish in the lake, the species actually may be found (according to the fishermen) in commercial quantities almost everywhere in depths of less than about 35 fathoms. Dymond (1926) records having taken specimens as deep as 50 fathoms.

SEASONAL MOVEMENTS

The fishing season begins when the ice leaves (usually in early May) and continues until the lake freezes in late November. According to the fishermen, most of the lake is relatively shallow, with holes of 25 to 35 fathoms scattered here and there. There is water as deep, at least, as 67 fathoms off Livingston Point, but areas covered by such depths are relatively limited. In spring the fishermen set their nets on the banks of these "bowls" in 17 to 35 fathoms and through the season move them up and down the banks. In spring and fall the fish are likely to be shallowest and in midsummer deepest, though the fishermen say they are not able, usually, to go shallower than 15 fathoms or they will load their nets with suckers, and deeper than 35 fathoms they seldom find whitefish in commercial quantities. However, several fishermen claim to have made profitable lifts from depths of 40 and even 45 fathoms.

BREEDING HABITS

According to John McIver and Andrew Sutherland, the whitefish spawn from the middle to the end of November. They select hard bottom and come into the shallowest water at that time. Nothing is known of their spawning behavior.

The Nipigon fish do not grow large. One of the largest specimens ever collected measured only 615 millimeters and weighed probably about 10 pounds, while specimens over 4 pounds are relatively uncommon. It is not known definitely at what size the fish mature sexually, but Mr. McIver says they may be sexually mature at less than 2 pounds in the round. I have only nine fish over 300 millimeters long, three of which have been eviscerated; and of the six fish in the round two males and a female of each group are immature at a length of 317, 325, and 321 millimeters, respectively (weight about 1 to 1¼ pounds), while the mature fish measure 331, 409, and 373 millimeters, respectively. All fish smaller than 300 millimeters uniformly show no maturity of the gonads. Superficial examination indicates, also, that the fish grow slowly. A slow rate of growth might be expected for fish from waters that are covered with ice for so long a period each year.

ABUNDANCE

The whitefish is the most important and most abundant commercial fish in Lake Nipigon. No other fish are marketable, except the lake trout and wall-eyed pike. Leucichthys of several species and suckers are very abundant but are not yet commercially valuable at points so far removed from the markets.

The lake was opened to commercial fishing in 1916. Production was insignificant that year, but for most of the time since the fisheries have been prosecuted by some dozen steam and gasoline boats operating gill nets. The number of fishing licenses has been limited more or less, and the production of the boats has been restricted to 80 tons a year per steam tug and 40 tons per gasoline vessel. The peak of production was reached in 1919, according to the Ontario report upon game and fisheries, when 1,620,970 pounds of whitefish, 617,900 pounds of trout, and 30,035 pounds of wall-eyes were taken. Figures for 1920 and 1921 show a continued decrease.

If all the whitefish grow as slowly as my specimens indicate, the reason for the decline in production is obviously due to the fact that the fish have been caught more rapidly than they were being produced, and in that case a serious depletion may be expected soon.

Coregonus clupeaformis of Lake Erie

The whitefish of Lake Erie is very similar to the Michigan form except that it is deeper bodied, as a rule, and the predorsal contour, therefore, is often strongly arched in smaller fish. Fish may be "bowbacked" as small as 2½ pounds round. All the whitefish are by no means thus humped at the nape, and often specimens weighing

3 or 4 pounds are found in which the predorsal contour line is as smooth as in the fish of the upper lakes. Such fish were particularly common off Merlin, Ontario, in November, 1924. The principal systematic characters of the two forms that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (24) 26–28 (30).[77]
- Erie, (25) 26–29 (30).[78]

Lateral-line scales:
- Michigan, (74) 81–88 (93).
- Erie, (73) 77–86 (93).

L/H:
- Michigan, (4.4) 4.5–4.8 (5.3).
- Erie, 4.7–5 (5.3).

H/E:
- Michigan, (4.4) 4.6–5.
- Erie, (4.3) 4.8–5 (5.2).

H/S:
- Michigan, (3.2) 3.4–3.8 (4.1).
- Erie, (3.3) 3.4–3.8 (4).

H/M:
- Michigan, (3) 3.2–3.3 (3.7).
- Erie, (3) 3.1–3.3 (3.7).

Pv/P:
- Michigan, (1.5) 1.7–1.9 (2.3).
- Erie, (1.6) 1.7–1.9 (2).

Av/V:
- Michigan, (1.4) 1.6–8 (1.2).
- Erie, (1.4) 1.6–1.7 (1.8).

L/D:
- Michigan, (3.3) 3.9–4.2 (4.8).
- Erie, (3.1) 3.3–3.6 (3.8).

Pectoral rays:
- Michigan, (14) 15–17.
- Erie, 13–15

Scale rows:
- Michigan, (46) 48–50 (52)–(36) 37–39 (40)–25–27 (28).
- Erie, (45) 46–48 (50)–(34) 35–37 (39)–(24) 25–27.

The two forms are in close agreement in respect to all proportions except those involving body depth, head in relation to total length and the eye, and it is probable that this disparity would be reduced in the former and eliminated in the last two if the specimens in the two groups were strictly comparable. In the matter of counts there appear to be differences. The Erie form tends apparently to have fewer pectoral rays, fewer scale rows, and possibly fewer lateral-line scales, but except for the latter character too few specimens have been examined to permit any conclusions.

The color in life is slightly paler than that described for Superior specimens. The iridescence of the sides also is fainter and more often pinkish. Alcoholic specimens show pigment distributed in the same manner as has been described for the form from northern Lake Michigan, except that pigmentation is much less intense. The smoky hue of the back and fins is much reduced. The pectorals are often nearly immaculate.

Pearl organs are developed in the breeding season by both males and females, and their development is like that described for Huron specimens.

VARIATIONS

Racial variations.—No studies have been made to determine the occurrence of local races.

Size variations.—The only whitefish seen have been those that were marketable, and there is not sufficient inequality in size to ascertain how the body changes with growth. It is probable that such changes are like those outlined for the species in other waters.

[77] Figures for Lake Michigan are given for 52 specimens ranging in length from 300 to 483 millimeters, except that those for gill rakers are given for 151 specimens, for lateral-line scales for 191, for pectoral rays and scale rows for 20.

[78] Figures for Lake Erie are given for 18 specimens ranging in length from 291 to 402 millimeters, except that those for gill rakers are given for 100 specimens and those for lateral-line scales for 324.

METHODS OF CAPTURE

The whitefish is caught in Lake Erie by means of gill nets, trap nets, and pound nets. In the eastern half of the lake gill nets are employed most commonly, while trap nets are most abundant on the south shore, chiefly over the western half, and pounds are used most at points along the north shore. The whitefish is now so reduced in numbers that gill-net fishing for whitefish is being discontinued gradually everywhere on the lake; but the use of the other nets is not affected so heavily, as this apparatus takes all kinds of fish and is not dependent on the whitefish for profit.

GEOGRAPHICAL DISTRIBUTION

Relatively few specimens have been collected, though many hundreds have been seen. The data for collected specimens are given in Table 92 and show records from four ports of the south shore. At least a few whitefish are to be had at some season out of any port on the lake, and formerly they were more or less abundant all along the shores and throughout the lake's extent, except possibly in the deepest part of the eastern depression.

SEASONAL MOVEMENTS

As in the other lakes, the whitefish approach and retreat from the shores during the season.

Data from the pound nets.—Pound nets are used most widely in the Canadian waters on the north shore of the lake. Data collected from the fishermen who operate such gear out of the ports of Pelee Island (John McCormick), Merlin (A. Crewe), Ridgetown (W. D. Bates), Port Bruce (W. McGuire), and Port Dover (A. B. Hoover and W. F. Kolbe) show that the whitefish run best in the pounds during the month of May. After June 1 to 15 the run is over entirely. In the fall the fish reappear toward the last of October and run through the month of November. In most ports the fall run exceeds that of the spring.

On the south shore few pound nets are employed, such apparatus being replaced by trap nets. At the west end of the lake whitefish are taken no longer except in the fall, when they appear on the shoals on the western flat in late October and during November.

Data from the gill nets.—In years past when whitefish were common throughout the lake they were taken in suitable gear during any part of the season. Now the employment of gill nets, which depend on whitefish alone for their profitable use, is restricted to certain weeks of the fishing season. At the eastern end of the lake the period of profitable netting for whitefish is longest. Out of Erieau, Ontario (Norman Macaulay), Port Stanley, Ontario (C. Finlay and Arthur Glover), Dunkirk, N. Y. (Walter Murray, George O'Brien, and Thomas Desmond), Barcelona, N. Y. (H. Monroe), Erie, Pa. (Joseph Ferguson), and Ashtabula, Ohio (C. Owen), nets are set in the spring around March 15 in Canadian waters outside of the 10-mile zone reserved for pound-net fisheries, and in American waters at depths of 10 to 25 fathoms. In late years the season lasted for four to six weeks, or until May 1 or 15. In July the nets again were put in the deep waters of the eastern end of the lake, and the season continued to August 1 to 15. In the fall whitefish have been available out of most ports on the lake except off the Canadian shore, and gill nets have been employed frequently to take them. The season ranges usually from October 1 into December, depending on the locality and the weather. Out of Dunkirk and Barcelona nets were set for whitefish into the month of January.

The data collected from the fishermen on the lake indicate that the whitefish are found by gill nets in early spring in the deeper waters, especially in the eastern half of the lake. In May the schools move onto the shoals but retreat again into deeper water in early June. In the deep water at the eastern end of the lake they have been found in commercial quantities during July. Thereafter, until the water cools in the fall, usually none are taken by any apparatus; but in October the gill nets get them again in the deeper waters, and later they move shallower and are caught in the pounds and traps. Later still they repair again to deeper water.

There is a widespread belief among American fishermen that there are only a few schools (or perhaps one) of whitefish in the lake and that these fish summer in the deep water of the east and migrate in the fall to spawn on the reefs to the west. Such a view places too much emphasis on the observation by the fish of the international boundary line and does not take into consideration at all what happens on the Canadian shore, where there have also been extensive whitefish fisheries. It is rather likely that there are several localized schools, none of which undertake extensive coastwise migrations. An intensive study of the fish of the various localities should throw light on this subject; or, better, if marking were feasible, actual migrations could be traced.

BREEDING HABITS

The whitefish spawn generally from about November 20 into December. The season, of course, varies from year to year. On November 30, 1920, at Sandusky and Toledo, Ohio, many of the fish had not yet begun to spawn, and at Merlin and Ridgetown, Ontario, spawning had not begun on November 24, 1924.

The largest spawning grounds of the lake are located around the Bass Islands and Pelee Island, on the limestone reefs in their vicinity, and off Port Maitland. Small reefs, some of which are known to be frequented by whitefish, are scattered along the shores of the lake. The bottom is largely honeycomb limestone rock or gravel, and the water is usually less than 30 feet deep. The western spawning grounds have been virtually deserted since 1920, which was the last good year, on account of the pollution by the Detroit River water, the fishermen believe.

The minimum size of spawning fish is not known exactly, but at Merlin, on November 24, 1924, spawning males were seen as small as 1¼ and 1½ pounds in the round. Many of the fishermen on the north shore inform me that males of this size commonly spawn, but that they do not recall seeing mature females so small.

Little is known of the spawning behavior of the species except that Charles Dircks, of Put in Bay, Ohio, says the males clean portions on the rocks 2 to 10 feet square and that he has seen the male accompanying the female while spawning on these cleaned areas.

ABUNDANCE

Early records show more whitefish taken on the western flats (where there are now no whitefish at all) than are taken in all Lake Erie. In the last five years the species has been of irregular occurrence everywhere and the average annual yield has been low. Around the beginning of the century there was also a period of low production, after which the species increased again. At that time the large-meshed nets went out of use because no other species could be caught with them and the quantity of trap nets and pound nets (which depended largely on the whitefish for profitable employment) decreased in numbers, and with the abatement of the persecution it had sustained, the stock had an opportunity to recover. At that time, too, the Canadian fisheries were being exploited but little, so that there was a kind of natural preserve across the border, besides which large quantities of fry were planted annually.

The present depletion is much more serious than any recorded before, and there is less reason to hope that time will repair it. The use of large-meshed nets is being discontinued again, but the other apparatus is not at all affected, because other species, which were not marketable 20 years ago, are being taken in profitable quantities; and even where whitefish are the mainstay of the fisheries the increased price paid per pound, which in 1922 was over two and one-half times the average price in 1903, permits the continuation of the fisheries even though the supply is less. Canadian fisheries also have expanded enormously in the last 15 years, and the waters across the boundary probably are as exhausted now as our own, so that there is much less of a reserve stock than formerly. The recuperation of the whitefish is impeded further by the excessive pollution of the Detroit and other rivers, also, which, the fishermen say, has driven them off the best spawning grounds in the lake.

ABNORMAL FORMS

The "mule whitefish."—Specimens of what are usually considered hybrids between *Coregonus clupeaformis* and *Leucichthys artedi* are taken occasionally out of many of the lake ports. Their occurrence has been known long, and specimens have been described. These so-called hybrids are frequently of greater average size than even the whitefish. I have a photograph of a male taken by W. D. Bates at Ridgetown on the north shore that weighed 11 pounds, 15 ounces.

A specimen 282 millimeters long was taken by me at Toledo, Ohio, on November 27, 1920. This fish was a male and showed pearl organs. A numerical expression of many of its systematic characters is given in Table 93, and a drawing of the head is shown in Figure 31, *A*.

The body outline is elliptical in side view, like that of a deep-bodied herring. The caudal peduncle also is short and thick, as in the herring *albus*. The premaxillaries are inclined backward, as in the whitefish, but in this specimen the angle is bent little more than 90°. The long adipose and maxillary are other characteristics of the whitefish. The number of gill rakers is clearly intermediate between that of the two forms. The other characters exhibited by this fish are such as are common to both of the supposed parents.

Artificially reared whitefish.—The New York aquarium reared whitefish from eggs of Lake Erie parents hatched in January, 1913. An account of their treatment is given by Mellen (1923). Thirty-two of these fish, which died during the years 1921 and 1922, were received from the aquarium authorities and are now preserved in the University of Michigan collection. These fish ranged in length from 203 to 328 millimeters, and many of them were sexually mature.

The body parts show great modification in all the specimens, and no e of them closely resemble any whitefish taken in the Great Lakes. The most striking differences are changes in the shape of head parts. The head throughout is much deeper than in normal whitefish, and its dorsal contour usually is decurved conspicuously

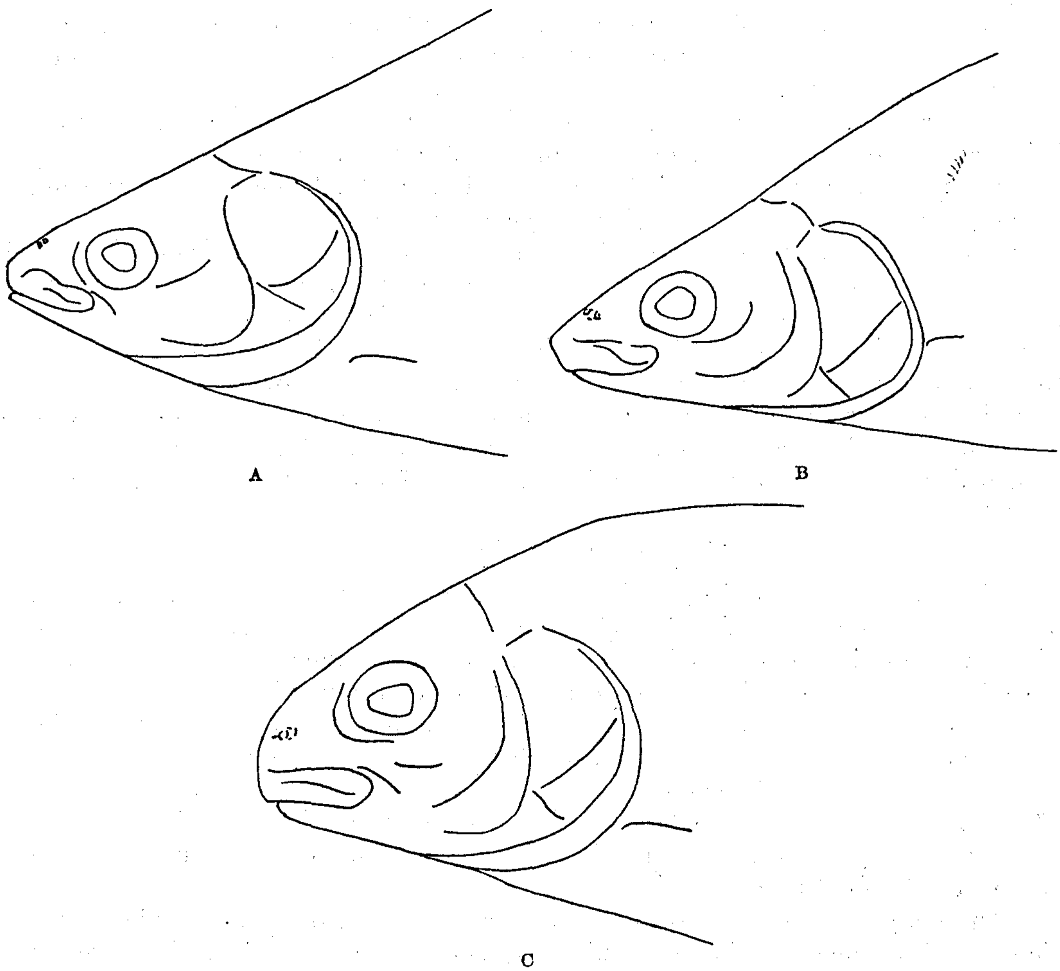

FIG. 31.—Comparison of the heads of the "mule whitefish" (A), a normal whitefish (B), and a New York aquarium specimen (C). The fish were about equal in size—A, 282 millimeters; B, 305 millimeters; and C, 315 millimeters

anterior to the orbit. (See fig. 31, *C*.) The premaxillaries are often vertical in position, which is not known to be the case in normally reared individuals. The head is broader, especially across the snout, and the adipose is much larger usually.

The characters that can be expressed numerically also are interestingly different. All the specimens from the Great Lakes less than 300 millimeters long (many of them less than 200 millimeters long), are combined for comparison in certain characters with those of the New York aquarium. The complete figures are given below:

L/H:	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5	5.1
All lakes	--	--	--	--	--	2	6	16	31	41	48	44	17	8	1
Aquarium	2	1	1	--	1	3	3	4	7	7	1	2	--	--	--

H/E:	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9
All lakes	--	--	--	--	4	5	23	25	31	42	45	30	5	2	1	1
Aquarium	2	1	3	5	3	6	4	3	--	3	--	1	--	--	--	--

H/M:	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
All lakes	--	1	2	22	48	40	45	30	13	5	5
Aquarium	2	5	7	9	4	3	--	--	--	--	--

H/S:	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4
All lakes	--	--	--	--	6	17	17	32	36	28	31	23	8	5	--	1
Aquarium	1	--	2	5	4	9	8	1	--	2	--	--	--	--	--	--

Pv/P:	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3
All lakes	--	--	2	8	19	33	44	36	45	18	4	2
Aquarium	3	3	11	8	4	2	--	1	--	--	--	--

Av/V:	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
All lakes	--	--	--	2	8	58	71	46	24	7
Aquarium	1	1	1	2	5	9	11	1	--	--

Gill rakers:	23	24	25	26	27	28	29	30	31	34
All lakes	--	2	35	136	172	180	79	15	3	--
Aquarium	5	7	8	5	3	2	--	--	--	1

It is clear that the artificially reared specimens have a proportionally longer head, eye, maxillary, snout, and paired fins, and fewer gill rakers than naturally reared fishes. (The one fish with 34 rakers (223 millimeters long) is probably a "mule whitefish.")

Aquarium conditions thus have produced or permitted the development of individuals that are strikingly different from those that are found in nature. Even characters that are considered generic, such as the position of the premaxillaries, have been altered. These observations are of especial interest in view of the striking differences that have been found to obtain in certain species of Leucichthys between forms of a species group.

Coregonus clupeaformis of Lake Ontario

The whitefish of Lake Ontario resembles that of Lake Michigan. The principal characters of the two forms are compared below:

Gill rakers on the first branchial arch:
- Michigan, (24) 26–28 (30).[79]
- Ontario, (25) 27–28 (31).[80]

Lateral-line scales:
- Michigan, (74) 81–88 (93).
- Ontario, (75) 80–88 (92).

L/H:
- Michigan, (4.2) 4.4–4.8 (5.3).
- Ontario, (4.4) 4.6–4.9 (5.2).

H/E:
- Michigan, (4.4) 4.6–4.9 (5).
- Ontario, (4.2) 4.7–5 (5.3).

H/M:
- Michigan, (3) 3.2–3.4 (3.8).
- Ontario, (3) 3.2–3.4 (3.7).

H/S:
- Michigan, (3.2) 3.4–3.7 (4.1).
- Ontario, (3.3) 3.6–3.8 (4.2).

Pv/P:
- Michigan, (1.5) 1.7–2 (2.3).
- Ontario, (1.4) 1.7–2 (2.2).

Av/V:
- Michigan, (1.3) 1.5–1.8 (2).
- Ontario, (1.3) 1.6–1.8 (1.9).

L/D:
- Michigan, (3.3) 3.9–4.3 (4.8).
- Ontario, (3.4) 3.7–4 (4.3).

[79] Figures for Lake Michigan, except those for gill rakers, lateral-line scales, and H/E, are based on an examination of 126 specimens ranging in length from 179 to 483 millimeters. The H/E figures are given for 52 specimens between the lengths of 300 and 483 millimeters, those for gill rakers for 151 specimens, and those for scales for 191.

[80] These and other figures for Lake Ontario, except those for lateral-line scales and H/E, are based on an examination of 39 specimens ranging in length from 253 to 444 millimeters. The H/E figures are given for 27 specimens over 300 millimeters long, and the scale figures have been supplemented by counts of 160 specimens, not preserved, from Brighton, Ontario.

The figures indicate no significant differences between the two forms, and such inequalities as are apparent probably would be reduced by a study of more specimens.

The color in life is not different, so far as has been observed, from that described for Superior specimens, and alcoholics do not differ materially in color from the preserved Superior specimens, except possibly pigment is less abundant, on the average, though it is distributed in the same areas.

Pearl organs are developed in the breeding season by the adults of both sexes. Only a few specimens ready to spawn were seen, and in these the development of the pearls was like that described for the Huron form.

VARIATIONS

Racial variations.—There are not enough collected specimens to analyze for the purpose of ascertaining the existence of local races. What specimens have been assembled do not indicate that these races, if they do exist, are marked by external features.

Size variations.—Most of the collected fish are approximately of the same size, but in Table 95, 10 fish are compared extensively, among which are the largest and the smallest specimens in the collection. The number of specimens is insufficient, of course, but it is apparent from these figures that the usual changes with growth, affecting at least the relative size of the head and the eye, are manifested by the Ontario whitefish also.

METHODS OF CAPTURE

The commercial use of pound nets is prohibited on the shores of Lake Ontario, and the trap and fyke nets are not particularly successful in taking whitefish, so that virtually all the whitefish marketed are produced by gill nets, which are usually of $4\frac{1}{2}$ or $4\frac{3}{4}$ inch mesh.

GEOGRAPHICAL DISTRIBUTION

In Table 94 are given the data for the specimens I have collected. These are platted on the chart of the lake in Figure 7. In addition to actual specimens, records of the occurrence of the species are included in the account of the habits of the species. From both sources it is apparent that the species is distributed along the lake's shores, though it is by no means abundant enough everywhere to be of commercial significance.

SEASONAL MOVEMENTS

Along the Canadian shore, where the whitefish is most abundant, the fishermen say the fish are to be found on the shoals when the ice leaves in April (Brighton, Port Hope, Bronte). In June they move into deeper water and are then fished for at about 8 to 12 fathoms. As the water becomes warmer they retreat still deeper and in August may be caught down to depths of 25 fathoms. The best lifts are made when the fish are in this deep water. A lift witnessed by me on August 27, 1923, off Sandy Pond, N. Y., from 24 fathoms had from 35 to 62 fish per 20 rods of net of $4\frac{3}{4}$-inch mesh. The nets had been set three nights. In September the weather usually is unsettled and the fish probably rise from the bottom; at least, not many are caught. In October they move inshore again, and in November the schools are back on the shoals to spawn. There are no good whitefish areas on the American shore, though a few fish are taken regularly at the eastern end of the lake. In the east (Sandy Pond, Selkirk) the fish behave as along the north shore, except that the fishermen do not find them so early. Whitefishing does not begin here until the last of May or early June, possibly because the New York laws have prohibited fishing within 1 mile from shore, within which zone the fish may occur until this date; though it would appear that if this were the case some, at least, would be taken farther out, whither occasional storms would drive them. Along other points on the New York shore (Oswego, Sodus Point, Wilson) whitefish are relatively scarce and of irregular occurrence.

BREEDING HABITS

The time of spawning is said to be November, usually the latter part, continuing sometimes into early December. Specimens collected at Port Hope, Ontario, on November 21, 1917, were nearly ready to spawn.

The best spawning grounds on the lake are in the Bay of Quinte, into which the spawning fish are said to move from the main lake through the Upper Gap. There are also smaller spawning grounds in other parts of the lake, especially along the north shore. Known spawning grounds along the south shore are rare and for the most part have been deserted by the fish latterly (Oak Orchard, Nine-Mile Point). The bottom selected for spawning, the fishermen say, is hard, as in the other lakes, and may be covered by depths of 15 fathoms. Nothing is known of their spawning behavior, except that at Brighton the Quick brothers say the larger fish spawn first.

In some sections the fish appear to mature at small size. The Quick brothers report that fish weighing 2 pounds in the round usually spawn, and that they have seen spawners as small even as 1 pound. Specimens weighing 1 pound in the round, collected in June, 1921, from the Duck Islands, showed no indication of spawning that year, but males taken on August 27, 1923, off Sandy Pond, N. Y., were mature at 1 pound 7 ounces.

ABUNDANCE

On the American shore the whitefish is almost extinct commercially. From 1,064,000 pounds in 1880 the production had fallen to 54,000 pounds in 1922, with no records in excess of 88,000 pounds in the present century. Across the boundary the catch of whitefish has shown a general increase from 1910, which reached its peak only in 1922, when 2,098,000 pounds were reported. The production has been maintained only by an unproportional increase in the quantity of fishing apparatus and has been stimulated by the ever-mounting prices that the markets offer. In most areas on the lake the fishermen believe the whitefish to have become commoner within the last 25 years, and in most ports the species is believed to be holding its own at present.

Genus PROSOPIUM Milner

Milner, in Jordan, 1878, p. 361 (*Coregonus quadrilateralis*).

The Great Lakes fish of the genus are never larger than 5 and usually not more than 2 pounds in weight. The body is subterete, its width equal to about 56 to 68 per cent of its depth. The premaxillaries are wider than long and retrorse in position.

The two openings of each nostril are separated by a single flap. (Fig. 27.) The exposed area of the scales of the lateral line is conspicuously smaller than that of those of the adjacent rows. The gill rakers on the first branchial arch are less than 21 and more than 13; the length of the longest is rarely more than 5 per cent of the head. There are no vestigial teeth. The prefrontal bone is but little developed and does not extend much beyond the anterior edge of the pupil. The cranial carina does not extend to the frontal-parietal suture.

PROSOPIUM QUADRILATERALE Richardson

PILOT, MENOMINEE, ROUND WHITEFISH, FROSTFISH, CISCO, GRAYBACK, CROSS WHITEFISH, LAKE MINNOW (FIG. 30)

Coregonus quadrilateralis Richardson, 1823, pp. 714–716 pl. 25, fig. 2, "small rivers about Fort Enterprise and in the Arctic Sea"; Evermann and Smith, 1896, pp. 296–297, pl. 16, New England to Alaska; Jordan and Evermann, 1911, pp. 38–39, Pl. VII, Alaska and upper Great Lakes to New England.

Prosopium quadrilaterale Dymond, 1926, pp. 54–55, Pl. VIII, fig. 1, Lake Nipigon.

Coregonus nov-angliæ Prescott, 1851, p. 342, Lake Winnepesaukee. Probably also Sea Gwiniad, Pennant, 1792, p. ccxcviii, Hudson Bay.

The species was described from specimens collected in "small rivers about Fort Enterprise and the Arctic Sea." No material from the type locality is available for examination, but there is little doubt that Richardson's description is of a Prosopium of some sort, and it is probable that our Great Lakes forms are very closely related to it. For the present, then, the specific name *quadrilaterale* is retained for them.

The pilot occurs in all the lakes of the Great Lakes series except Erie, and in Lake Nipigon. The representatives of the species in one lake resemble those in another very closely, the differences between them being chiefly such differences as are evident between mature and immature individuals in any one of the lakes. No complete account of the natural history of the species is available for any of the lakes, but such details as are known indicate that the habitat selected is the same throughout the basin; and it is probable, further, that the breeding habits, making due allowance for differences in latitude, which probably affect the time of spawning, are the same. The flesh is not of the best, and the species is of relatively little or no commerical importance anywhere.

Prosopium quadrilaterale of Lake Michigan

The body is subterete, much elongated, little compressed (except at the snout and tail—much less compressed than the whitefish), and uniformly tapered. Its greatest depth is through a point at the front of the dorsal. In adults this measurement is usually about 20 to 22 per cent of the length, though in the largest examples, especially gravid females, it commonly becomes 24 per cent. Owing to the moderate depth of the body, its profiles are gently and uniformly curved. The head is very small and is contained (4.9) 5.2–5.4 (5.6)[81] times in the total length of the body. In side view the outline of the head is roughly ovoid, its dorsal contour curving sharply downward from a point between the orbit and the nares, so that the snout is always

[81] These and succeeding figures, unless otherwise marked, are given for 34 collected specimens ranging from 200 to 419 millimeters in length.

rounded, even in individuals in which the premaxillaries are most retrorse. Its lateral surfaces are nearly flat to a line on a level with the superior edge of the maxillaries and from thence converge sharply in a downward direction, the more sharply as the snout is approached. The dorsal surface of the head is acutely triangular owing to the compression of the entire preorbital and mandibular regions. The width of the head through the nostrils is 17 to 21 per cent of the head length. Its interorbital space is flat or only very faintly convex. A short but heavy median keel runs from a point above the postoculars to a point approximately above the anterior edge of the pupil. A fainter keel originates on each side of it, slightly farther craniad, and extends almost to the nares. The ventral surface of the head is likewise acutely triangular in form but is strongly convex from side to side. The branchiostegal membrane, which has 7 or 8 short rays, is trapezoidal in shape. From it the isthmus narrows distinctly to join the mandible. The premaxillaries are more or less retrorse in position, usually making an angle of 100° to 110° with the horizontal axis of the head. The eye is moderate in proportion to the head, contained (3.9) 4.3–4.6 (5) times in the head length. Its pupil is oval, so that its cranial angle, usually conspicuous in the coregonids, is rounded off. There are (5) 6–7 (8) + (9) 10–11 (12) = (15) 16–18 (19) gill rakers on the first branchial arch. The lateral-line scales run in a nearly straight row and number (84) 87–95 (100).[82] Scale rows[83] around the body, just in front of the dorsal and ventrals, are (40) 42–45 (46); in front of the adipose and the anus, (31) 33–35 (36); and around the caudal peduncle at its commencement, (24) 25–27 (28). There are usually a few scales conspicuously larger than the rest just behind the occiput. The dorsal rays number 11–12 (13);[83] anal rays, 9–11;[83] pectoral rays, 14–16 (17);[83] ventral rays, 10–11.[83] The length of the pectorals is contained (1.8) 1.9–2.2 (2.3) times in the distance from their origin to that of the ventrals. The length of the ventrals is contained 2.1–2.3 (2.5) times in distance from their origin to the anal. (See fig. 12.)

The color in life is silvery, as in the other forms, but in the pilot it is less striking on account of the presence of brighter superficial colorations. The entire dorsal surface, including the cranium, is virtually a uniform bronze to sepia brown tinged with green. The exposed surface of the scales of the back, particularly in the predorsal area, is margined with a band of pigment dots, which tend to obscure the coloration. The sides are brownish; the color is strongest above the lateral line, where it is overlaid by silvery with a pinkish cast. The pinkish cast is brightest below the lateral line, but both the pink and the brown beneath it fade as the colorless belly is approached. The sides of the head are also silvery, with a tinge of bronze, which is strongest in the preorbital region, on the dorsal tip of the operculum, and on the iris. The premaxillaries and tip of the mandible are whitish. The maxillary is spotted with fine dots of brown. The basal half of the paired fins and often of the anal is bright salmon pink. The dorsal fin and the basal half of the shortest and three-fourths of the longest rays of the caudal are brown.

After preservation, all color, including the silvery tone, eventually fades, disclosing further details of pigmentation. Pigment is evident, then, also on the sides

[82] Sixty-five specimens.

[83] Twelve specimens.

above the lateral line, with a sprinkling of dots down to about the fifth row below. The top of the head and the preorbital area are heavily sprinkled with fine dots, which often collect to form small spots, particularly in the occipital region. Pigment is present on the oculars and on the operculum. The cranial border of the dorsal, the tips of its rays, and the rim of the caudal are washed with smoky. The other fins are usually immaculate, though there are occasionally a few pigment dots on the pectorals and ventrals, particularly on their inner surface.

Pearl organs have been seen on no individuals of the species. Only one adult specimen was taken in the breeding season, and in the case of this specimen (collected on November 19, 1920, out of Michigan City) the epidermal excrescences may have been eliminated by rough treatment subsequent to its capture. It is probable that the development of pearls in the species of Lake Michigan is not different from that in the Lake Huron form.

VARIATIONS

Racial variations.—There are no data available for a discussion of local variations.

Size variations.—An examination of 42 specimens ranging in length between 156 and 210 millimeters, taken in Platte Bay on the Michigan shore, indicates that small individuals have a larger head and eye and somewhat longer paired fins. A comparison of these values for the two classes of specimens follows:

L/H:
- Large fish, (4.9) 5.2–5.4 (5.6).
- Small fish, (4.7) 5–5.1 (5.2).

H/E:
- Large fish, (4.1) 4.3–4.6 (5).
- Small fish, (3.5) 3.7–3.9 (4).

Pv/P:
- Large fish, (1.8) 1.9–2.2 (2.3).
- Small fish, (1.8) 1.9–2 (2.1).

Av/V:
- Large fish, 2.1–2.3 (2.5).
- Small fish, (1.8) 2–2.2 (2.5).

The body depth, of course, is also less, proportionally, in small specimens.

Small individuals in the collection (all those under 200 millimeters and often those up to 230 millimeters) show parr marks. These marks are distinct, roundish, dusky spots 2 to 4 millimeters in diameter, irregularly spaced, separated 2 to 8 millimeters from one another, and scattered more or less at random over the dorsolateral and dorsal surfaces, though there is often an appearance of arrangement in sinuous rows. They are most conspicuous and most numerous on the second to fifth rows of scales above the lateral line and disappear last in this region as the individual grows. Frequently there are dots along the lateral line, also, which are larger and fewer in number than on the rows above it; and there are also fainter marks on the dorsal surface, particularly in the predorsal area. Dymond (1926, Pl. VIII, fig. 1) shows a specimen with these parr marks.

It is noteworthy that of 17 collected specimens between the length of 220 and 300 millimeters, only 4 are sexually mature. They are divided as follows, according to size and sex: Mature—255 female, 267 male, 279 female, and 295 male; immature—220 male, 220 male, 221 male, 226 female, 232 female, 239 male, 242 female, 249 female, 254 female, 256 female, 269 male, 270 female, and 293 female.

The maximum size reported for the lake is about 4 pounds.

GEOGRAPHICAL DISTRIBUTION

Like the blue-backed herring and whitefish, the pilot occurs in schools in suitable localities all along the shores of Lake Michigan. It is fished for even less extensively than the herring, due probably to the fact that it is by no means so abundant nor so easily taken, and consequently complete data on its range and abundance are not available. Unless nets are set for pilots, the numbers of the fish or even their presence may be unsuspected, as they seldom become entangled in the pound or gill nets set for larger fish and are never seen swimming in the open lake. Like the herring, they enter harbors occasionally and may then be taken with hand lines.

R. F. Kleinke, of Menominee, Mich., says there are not now and to his knowledge never were any pilot in Green Bay. At Washington Harbor, Wis., at the mouth of the bay, John Ellafson reports a few taken occasionally both in trout and perch nets. At Sturgeon Bay and at Algoma, Wis., they are taken occasionally in commercial quantities, according to the statement of George Knipfer, who has set nets for these fish. At Port Washington and Milwaukee, Wis., none ever are taken for market but a few are caught in other nets during the year, according to the statement of Delos H. Smith and August B. Budzisz. At Michigan City, Ind., and Grand Haven, Ludington, and Manistee, Mich., the fishermen likewise report the taking of only an occasional pilot. Otto Anderson says he has fished for pilot in the fall out of Arcadia, Mich., and has taken them in commercial quantities. The other ports, all in the State of Michigan, which have at times taken the fish for market are Northport (Hans Anderson and Carl Schrader), Traverse City (Will Hopkins), St. James on Beaver Island (Dennis and Hugh Boyle, James Martin, Robert Gibson, and Hugh Connaghan), and Seul Choix Point (Alex Goudreau).

I have collected specimens from several ports on the lake, all of them casual inclusions with the catches of other species. Data for these are given in Table 96. They are shown platted on the lake chart in Figure 4.

METHOD OF CAPTURE

Unlike the whitefish, the pilot will not follow a lead readily and consequently is taken seldom in the pound or trap nets. Gill nets alone are employed in their capture, therefore, the mesh used ranging between 2½ and 3 inches. Other species, notably herring and perch, also are taken often with the pilot by these nets.

SEASONAL MOVEMENTS

The pilot moves in and off shore like the other shallow-water coregonids. As the species is not sought for regularly, only scattered data on its movements are available.

Data on the occurrence in fall and spring.—Out of Washington Harbor, Sturgeon Bay, Algoma, Arcadia, Northport, Traverse City, St. James, and Seul Choix Point, according to the statements of those fishermen who have attested to the occurrence of the species out of these ports, the pilot can be found inshore on gravel and honeycomb rock in 2 to 6 fathoms in November and often into December, if the weather permits. At this time it is taken frequently in commercial quantities at these ports.

The records in Table 96 show occasional specimens taken in the chub nets on November 19, 1920, 17 miles NNW. and 17½ miles NW. by N. ¾ N. of Michigan City, Ind., in 28 to 32 fathoms, and on March 4, 1921, 15 miles NW. by N. ½ N. of that port in 28 fathoms. Out of Northport pilot are known to occur with the herring in 2 or 3 fathoms for about two weeks when the ice leaves around April 1, but elsewhere no nets are set for pilot in spring, and hence nothing is known of the movements of the species in spring.

Data on the occurrence in summer.—A few fishermen have tried to take the pilot in commercial quantities in the summer. John Ellafson, of Washington Harbor, says that he has taken them in August and September at depths of 6 to 12 fathoms on sand. Otto Anderson, of Arcadia, claims to have found them in 8 to 10 fathoms in September. Robert Gibson, of St. James, says that several years ago, in July and August, in 5 to 8 fathoms on sand and gravel around Garden and Hog Island of the Beaver group, he caught on an average of 500 to 600 pounds of these fish at a lift in 8,000 feet of nets, when lifted after two nights out. In September, Mr. Gibson says, the fish disappeared and could be found neither shallower nor deeper. The other St. James fishermen and Mr. Schrader, of Northport, concur with Mr. Gibson in the assertion that the pilot schools are very erratic in their movements. They visit and leave certain grounds for no apparent reason, and can not be followed in their migrations. Out of Washington Harbor, Northport, Traverse City, and the Beaver Islands an occasional specimen becomes entangled in the trout nets at depths of 6 to 16 fathoms during the summer months.

No individuals have been seen by me or reported by the fishermen from the 1½-inch nets that are set at 30 fathoms out of many ports for bloaters, and none have been seen by me in the chub nets, except those from off Michigan City in 28 to 32 fathoms in November and March, so that the maximum depth to which the species retires is probably about 30 fathoms.

The records indicate, then, that the pilot are found inshore in numbers on honeycomb rock and gravel in November and into December. Little is known of their movements during the remainder of the year, but at one locality, at least, they are found on the beaches again when the ice leaves in the spring. Fishing operations have been conducted for the species out of several ports in July, August, and September, and these operations have disclosed the presence of the species at depths of 5 to 12 fathoms. Casual specimens have been taken out of many ports as deep as 16 fathoms and out of one port as deep as 28 to 32 fathoms, so that 32 fathoms probably marks the upper limit of the depth range of the species.

BREEDING HABITS

The fall inshore movement is for the purpose of spawning. There are no more definite data available than that the fish can be taken abundantly in November and even in December if the weather permits fishing so late. Spawning takes place, according to the fishermen, on honeycomb rock and gravel in 2 to 6 fathoms of water.

FOOD

No studies have been made of the food of the species in Lake Michigan, except that small individuals taken on July 30, 1923, off South Manitou Island were feeding chiefly on Chironomus larvæ and pupæ. It is probable that its food preferences are similar to those of its relative in Huron. As in Lake Huron, the species is charged with the destruction of trout spawn by virtually every fisherman who is familiar with it, and all these men claim to have seen the trout eggs in the pilot's stomach. Some data on this propensity of the pilot are given on page 552.

COMMERCIAL VALUE

As a food fish the pilot is always rated above the herring, but in this respect it does not even approach the whitefish. The flesh has little fat and spoils readily, so that the pilot nets have to be lifted at short intervals. The fish are sold either fresh or salted.

Prosopium quadrilaterale of Lake Huron

The pilot of Lake Huron differs in few characters from its relative in Lake Michigan. The principal characters capable of numerical expression are compared below:

Gill rakers on the first branchial arch:
- Michigan, (15) 16–18 (19).[84]
- Huron, (15) 16–17 (19).[85]

Lateral-line scales:
- Michigan, (84) 87–95 (100).
- Huron, (80) 84–91 (95).

L/H:
- Michigan, (4.9) 5.2–5.4 (5.6).
- Huron, (4.5) 4.8–5.1 (5.3).

H/E:
- Michigan, (3.9) 4.3–4.6 (5).
- Huron, (4) 4.2–4.5 (4.9).

Pv/P:
- Michigan, (1.8) 1.9–2.2 (2.3).
- Huron, (1.5) 1.8–2 (2.3).

Av/V:
- Michigan, 2.1–2.3 (2.5).
- Huron, (1.8) 2.1–2.2 (2.4).

It appears, thus, that Huron specimens tend to have a proportionally larger head, somewhat longer paired fins, and slightly fewer lateral-line scales. Of course, data are required from many more specimens from both lakes in order to establish the course of the distribution curve for any characters.

The color in life is as in the Michigan form, except that, as a rule, specimens are more heavily pigmented. This character, of course, is most in evidence in alcoholic material. The pigment below the lateral line, besides being more abundant, extends often to the belly. The paired fins often are pigmented distinctly, and frequently there are dots on the anal.

Pearl organs are well developed on males during the breeding season and at least faintly indicated on some females. I have collected no specimens during or immediately previous to the spawning period, and therefore I do not know to what extent nuptial buttons are developed on the two sexes. Pearls were beginning to appear on males taken at the Greater Duck Island on October 18, 1919, were present on males and a few females taken at Wiarton, Ontario, on November 5, 1917, at Kagawong, Ontario, on November 10, 1917, at Alpena, Mich., on November 15, 1919, and in Au Sable River, Mich., in November, 1924. None of these fish were ripe. The maximum development of pearls that I have seem for the species is exhibited by specimen No. 1087 from Wiarton. On this fish they are present on the lateral line and on each scale of the first four rows above and below it. On the fifth

[84] Figures for Michigan, excepting those for scales, are based on an examination of 34 specimens ranging in length from 200 to 419 millimeters. Figures for scales are given for 65 specimens.

[85] Figures for Huron are based on an examination of 72 specimens ranging in length from 200 to 393 millimeters.

and sixth rows above and below they become faint, and their distribution is often discontinuous. There are none on the belly or head and only a few on the back. There is usually only one pearl present on each scale, except on the lateral line, where there are sometimes two. In shape the pearls are rounded, showing faintly a narrow longitudinal thickening, are situated in the center and occupy one-third to one-fourth of the exposed scale surface on the rows bordering the lateral line. They diminish gradually in size dorsad and ventrad. On the lateral line they are less than one-fourth as large as on the adjacent rows and are situated laterad and slightly caudad to the pore.

VARIATIONS

Racial variations.—Specimens are available for comparison from Alpena, Mich., and from the Duck Islands across the lake, but the two groups appear little different in their systematic characters.

Size variations.—The same changes with growth outlined for Lake Michigan specimens seem to obtain in Lake Huron, namely, that small specimens have a larger head and eye, longer paired fins, and less body depth. The figures for specimens under 30 centimeters in length and for those of greater length are compared below for most of these characters:

L/H:
- Large fish, (4.8) 4.9–5.2 (5.3).
- Small fish, (4.5) 4.7–5.1 (5.3).

H/E:
- Large fish, 4.4–4.9.
- Small fish, (3.7) 4–4.3 (4.5).

Pv/P:
- Large fish, (1.8) 1.9–2.1 (2.3).
- Small fish, (1.5) 1.7–2 (2.2).

Av/V:
- Large fish, 2.1–2.3.
- Small fish, (1.9) 2–2.3 (2.4).

Individuals apparently show parr marks in their juvenile stages, which, to judge from the two collected specimens under 20 centimeters in length, are not different from those described for small specimens in Lake Michigan.

None of the collected specimens less than 23 centimeters long are sexually mature, and none over 25 centimeters are immature.

The maximum size reported for the lake is about 4 pounds.

GEOGRAPHICAL DISTRIBUTION

As in Lake Michigan, schools of pilot are to be found in suitable localities all along the shores of Lake Huron. Likewise the species is not sought much in Lake Huron, and therefore the same limitations exist to the securing of data on the occurrence and habits of the species.

On the Canadian shore the pilot seldom is caught for market, but it does occur at other localities in addition to those from which I have collected it, namely, at Tobermory and Providence Bay, according to the statements of Kenneth McLeod and John Purvis. There are other Canadian ports, no doubt, from which it could be caught. On the American shore it is taken not uncommonly, particularly in the fall. It is found in some numbers along the shore from St. Martins Bay to Hammonds Bay, from which area a few are taken to market, both at St. Ignace and Cheboygan. From Hammonds Bay to Middle Island there are said to be none, although in some parts of this area, at least, they have been sought. The Schmekel brothers, of Rogers, say that they have tried nets at Presque Isle for eight years but never yet have got pilot in them. In the area between Middle Island and Scarecrow Island more pilot are caught than from all the rest of the lake. South of the latter point and in the Saginaw Bay region the fish are rarer again, although about 1902, according to Oscar Hurkett, of Harbor Beach, a heavy run entered the bay. At the south end of the lake between Harbor Beach and Port Huron the species has been, or still is, common. At the former port there has been a marked decrease in its numbers in recent years.

I have collected specimens from many ports on the lake, most of them casual inclusions with the catches of other species. The data for these are given in Table 98. They are shown platted on the chart in Figure 5.

METHOD OF CAPTURE

As in Lake Michigan, the pilot will not follow a lead readily, and consequently it is not taken commonly in the pound or trap nets. In less than 30 fathoms gill nets of 2¾ or 3 inch mesh usually are employed to capture it. At some ports these nets are used for herring, also, and are set most often in the fall.

SEASONAL MOVEMENTS

The pilot moves in and off shore like the other shallow-water coregonids. Few nets suitable for pilot are used in spring, and therefore it is not known when the fish leave the shoals.

Data on occurrence in the fall and spring.—These records are from American waters only. At Cheboygan (according to Louis Peets) and at Middle Island (according to the records of the Alpena and Rogers boats) the schools begin moving into 3 to 5 fathoms about the middle of October on honeycomb rock and gravel. During November the run is at its height. In the spring the Alpena tugs again put their nets on these grounds when navigation opens about April 1. They sometimes get a few lifts of pilot. Bert Andrews, of Port Huron, informs me the pilot came inshore 10 to 12 miles north of Port Huron in 4 fathoms on November 1, 1913. On the 9th and thereafter 4 tons or more were taken in a single lift in 7 to 8 fathoms. The fish gradually retreated northward toward the last of the month. Few are found on these grounds in the spring.

Data on occurrence in summer.—The nets used for other fish in summer are not suitable for pilot, and therefore there are few data on summer occurrence. The pilot are probably at no time in deep water. None ever are taken in the 2¾-inch chub nets in 35 to 50 fathoms off Cheboygan; none were taken in the box of 2¾-inch nets lifted off Alpena from 30 fathoms with a trout gang on September 19, 1917, nor have any ever been reported at any season from the 1½-inch bait nets set at 30 fathoms either at Alpena or Harbor Beach. The identity of the fish is so unmistakable that no fishermen would fail to recognize it when taken. Frank Hebert tells me that off Nine-Mile Point during the first week in September, 1917, a gang of 2¾-inch nets set in 17 to 20 fathoms got 500 pounds of pilot four nights out. On September 2, 1917, I found pilot in the stomachs of trout caught in 20 fathoms. This observation alone has little value in fixing the occurrence of the fish, as there is nothing to indicate that the pilot were caught in 20 fathoms also, but it need not be ignored when supported by the preceding record. A box (2,250 feet) of nets of 2¾-inch mesh lifted with a whitefish gang in 15 fathoms on September 17, 1917, caught 27 fish of this species. On September 26, 1917, a box of nets in 17 fathoms had 29. On September 24, 1917, a gang set from the can buoy in Thunder Bay to Sulphur Island in 8 to 10 fathoms got 600 pounds three nights out.

Thus all the records indicate that the pilot begin to move inshore in numbers on honeycomb rock and gravel about the middle of October, and that they remain there until the nets are pulled in. Since few gill nets of a mesh suitable for pilot are set in the spring, not much is known about the offshore movement. The depth to which the fish migrate in summer is certainly not over 30 fathoms and probably not over 20. At depths of 10 to 24 fathoms I took specimens off Alpena on September 10, 14, 17, 20, 22, and 26, 1917. Commercial quantities were taken in 1917 at 17 to 20 fathoms the first week of September and in 8 to 10 fathoms on September 24. The inshore movement apparently had already begun on the 24th.

BREEDING HABITS

The inshore movement in fall is for the purpose of spawning. While there are no definite dates available as to when the eggs are deposited, the fishermen say that the run is heaviest during the last two weeks of November, which may indicate that this is the spawning period. The spawning season certainly falls in November, as males taken during the first half of November, 1917, at Kagawong, Gore Bay, Wiarton and Alpena show pearls. They spawn at depths of 4 to 8 fathoms on honeycomb rock and gravel, according to the fishermen. It is interesting to note that the herring spawns at about the same time and at about the same depth; in fact, both fish may be caught in the same nets. The herring are said to spawn on sand and gravel, while the pilot spawns on gravel and honeycomb rock. This leaves gravel as spawning ground common to both. It may be found that the character of the gravel bottom selected by the two species is different and that actually they do not spawn on the same grounds at the same time.

FOOD

An examination of about 50 stomachs collected during October and November, 1917, at Alpena, Mich., and Kagawong, Ontario, shows the main items of food to be Gastropoda, larval and pupal Trichoptera, and larval Ephemeridæ. Adult insects, larval Chironomidæ, Asellus, Cambarus, Bryozoa, plant remains, and sand are included among the articles occasionally ingested.

The pilot is said to eat the spawn of other fish, and probably there is truth in the charge. In fact, almost any fish will eat spawn if it gets a chance, and a fish that feeds habitually on the bottom might be expected to prey heavily on spawn. At least, the fish will eat spawn readily if it is offered them. During the last of October, 1919, pilot were common in 10 feet of water about the docks on the Greater Duck Island. Hooks baited with trout spawn were grabbed instantly. It may be noted in passing that as a game fish the pilot is not to be despised. On one occasion I had an opportunity to determine whether the pilot sought the spawning grounds of other fish. A box (2,250 feet) of 2¾-inch nets was set on October 30, 1917, on the spawning grounds of the trout 7 miles ENE. of the Alpena can buoy in 15 fathoms. When lifted on November 2 these nets had, among other fish, 41 pilot. The number of pilot caught is not great, but there are reasons, perhaps, why the fish were not abundant. First, the trout had not yet left the grounds, and second, the majority of the pilot were already moving onto their own spawning grounds in 3 to 5 fathoms. Of the 41 fish, 21 had nothing in their stomachs, 12 had trout eggs, and 8 had other food. Thus, 29 per cent of the fish taken are known to have been feeding on trout eggs and 19 per cent were feeding on other things. The remaining 52 per cent may or may not have eaten eggs. The nets had been set for about 48 hours, and if these fish had been caught in the earlier half of this period, there would have been ample time to digest the eggs if they had eaten them. All the fish were alive when taken. The results obtained on this occasion are by no means conclusive, and many more data must be obtained before the pilot can be condemned as a spawn eater.

Prosopium quadrilaterale of Lake Superior

The pilot of Superior agrees in its principal characters rather closely with that of Michigan. The principal characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (15) 16–18 (19).[86]
- Superior, (15) 16–18 (20).[87]

Lateral-line scales:
- Michigan, (84) 87–95 (100).
- Superior, (84) 86–93 (98).[88]

L/H:
- Michigan, (4.9) 5.2–5.4 (5.6).
- Superior, (4.6) 4.8–5.1 (5.3).

H/E:
- Michigan, (3.9) 4.3–4.6 (5).
- Superior, (4) 4.2–4.6 (5.1).

Pv/P:
- Michigan, (1.8) 1.9–2.2 (2.3).
- Superior, (1.5) 1.7–1.9 (2.1).

Av/V:
- Michigan, 2.1–2.3 (2.5).
- Superior, (1.9) 2–2.2 (2.5).

It appears that the Superior specimens differ from those of Michigan chiefly in having a proportionally longer head and longer paired fins, especially pectorals.

The color in life is like that of Michigan specimens. Fingerlings are less brilliantly colored than adults. A description of these small fish is given under "Size variations." In spirits the coloration averages about as in Huron specimens.

There are indications of pearl organs on both male and female specimens collected on October 1, 1921, at Rossport, Ontario, and it is likely that in the breeding season both sexes are conspicuously pearled, as is known to be the case in the Huron form.

VARIATIONS

Racial variations.—There are no data on local variations.

Size variations.—The depth increases and the head, eye, and ventrals decrease with age, as in the Lake Huron form. For 17 individuals ranging from 65 to 200 millimeters, the L/H ratio is 4.3–4.9 (5.2). This value for the group of specimens less than 300 millimeters and for that of more than 300 millimeters is (4.6) 4.8–5.1 (5.3),

[86] Figures for Michigan, except those for scales, are based on an examination of 34 specimens ranging in length from 200 to 419 millimeters. Lateral-line scales have been counted for 65 specimens.

[87] Figures for Superior are based on an examination of 63 specimens ranging in length from 236 to 387 millimeters.

[88] One specimen with 74.

indicating but little change in the proportion between head length and total length after maturity. The eye decreases more conspicuously in size with age. In specimens 200 millimeters or less in length the H/E ratio ranges from 3.2 to 4.1; in those less than 300 millimeters, (4) 4.1–4.5 (4.6); in those 300 millimeters or over, (4.3) 4.5–5.1. The differences in the Av/V ratio are distinctive only for the group of individuals less than 200 millimeters and for that of the largest fish. The values are (1.7) 1.8–2.1 (2.2) and (1.9) 2–2.2 (2.5), respectively.

The coloration of small specimens is distinctly different from that of adults. The fingerlings (65 to 77 millimeters long) taken at the mouth of the Devils Track River near the international boundary on July 17, 1922, have the back pale sepia with two rows of irregular black spots 1 to 2 millimeters in diameter lying at intervals of less than a diameter close to the median line. Often two spots join and make an elongated patch. The sides are silvery, with a row of black dots much smaller than those on the back lying halfway between the lateral line and the dorsal. These spots also are irregular in size, shape, and spacing. Those in the area anterior to the caudal edge of the dorsal are largest (about 1 millimeter in diameter) and are arranged in a more or less straight line. In the region caudad to this point the spots become smaller and are scattered. At each end of the lateral line lies a conspicuous blackish patch 2 to 3 millimeters in diameter. On the line, spaced at intervals of 2 to 5 millimeters, are found 7 to 10 other patches of similar size and shape. The belly is white. The iris is silvery, tinged with sepia. The paired fins are yellowish, with the yellow of the anal fainter. The ring of pigment around the free edge of the scales of the back characteristic of the adults is very evident.

The spots seem to disappear first on the back. The pigment apparently diffuses over the surface. The dots on the side above the lateral line linger longest and usually split so as to give the appearance of two or three irregular rows. They increase in size as the fish grows but become proportionally smaller until they finally fade. In the specimens 134 to 200 millimeters in length the dorsal spots are paling. In a few mature fish 260 millimeters long there still remain traces of the lateral spotting.

No individuals ranging in size between 200 and 245 millimeters were seen, and these limits are those between the immature and mature fish. The maximum size reported for the lake is about 5 pounds.

GEOGRAPHICAL DISTRIBUTION

I have collected specimens of pilot from Rossport, Black Bay, and Batchawanna on the Canadian shore, from Stannard Rock reef, the Apostle Islands, and from Grand Marais, Minn. Data for these are given in Table 100. They are also shown platted on the chart of the lake in Figure 3. Pilot are known, from the reports of the fishermen, out of Sault Sainte Marie (Will Muntinga), Grand Marais, Mich. (Charles McDonald), Marquette, Mich. (Will Parker), Ontonagon, Mich. (Earl Couture), Gargantua, Ontario (J. A. McMillan), and Michipicoten Island (L. McArthur), and it is probable that the species is distributed generally along the shores of the lake where bottom conditions are suitable.

SEASONAL MOVEMENTS

As on the other lakes, pilot are not caught often for the market, and knowledge of their habits is derived principally from the experience of those fishermen who take the fish for home consumption. Out of Grand Marais, Marquette, on Stannard Rock reef, and Ontonagon in Michigan, Grand Marais, Minn., and Gargantua and Michipicoten Island, Ontario, the fish may be taken in numbers from about November 1 to freezing. At the two latter localities it is reported that they enter the small creeks as early as October and again in early spring. At Grand Marais, Mich., a few are taken under the ice by means of spears. They are known to remain in some abundance on the beaches at this point until July. On Iroquois Shoal above the Sault, Will Muntinga found a few in 15 feet on June 12, 1922. I found them common on July 12, 1922, in a 2¾-inch gill net set from the shore of the South Twin Island, Wis., at a depth of 24 feet. A few were seined off Grand Marais, Minn., also, on July 17 and 18, 1922, and stray specimens were collected from pound nets in Black Bay on July 20, 1922, and out of Rossport on August 10, 1922. As pilot do not enter a pound readily, the taking of only stragglers is no indication of abundance. A few were taken in a 2¾-inch gill net set at Rossport, Ontario, on October 1, 1921, in 24 feet. Numbers were seen around Les Petits Ecrits on October 4, 1921, and off Porphyry Island on September 19, 1923. At these points they could be taken abundantly with a hand line.

It appears, then, that the pilot at no time moves far from the beaches. It is likely that the shallow water on the shores of Lake Superior does not often become too warm for the fish.

BREEDING HABITS

Little is known of the breeding habits of the species. Will Parker informs me that when he fishes herring from November 10 to December 1 on the grounds between Partridge Island and Toneys Point and Sachs Head he gets pilot on the gravel bottom and herring on the sand. Earl Couture says the fish spawn out of Ontonagon from the last of November into December on gravel near shore. Out of Grand Marais, Minn., the fish spawn during December, according to James Scott, at the mouth of Cascade River and at the mouth of the Devils Track River. The bottom selected is bowlders and gravel along the shore. It is not known that the fish spawn when they run into the creeks around Gargantua and on Michipicoten Island in the fall, but no doubt they do.

Prosopium quadrilaterale of Lake Nipigon

Two specimens collected off the mouth of Blackwater River on July 29, 1922, in 10 to 20 feet of water on gravel bottom are not different in their characters from specimens from the Great Lakes. The individuals taken measure 191 and 318 millimeters. Both are females, the smaller one immature. Gill rakers, 7 + 10 and 9 + 10; lateral-line scales, 89 and 95; L/H, 4.7 and 5; H/E, 4.2 and 4.4; Pv/P, 1.8 and 1.9; Av/V, 2 and 2.2.

Little is known of the distribution or habits of the pilot in the lake. The fishermen never get them in their whitefish nets, it appears, and no nets of smaller mesh are employed. Dymond (1926) says pilot usually are found at depths of less than 40 feet and that they prefer the shallow northern bays and the mouth of rivers.

Prosopium quadrilaterale of Lake Ontario

Only six specimens, ranging in length between 213 and 361 millimeters, have been seen from Lake Ontario, and these do not differ from those of other lakes. The gill rakers in five number 17, in one 18; the lateral-line scales range between 86 and 93; L/H values range between 4.9 and 5.5; H/E, between 4 and 4.8; Pv/P, between 1.7 and 2; and Av/V, between 2.2 and 2.4. The smallest example shows several distinct "parr marks" on the caudal peduncle.

The maximum size reported for the lake is about 4 pounds.

GEOGRAPHICAL DISTRIBUTION

Few pilot are caught for the market, and virtually all of these are taken from ports on the north shore of the lake. At Port Hope and Coburg, Ontario, the species formerly was and still is abundant, according to T. J. McMahon, and at Brighton, Ontario, Harry and W. A. Quick say it is found in commercial numbers. D. M. Wheeler, of Wilson, N. Y., says that pilot were common in the early days off Braddocks Point, a report recently confirmed by H. A. Donovan, of Charlotte, N. Y. At Bronte and Burlington, Ontario, and Wilson, Sodus Point, and Selkirk, N. Y., a few specimens are taken occasionally, so that every fisherman is acquainted with the appearance of the species. A specimen was seen at Port Hope, Ontario, on November 23, 1917; two were collected at Winona, Ontario, on November 23, 1917; two at Brighton, Ontario, on June 6 and 18, 1922; one at Sandy Pond, N. Y., on August 24, 1923; and one was obtained from the collection of the University of Toronto.

SEASONAL MOVEMENTS

On account of the commercial insignificance of the pilot the fishermen know little about its habits. The Quick brothers, of Brighton, say that the fish travel in schools and that these schools are very erratic in their movements, so that netters have difficulty in following them. They are on the beaches during the winter and up to June, according to Messrs. Quick, and thereafter they occur at depths of 6 to 16 fathoms, where they are caught occasionally in the whitefish nets. At Wilson stray individuals are caught at times in the 3-inch herring nets, which are set in spring and fall in 50 to 75 feet.

No data are at hand on the breeding habits of the species.

TABLE 1.—*Localities from which data and specimens were obtained on Lakes Superior and Nipigon. Where ports were visited, the amount of time spent at each and the number of commercial and special lifts examined are given*

Location	Dates	Number of specimens collected									Lifts examined			
		nipigon	zenithicus	reighardi	nigripinnis	kiyi	hoyi	artedi	clupeaformis	quadrilaterale	Special	Whitefish	Herring	Bloaters
LAKE SUPERIOR														
Grand Marais, Mich	Oct. 3-4, 1917		52		25	6		4						
Marquette, Mich	Aug. 2-12, 1921		184		47	15	28	21	16		2	1	1	1
Ontonagon, Mich	Aug. 13-30, 1921		112	5	2		39	12	16		2			
Grand Marais, Minn	Sept. 1-21, 1921		40	2	3		30				1			
Rossport, Ontario	Sept. 24-Oct. 8, 1921		42		23		2	7		17	1		1	
Sault Ste. Marie, Mich	June 8-18, 1922		88		2		1	17	13	1	1	1		
Michipicoten Island, Ontario	June 18-23, 1922		62		22			4			1	1		
Coppermine Point, Ontario	June 24-July 7, 1922		78		28	1		7	3		1	1		
South Twin Island, Wis	July 10-15, 1922		211	2	4	5	199	1	1	31	2			
Duluth, Minn	July 15-16, 1922													
Grand Marais, Minn	July 17-18, 1922		21		1		12	[1] 600		[1] 17				
Port Arthur, Ontario	July 19-21, 1922			3				12	34	5		1		
Rossport, Ontario	Aug. 3-10, 1922			14				31	13	3		2		
Port Arthur, Ontario	Sept. 13-21, 1923		68	111			35	12		1	5			
Rossport, Ontario	Sept. 21-Oct. 2, 1923		26	9			2	7	8	8	3			
Marquette, Mich	Feb, 8, 1921 [2]							15	1					
	Nov. 22-Dec. 5, 1922 [2]		100			52								
	1923 [2]		1		10	1								
	November, 1925 [2]		2			1		5						
Rossport, Ontario	Mar. 10, 1922 [2]			1				62						
Duluth, Minn	July 17, 1922 [2]		500	2	2		2	2						
Port Arthur, Ontario	Nov. 25, 1922 [2]			199				12						
Stannard Rock, Mich	August, 1923 [2]									1				
Port Coldwell, Ontario	Oct. 22, 1923 [2]		1		5									
LAKE NIPIGON														
Macdiarmid, Ontario	July 21-Aug. 3, 1922	14	128	66	143		77	17	31	2	4	3		
	Oct. 26, 1922 [2]	1	5	5	5		17	2						

[1] Fingerlings caught with seine. [2] Additional specimens received from other collectors.

TABLE 2.—*Localities from which data and specimens were obtained on Lake Michigan. Where ports were visited, the amount of time spent at each and the number of commercial lifts examined are given*

Location	Dates	Number of specimens collected										Lifts examined			
		johannæ	alpenæ	zenithicus	reighardi	nigripinnis	kiyi	hoyi	artedi	clupeaformis	quadrilaterale	Chub	Whitefish	Herring	Bloaters
Petoskey, Mich	July 14, 1917									2			1		
Charlevoix, Mich	do												1		
St. Ignace, Mich	July 15-17, 1917									[1] 2	[1] 3				
Grand Haven, Mich	Mar. 19-22, 1919	10	7	3	7	5	12	161				2			
Milwaukee, Wis	Mar. 22-25, 1919			3	2	5		69	9			2		1	
Northport, Mich	June 22-24, 1920	1	18		56	4		70	4	4		1	1		1
Traverse City, Mich	June 24-25, 1920								13	13	3		1	1	
St. James, Mich	June 26-28, 1920									18	3		1		
Charlevoix, Mich	June 28-30, 1920	1	8	2	11	1	6	78				1			
Manistique, Mich	Aug. 10-13, 1920	1	6	1	6	1	1	50	11			1			
Menominee, Mich	Aug. 13-17, 1920							34	20					3	
Washington Harbor, Wis	Aug. 17-20, 1920	11	4		14	2	22	103	52		1	1		2	
Sturgeon Bay, Wis	Aug. 20-24, 1920	5		2	3	1	20	19				1			
Algoma, Wis	Aug. 24, 1920	1	1	2	16		6	24				1			
Manistee, Mich	Aug. 27-28, 1920				4		1	12	2		2			1	
Ludington, Mich	Aug. 28-30, 1920	13			1	4	23	56				1			
Muskegon, Mich	Aug. 31, 1920								1						
Michigan City, Ind	Sept. 2-5, 1920	4	9	11	4	1	4	24	8			1			
Milwaukee, Wis	Sept. 21-24, 1920	2	1	14	2	2	5	45	4			2			
Port Washington, Wis	Sept. 24-27, 1920	3	2	9	6	2	8	56	11	4		1		1	1
Sheboygan, Wis	Sept. 27-Oct. 2, 1920	2	2	12	48		12	120				2			1

[1] Taken near Epoufette, Mich.

TABLE 2.—*Localities from which data and specimens were obtained on Lake Michigan. Where ports were visited, the amount of time spent at each and the number of commercial lifts examined are given*—Continued

Location	Dates	Number of specimens collected										Lifts examined			
		johannæ	alpenæ	zenithicus	reighardi	nigripinnis	kiyi	hoyi	artedi	clupeaformis	quadrilaterale	Chub	Whitefish	Herring	Bloaters
Frankfort, Mich.	Oct. 2-5, 1920	1	5	2	5	1	7	37				1			
Racine, Wis.	Oct. 7-9, 1920														1
Michigan City, Ind.	Oct. 9-12, 1920		3	5	15		2	13				1			
	Nov. 7-9, 1920		4	11	7		1	12				1			
Milwaukee, Wis.	Nov. 12-16, 1920		4	15				12	5	11	2	2			
Oconto, Wis.	Nov. 17, 1920								34					2	
Michigan City, Ind.	Nov. 18-22, 1920		17	19	8			51			3	3			
	Mar. 2-4, 1921			3	11			24	9	4	1	2			1
Traverse City, Mich.	July 17-20, 1923								14	21		([2])			1
Platte Bay, Mich.	July 21-23, 1923		2					8	13		42	([2])			
Traverse City, Mich.	July 24-26, 1923		1		3			3	43	1		([2])			
South Manitou Island, Mich.	July 28-31, 1923		3						1	22	4	([2])	1		
Charlevoix, Mich.	Aug. 10-11, 1923	1	4		35	3	7	1		1		2			
Seul Choix Point, Mich.	Aug. 20, 1920 [3]								7	15					
Michigan City, Ind.	Apr. 1, 1921 [3]			2	47			2							
Port Washington, Wis.	May 26, 1922 [3]	1		2	8	5	1	1							
Northport, Mich.	July 31, 1923 [3]	15	156	5	94	13	36	43	4						
Charlevoix, Mich.	June 15, 1923 [3]		50		10										
	Aug. 21, 1923 [3]		52		3			1							
	May 3, 1924 [3]		4		43										

[2] Specimens also taken by seines and special gill nets. [3] Additional specimens received from other collectors.

TABLE 3.—*Localities from which data and specimens were obtained on Lake Huron. Where ports were visited, the amount of time spent at each and the number of commercial lifts examined are given*

Location	Dates	Number of specimens collected									Lifts examined			
		johannæ	alpenæ	zenithicus	nigripinnis	kiyi	hoyi	artedi	clupeaformis	quadrilaterale	Chub	Whitefish	Herring	Bloaters
St. Ignace, Mich.	July 15-17, 1917							11	1	4		1	1	
Cheboygan, Mich.	July 21-24, 1917	11	12	11	1		16		2	1	1	1		
Rogers, Mich.	July 24, 1917	18	9	5	3				3		1			
Alpena, Mich.	Aug. 11-14, 1917	13	19	2	10		10	11	4		1		1	
	Sept. 1-27, 1917	90	51	55	13	96	306	47	55	12	10	4	5	1
Cheboygan, Mich.	Sept. 27-Oct. 2, 1917	2	3	11			20	7			2			
Blind River, Ontario	Oct. 5-10, 1917									6				
Cheboygan, Mich.	Oct. 11-12, 1917													
Rogers, Mich.	Oct. 13-14, 1917		5	11			31	2			1			
Alpena, Mich.	Oct. 14-21, 1917	5	4	5	12	5					2	1		
East Tawas, Mich.	Oct. 21-22, 1917							27	16			1	1	
Bay City, Mich.	Oct. 22-25, 1917							26	15			1	2	
Port Huron, Mich.	Oct. 25-26, 1917													
Harbor Beach, Mich.	Oct. 26-29, 1917	15	13	3	1		26				1			
Southampton, Ontario	Nov. 3-5, 1917													
Wiarton, Ontario	Nov. 5-6, 1917	4	14	1	2			15	1	6	1	1	1	
Blind River, Ontario	Nov. 7-8, 1917							6						
Cutler, Ontario	Nov. 8-9, 1917													
Kagawong, Ontario	Nov. 9-10, 1917							3	4	3		1		
Gore Bay, Ontario	Nov. 10-13, 1917							2	4	2				
Cutler, Ontario	Nov. 11, 1917							20					1	
Gore Bay, Ontario	Nov. 12, 1917								3					
Cheboygan, Mich.	Nov. 13-14, 1917													
Alpena, Mich.	Nov. 14-16, 1917											1		
Wiarton, Ontario	July 26-29, 1919	6	30		4	1	76	6	6		1		1	
Lions Head, Ontario	July 29-31, 1919	13	28	2	5	2	43				1			
Alpena, Mich.	Aug. 24-Sept. 19, 1919	39	2	5	4	31	102				5	3		2
Cheboygan, Mich.	Sept. 19-22, 1919													
Gore Bay, Ontario	Sept. 23-29, 1919								10			1		
Providence Bay, Ontario	Sept. 29-Oct. 1, 1919								2					
Tobermory, Ontario	Oct. 1-3, 1919							3						
Lions Head, Ontario	Oct. 3-6, 1919	8	6		10	2	52				1			

TABLE 3—*Localities from which data and specimens were obtained on Lake Huron. Where ports were visited, the amount of time spent at each and the number of commercial lifts examined are given.*—Continued

Location	Dates	Number of specimens collected: johannæ	alpenæ	zenithicus	nigripinnis	kiyi	hoyi	artedi	clupeaformis	quadrilaterale	Lifts examined: Chub	Whitefish	Herring	Bloaters
Killarney, Ontario	Oct. 8–15, 1919							41	16	1		2		
Kagawong, Ontario	Oct. 15–16, 1919							1	7	2		1		
Gore Bay, Ontario	Oct. 17, 1919													
Duck Islands, Ontario	Oct. 18–26, 1919							12	7	34		1		
Wiarton, Ontario	Nov. 26–Dec. 4, 1919		14				32	15	2		4			
Alpena, Mich	Aug. 7, 1920										1			
	June 28–July 10, 1923	37	43	16	19	80	32				5	2		
Alpena, Mich	Nov. 2, 1917 [1]							13		41				
	Nov. 15, 1919 [1]							18		40				
Harbor Beach, Mich	Dec. 9, 1917 [1]							11						
	do [1]						25							
	Mar. 15, 1919 [1]		46	30			92	1						
Hammond Bay, Mich	Sept. 28, 1919 [1]								8					
Cheboygan, Mich	Oct. 15, 1919 [1]		42	12			44							
Bay City, Mich	Oct.–Nov., 1921 [1]		1					300						
	November, 1922 [1]							500						
	November, 1924 [1]							250						
	Nov. 25, 1925 [1]		3											
Oscoda, Mich	Nov. 2, 1922 [1]							362						
Wiarton, Ontario	June 10, 1922 [1]	25	25		100									
	June 26, 1923 [1]	25	100		25									

[1] Additional specimens received from other collections.

TABLE 4.—*Localities from which data and specimens were obtained on Lakes Erie and Ontario. Where ports were visited, the amount of time spent at each and the number of commercial and special lifts examined are given*

Location	Dates	Number of specimens collected: reighardi	kiyi	hoyi	artedi	clupeaformis	quadrilaterale	Lifts examined: Special nets	Herring	Whitefish
LAKE ONTARIO										
Port Hope, Ontario	Nov. 21, 1917					4				1
Brighton, Ontario	Nov. 22, 1917				12				1	
Bronte, Ontario	Nov. 23, 1917				16	2			1	
Winona, Ontario	do			1	12	2	2		1	
Brighton, Ontario	June 5–6, 1921						1			1
Cape Vincent, N. Y	June 7, 1921				12	16			1	1
Brighton, Ontario	June 10–11, 1921	18	1	16	4			1		2
	June 16–20, 1921	16		12		3	1	1		1
Wilson, N. Y	June 21–26, 1921	2	18	28				2		
Bronte, Ontario	June 27–30, 1921		7	10	6	2		1		2
Charlotte, N. Y	July 1–6, 1921	1	31	58	1			1		
Selkirk, N. Y	July 7–11, 1921	4	2	10	28	1			1	1
Sodus Point, N. Y	July 12–13, 1921	3	27	74				1	1	
Wilson, N. Y	July 14–21, 1921	10	36	15	39			3		
Sandy Pond, N. Y	Aug. 23–31, 1923	23	1	20	60	8	1	1	1	1
Oswego, N. Y	Sept. 1–5 1923	1	12	13	5			1	1	
LAKE ERIE										
Ashtabula, Ohio	Oct. ϑ–23, 1920				8	2				1
Erie, Pa	Oct. 24–26, 1920				75	4			5	5
Dunkirk, N. Y	Oct. 27–28, 1920				59				4	
Toledo, Ohio	Nov. 27, 1920					3				1
Sandusky, Ohio	Nov. 28–29, 1920				19	5			1	2
Westfield, N. Y	July 21, 1921								1	
Merlin, Ontario	Nov. 22–24, 1924								1	1
Erieau, Ontario	Nov. 24–25, 1924								1	
Ridgetown, Ontario	Nov. 25–26, 1924									1
Port Stanley, Ontario	Nov. 26, 1924									
Monroe, Mich	1920 [1]				12	2				
Port Stanley, Ontario	December, 1922 [1]				62					
Erieau, Ontario	December, 1924 [1]				25					

[1] Other collectors.

TABLE 5.—*Distribution of the species of Coregonidæ in the larger lakes of the Laurentian Basin*

Species	Nipigon	Superior	Michigan	Huron	Erie	Ontario
Leucichthys johannæ	----	----	×	×	----	----
L. alpenæ	----	----	×	×	----	----
L. zenithicus	×	×	×	×	----	----
L. reighardi	×	×	×	----	----	×
L. nigripinnis	×	×	×	×	----	×
L. kiyi	----	×	×	×	----	×
L. hoyi	×	×	×	×	----	×
L. artedi	×	×	×	×	×	×
L. nipigon	×	----	----	----	----	----
Coregonus clupeaformis	×	×	×	×	×	×
Prosopium quadrilaterale	×	×	×	×	----	×

TABLE 6.—*Frequency distribution of the total number of gill rakers on the first branchial arch for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the tops of the columns are classes of gill-raker numbers; entries below these are numbers of individuals in each class; entries in the last column are the number of specimens of each form included in the table]

Species and lake	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Johannæ:																		
Michigan	----	----	----	----	----	----	----	----	----	----	----	1	11	18	20	26	15	14
Huron	----	----	----	----	----	----	----	----	----	----	4	18	42	91	122	82	49	19
Alpenæ:																		
Huron	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	3	15
Zenithicus:																		
Superior	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Huron	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	4
Reighardi:																		
Nipigon	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	8
Superior	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	3
Michigan	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	1	10
Clupeaformis:																		
Nipigon	----	----	----	----	----	----	----	----	----	----	----	1	6	11	11	4	----	----
Superior	----	----	----	----	----	----	----	----	----	----	2	24	34	32	15	2	----	----
Michigan	----	----	----	----	----	----	----	----	----	1	9	44	43	42	11	1	----	----
Huron	----	----	----	----	----	----	----	----	----	1	20	44	55	49	18	4	2	----
Erie	----	----	----	----	----	----	----	----	----	----	3	18	21	36	20	2	----	----
Ontario	----	----	----	----	----	----	----	----	----	----	1	5	13	10	4	2	1	----
Quadrilaterale:																		
Nipigon	----	----	1	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----
Superior	4	12	28	14	4	1	----	----	----	----	----	----	----	----	----	----	----	----
Michigan	4	5	10	6	1	----	----	----	----	----	----	----	----	----	----	----	----	----
Huron	6	22	25	11	3	----	----	----	----	----	----	----	----	----	----	----	----	----
Ontario	----	----	5	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Species and lake	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Johannæ:																	
Michigan	9	6	1	1	----	----	----	----	----	----	----	----	----	----	----	----	----
Huron	9	4	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Alpenæ:																	
Michigan	1	8	15	26	31	47	47	60	54	41	29	14	4	6	----	----	----
Huron	32	38	47	55	40	37	52	34	21	10	2	1	----	----	----	----	----
Zenithicus:																	
Nipigon	2	1	13	19	35	36	38	9	3	4	----	----	----	----	----	----	----
Superior	1	2	10	27	59	72	115	182	171	132	72	27	8	4	----	----	----
Michigan	----	----	2	4	5	20	31	19	17	13	7	4	----	----	----	----	----
Huron	3	9	16	17	28	29	19	23	7	----	1	1	----	----	----	----	----
Reighardi:																	
Nipigon	13	17	35	15	8	1	----	----	----	----	----	----	----	----	----	----	----
Superior	11	31	44	52	43	25	12	6	5	2	----	----	----	----	----	----	----
Michigan	25	46	73	87	63	45	26	14	7	5	3	----	----	----	----	----	----
Ontario	2	8	14	20	13	11	1	4	2	1	----	----	----	----	----	----	----
Nigripinnis:																	
Nipigon	----	----	----	----	----	----	----	----	----	----	----	4	5	9	13	37	37
Superior	----	----	----	1	6	17	18	46	33	15	7	5	2	1	----	1	----
Michigan	----	----	----	----	----	----	----	----	1	1	----	4	4	7	8	9	5
Huron	----	----	----	----	----	----	----	2	1	3	1	14	10	20	29	19	9
Kiyi:																	
Superior	----	----	----	3	8	11	13	23	7	7	3	1	1	----	----	----	----
Michigan	----	2	7	20	41	42	37	32	22	6	1	1	1	----	----	----	----
Huron	----	1	8	24	51	47	30	25	14	7	4	1	----	----	----	----	----
Ontario	----	----	----	----	----	----	----	----	7	10	22	21	27	15	14	4	----

TABLE 6.—*Frequency distribution of the total number of gill rakers on the first branchial arch for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Hoyi:																	
Nipigon	----	----	----	----	----	----	----	6	12	26	19	41	28	23	5	2	----
Superior	----	----	----	----	1	11	15	28	74	63	68	36	24	8	2	----	1
Michigan	----	----	----	----	3	17	31	99	160	218	226	174	107	44	18	3	----
Huron	----	----	----	----	8	33	72	138	202	194	134	63	15	9	2	----	----
Ontario	----	----	----	----	----	----	1	2	8	25	35	48	33	45	36	4	5
Artedi:																	
Nipigon	----	----	----	----	----	----	----	----	1	1	----	2	4	10	14	11	14
Superior	----	----	----	----	----	1	----	----	1	1	7	21	37	37	48	48	23
Michigan	----	----	----	----	----	----	----	----	1	2	7	18	24	46	57	62	49
Huron	----	----	----	----	----	----	----	1	1	4	10	17	38	47	57	42	36
Erie	----	----	----	----	----	----	----	----	2	5	23	32	37	56	58	40	41
Ontario	----	----	----	----	----	----	----	----	3	3	7	11	15	24	28	26	23

Species and lake	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	Total
Johannæ:																		
Michigan	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	122
Huron	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	441
Alpenæ:																		
Michigan	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	383
Huron	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	417
Zenithicus:																		
Nipigon	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	160
Superior	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	883
Michigan	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	122
Huron	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	157
Reighardi:																		
Nipigon	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	97
Superior	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	234
Michigan	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	406
Ontario	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	76
Nigripinnis:																		
Nipigon	49	32	12	11	4	----	----	----	----	----	----	----	----	----	----	----	----	213
Superior	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	152
Michigan	6	5	3	----	----	----	----	----	----	----	----	----	----	----	----	----	----	53
Huron	12	7	2	----	----	----	----	----	----	----	----	----	----	----	----	----	----	129
Kiyi:																		
Superior	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	77
Michigan	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	212
Huron	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	212
Ontario	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	120
Hoyi:																		
Nipigon	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	162
Superior	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	331
Michigan	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1,100
Huron	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	870
Ontario	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	243
Artedi:																		
Nipigon	5	6	2	1	----	----	----	----	----	----	----	----	----	----	----	----	----	71
Superior	13	4	4	3	----	----	----	----	----	----	----	----	----	----	----	----	----	248
Michigan	37	44	22	14	4	4	----	----	----	----	----	----	----	----	----	----	----	391
Huron	31	11	6	1	----	----	----	----	----	----	----	----	----	----	----	----	----	302
Erie	13	3	1	2	----	----	----	----	----	----	----	----	----	----	----	----	----	313
Ontario	24	11	8	7	1	----	----	----	----	----	----	----	----	----	----	----	----	191
Nipigon:																		
Nipigon	----	----	----	----	3	4	10	5	1	7	2	2	2	0	1	1	1	39
Clupeaformis:																		
Nipigon	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	33
Superior	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	109
Michigan	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	151
Huron	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	193
Erie	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	100
Ontario	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	36
Quadrilaterale:																		
Nipigon	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2
Superior	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	63
Michigan	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	26
Huron	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	67
Ontario	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	6

TABLE 7.—*Frequency distribution of the number of scales in the lateral line for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the tops of the columns indicate the classes of scale numbers; entries below these show the number of individuals of each form, by classes; in the last column is given the number of individuals of each form included in the table]

Species and lake	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81
Johannæ:																						
Michigan															1			2	3	2	3	11
Huron								1						4	2	11	6	17	18	9	37	34
Alpenæ:																						
Michigan												2	2	1	9	12	13	14	20	32	33	36
Huron											2	4	5	9	12	16	33	28	29	39	39	40
Zenithicus:																						
Nipigon							1	2	4	8	13	10	16	11	21	16	16	17	7		3	
Superior										5	3	7	13	26	38	58	75	84	100	102	126	95
Michigan											3	2	4	2	4	11	11	11	11	13	17	14
Huron											1	4	10	6	14	17	10	18	13	13	11	11
Reighardi:																						
Nipigon					1	1	7	5	8	7	15	10	12	7	5	2	3	3				
Superior						1	2	9	9	10	15	23	25	29	29	17	20	18	6	7	7	5
Michigan							1	1	3	9	10	13	25	29	32	33	38	37	34	27	29	24
Ontario							1					4	3	3	9	10	10	1	11	2	6	3
Nigripinnis:																						
Nipigon							2	1	1	8	16	19	21	17	26	21	17	14	10	3	6	1
Superior														1		2	4	4	8	10	15	15
Michigan															1		3	1	1	2	9	8
Huron													3	3	2	6	6	11	16	12	13	8
Kiyi:																						
Superior													1	2	2	4	8	7	11	8	12	6
Michigan												1	1	2	3		5	8	10	16	19	12
Huron											2	3	5	6	8	14	20	17	19	19	35	18
Ontario												1		1	4	1	7	15	9	13	14	14
Hoyi:																						
Nipigon							1		1	3	5	8	7	9	20	13	17	13	13	12	13	7
Superior						1	5	14	14	22	26	22	32	38	28	34	36	17	20	7	10	3
Michigan	1		2	6	5	17	21	48	41	88	107	97	142	134	116	94	82	52	36	16	13	11
Huron				1	1	11	16	18	47	53	84	64	95	80	94	85	48	33	26	21	5	10
Ontario				1	1	3	4	11	15	15	23	26	34	24	29	26	16	5	8	5	1	1
Artedi:																						
Nipigon						1			3	4	5	9	7	6	10	6	8	3	4	3	2	1
Superior													1	1	3	3	4	5	3	8	8	7
Michigan									1			1	1	3	2	6	13	15	15	19	24	40
Huron									1	1	1	3	4	3	9	7	13	16	11	20	23	23
Erie					1		2	3	6	17	22	35	48	64	80	76	97	74	66	47	35	31
Ontario							1		3	1	11	8	6	17	26	25	23	31	19	15	26	17
Nipigon: Nipigon									1	1		2	4	2	6	7	2	8	0	1	1	3
Clupeaformis:																						
Nipigon																	1	2	3	3	1	3
Superior																		3	4	7	8	6
Michigan															1	1	1	3	2	7	7	17
Huron														2	1	1	1	4	6	10	13	13
Erie														2	3	8	6	18	19	24	42	44
Ontario																1	3	1	6	9	13	13
Quadrilaterale:																						
Superior															1							
Huron																					1	

Species and lake	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	105	Total
Johannæ:																					
Michigan	3	7	8	8	5	4	6	4	4	1	1			1							74
Huron	27	16	12	20	16	12	7	6	2	1											258
Alpenæ:																					
Michigan	37	35	26	21	13	11	8	1	1	0	1				1						329
Huron	17	27	11	1	5	3			2	1											323
Zenithicus:																					
Nipigon	1	1																			147
Superior	78	48	44	24	13	7	7	1	2												956
Michigan	7	9	6	5	4	4	1			1											140
Huron	6	3	4		1	1	1														144
Reighardi:																					
Nipigon																					86
Superior		1																			233
Michigan	9	13	10	4	5	5	1		2						1						395
Ontario	2	2		1	1																69
Nigripinnis:																					
Nipigon																					183
Superior	15	20	13	19	14	6	6	5	2	3											162
Michigan	2	3	5	4	6	3	1	2													51
Huron	8	11	2	6	1	2	1														111

TABLE 7.—*Frequency distribution of the number of scales in the lateral line for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	105	Total
Kiyi:																					
Superior	2	3	6	3	2	1															78
Michigan	21	21	14	12	8	8	4	2	3	1											171
Huron	12	14	4	5	3	1	1	1													207
Ontario	11	15	6	5	6	6	2	1		1											132
Hoyi:																					
Nipigon	2	1		1																	146
Superior	2	1	1																		333
Michigan	3	1	1																		1, 134
Huron	2	1	1																		796
Ontario	1																				249
Artedi:																					
Nipigon																					72
Superior	8	8	18	12	17	20	19	14	18	17	16	15	7	5	6	6	1	1	1	1	253
Michigan	37	38	29	40	24	20	13	14	5	4	2	4	1								371
Huron	31	29	34	17	14	13	9	10	9	3		1	1	1			1				308
Erie	14	12	9	7	2		1	1													750
Ontario	15	9	4	5	2		1	1													266
Nipigon: Nipigon	2																				40
Clupeaformis:																					
Nipigon	3	4	2	5	1	3	1	2													34
Superior	15	14	14	9	12	2	5	3	2	2	0	0	1								107
Michigan	12	17	16	23	29	18	14	9	5	5	2	2									191
Huron	18	14	21	26	18	13	9	8	13	4											195
Erie	38	30	25	16	15	13	6	5	6	3		1									324
Ontario	23	21	34	17	16	11	14	5	6	3	2										198
Quadrilaterale:																					
Nipigon								1						1							2
Superior			1	1	7	12	3	9	8	7	5	6	1	4	1	2	1				69
Michigan			1	1		4	6	8	5	4	10	6	3	6	4	2	2	2	1		65
Huron	2	1	5	8	2	8	10	12	6	4	1	1		3							64
Ontario					1	1		1			1	2									6

TABLE 8.—*Frequency distribution of the ratio between the length of the body and the length of the head (L/H) for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the top of the columns indicate the classes of ratios; entries beneath these are the numbers of each form, by classes; numbers in the last column give, for each group, the total numbers of specimens included in the table. The various species in each lake often are divided into two size groups. The numbers expressing millimeters, given after the name of the lake, indicate, when preceded by a plus (+) sign, the lower length limit of specimens of the group; when preceded by a minus (−) sign, the upper length limit]

Species and lake	Length, in millimeters	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5
Johannæ:													
Michigan	+200					5	7	17	23	12	8	1	
Huron	+200	1	1	5	11	30	54	65	31	10	1		
	−200			1	17	32	31	15	1	1			
Alpenæ:													
Michigan	+210					3	3	12	61	63	87	45	15
	−210						1	5	4	3	1		
Huron	+210			1	1	7	16	27	43	40	21	8	
	−210	1		3	10	44	69	46	24	3			
Zenithicus:													
Nipigon	+200		2	3	19	36	42	30	8	2			
	−200			1		7	3	2	1				
Superior	+200			3	32	111	178	221	157	31	11	1	
	−200		4	9	26	36	41	40	13	4			
Michigan	+200						6	17	24	36	22	6	3
	−200							6	3	1			
Huron	+200						9	10	23	18	16	8	1
	−200				1	6	4	22	25	14	4	1	
Reighardi:													
Nipigon	+200		3	5	24	20	16	10	1				
	−200			3	3	6	1						
Superior	+200				1	19	50	88	45	22	5	2	
Michigan	+200						1	8	36	73	74	56	32
	−200							6	15	22	32	19	7
Ontario	+200							1		1	7	6	25
Nigripinnis:													
Nipigon	+200			1	5	30	41	60	56	21	3	2	
	−200			2			1						
Superior	+200				1	4	23	42	53	21	13	3	
Michigan	+200					1		3	10	10	12	10	3
Huron	+200				2	3	12	35	34	27	11	6	

TABLE 8.—*Frequency distribution of the ratio between the length of the body and the length of the head (L/H) for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	Length, in millimeters	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5
Kiyi:													
Superior	−200		3	8	27	15	13	10	1				
Michigan	+200				4	18	31	34	28	7	3		
	−200					8	12	17	6	1			
Huron	+200					7	9	4					
	−200		13	35	55	50	24	9	4				
Ontario [1]						2	5	11	44	43	19	7	
Hoyi:													
Nipigon [2]				10	15	35	37	50	23	4			
Superior [2]		1	2	16	52	76	88	59	28	6	3		
Michigan	+200						3	13	32	43	26	16	5
	−200			4	33	53	135	269	212	197	73	25	9
Huron	−200		1	10	59	105	155	264	164	68	38	6	3
Ontario [1]					1	4	15	56	69	61	29	14	4
Artedi:													
Nipigon	+225					1		3	3	3	2	1	
	−225						1	5	11	19	19	6	6
Superior	+225								6	8	21	35	53
	−225							2	3	11	12	12	15
Michigan	+225								1	13	25	35	32
	−225							5	14	30	36	32	21
Huron	+225						1	8	13	19	24	36	49
	−225							4	10	24	34	28	22
Erie	+225								1	4	15	20	35
	−225						1	5	10	30	40	26	8
Ontario	+225				1			0	3	18	29	37	44
	−225						3	1	5	7	11	15	5
Nipigon:													
Nipigon	+200					2	11	14	10	3	1	0	1
Clupeaformis: [1]													
Nipigon									1		9	10	7
Superior												4	14
Michigan										2	5	14	18
Huron								1		1	1	2	17
Ontario												2	4
Quadrilaterale:													
Nipigon	+200												
Superior	+200												
	−200										2	3	2
Michigan	+200												
	−200												
Huron	+200												1
Ontario	+200												1

Species and lake	4.6	4.7	4.8	4.9	5	5.1	5.2	5.3	5.4	5.5	5.6	Total
Johannæ:												
Michigan												73
Huron												209
												98
Alpenæ:												
Michigan	1											290
												14
Huron												164
												200
Zenithicus:												
Nipigon												141
												14
Superior												745
												173
Michigan												114
												10
Huron												85
												77
Reighardi:												
Nipigon												79
												13
Superior												232
Michigan	17	3	1									301
	1											102
Ontario	18	14	3		1							75

[1] Mostly specimens over 200 millimeters long.

[2] Mostly specimens under 200 millimeters long.

TABLE 8.—*Frequency distribution of the ratio between the length of the body and the length of the head (L/H) for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	4.6	4.7	4.8	4.9	5	5.1	5.2	5.3	5.4	5.5	5.6	Total
Nigripinnis:												
Nipigon												219
												3
Superior												160
Michigan	1	1										51
Huron												130
Kiyi:												
Superior												77
Michigan												125
												44
Huron												20
												190
Ontario [1]												131
Hoyi:												
Nipigon [2]												174
Superior [2]												331
Michigan	1											139
												1,010
Huron												873
Ontario [1]	1											254
Artedi:												
Nipigon												13
	1											68
Superior	37	11	5	1	2	2						181
	14	1	1									71
Michigan	15	10	5		2							138
	8											146
Huron	34	14	6	2	1							207
	9	1	1									133
Erie	31	26	13	4	5		1					155
	3	2										125
Ontario	31	28	5	1	1							198
	2											50
Nipigon:												
Nipigon												42
Clupeaformis:[1]												
Nipigon	4	2	1									34
Superior	27	28	21	11	4							109
Michigan	22	18	27	8	4	2	3	1				124
Huron	28	55	46	21	19	1						192
Erie		5	5	2	5			1				18
Ontario	6	6	8	8	3	1	1					39
Quadrilaterale:												
Nipigon		1			1							2
Superior	1	1	11	14	15	14	3	3				62
	3		2	3	1		1					17
Michigan				1	4	5	5	7	7	4	1	34
		2	4	3	20	8	2					39
Huron	4	7	11	8	16	14	7	4				72
Ontario				1	1		2			1		6

[1] Mostly specimens over 200 millimeters long. [2] Mostly specimens under 200 millimeters long.

TABLE 9.—*Frequency distribution of the ratio between the length of the head and the diameter of the eye (H/E) for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the top of the columns indicate the classes of ratios; entries beneath these are the numbers of each form, by classes; numbers in the last column give, for each group, the total numbers of specimens included in the table. The various species in each lake often are divided into two size groups. The numbers expressing millimeters, given after the name of the lake, indicate, when preceded by a plus (+) sign, the lower length limit of specimens of the group; when preceded by a minus (−) sign, the upper length limit]

Species and lake	Length, in millimeters	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3
Johannæ:														
Michigan	+200										1	5	4	9
Huron	+200									1	2	9	15	20
	−200						1	1	2	6	15	23	23	13
Alpenæ:														
Michigan	+210								1	1	5	8	37	40
	−210							1	2	0	2	3	4	3
Huron	+210										4	2	7	5
	−210						5	8	30	41	55	33	19	11

TABLE 9.—*Frequency distribution of the ratio between the length of the head and the diameter of the eye (H/E) for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	Length, in millimeters	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3
Zenithicus:														
Nipigon	+200						1			7	16	30	32	19
	−200						1		1		1	5	1	
Superior	+200									6	22	35	88	112
	−200						10	16	31	48	40	17	7	2
Michigan	+200										3	4	21	33
	−200								1		3	2	4	
Huron	+200									2	4	4	15	16
	−200					3	6	13	5	9	17	8	7	1
Reighardi:														
Nipigon	+200						1	1	5	6	17	8	7	7
	−200							5	4	6				
Superior	+200						1	4	9	35	68	49	43	16
Michigan	+200						1	4	19	49	93	50	51	22
	−200					2	19	25	25	11	15	3	1	1
Ontario	+200										9	8	20	14
Nigripinnis:														
Nipigon	+200					1	19	32	48	44	39	32	6	5
	−200		1	1	1				1					
Superior	+200										1	2	18	32
Michigan	+200										5	8	13	13
Huron	+200						1	1	4	16	41	33	17	11
Kiyi:														
Superior	−200				2	13	17	22	14	7	2	1		
Michigan	+200						2	1	14	14	51	19	17	8
	−200						1	3	16	14	7	3		
Huron	+200							2	2	4	5	2	2	3
	−200			1	8	22	43	48	37	19	10			
Ontario	(1)						1	3	5	15	46	34	18	9
Hoyi:														
Nipigon	(2)	1	1	1	2	18	29	36	46	25	12	1	2	
Superior	(2)		1	1	13	39	61	108	49	30	24	3	2	1
Michigan	+200								7	22	57	24	16	8
	−200			1	4	22	81	188	297	199	152	39	9	
Huron	(2)			5	24	94	187	224	188	85	50	6	2	
Ontario	(1)							3	3	7	27	35	58	60
Artedi:														
Nipigon	+225							1		4	7	1		
	−225					1	6	19	16	10	14	3		
Superior	+225						1		4	3	15	22	28	27
	−225				1	2	3	4	2	5	14	15	19	7
Michigan	+225						1	1	2	13	37	33	26	11
	−225					3	7	17	28	30	36	13	8	1
Huron	+225				1			17	17	21	46	37	21	22
	−225						2	17	24	25	29	15	10	7
Erie	+225								1		8	16	24	22
	−225							2	9	24	42	26	12	7
Ontario	+225									5	16	18	39	30
	−225								3	4	8	12	12	5
Nipigon: Nipigon	+200								1		1	1	7	2
Clupeaformis: [1]														
Nipigon										4	5	2	6	5
Superior									1		1	4	10	19
Michigan									3	5	15	9	7	14
Huron									1		7	11	15	15
Erie														2
Ontario												1	4	2
Quadrilaterale:														
Nipigon	+200												1	
Superior	+200										2	6	14	6
	−200		1	4	3	4	0	1	1	1	1	1		
Michigan	+200									7		1	1	3
	−200					2	4	11	10	8	3			
Huron	+200										10	8	12	6
Ontario	+200										1			1

[1] Mostly specimens over 200 millimeters long. [2] Mostly specimens under 200 millimeters long.

TABLE 9.—*Frequency distribution of the ratio between the length of the head and the diameter of the eye (H/E) for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	4.4	4.5	4.6	4.7	4.8	4.9	5	5.1	5.2	5.3	5.4	Total
Johannæ:												
Michigan	16	20	6	9	2	1						73
Huron	37	45	17	16	17	8	7	2	1	1		208
	5	2										98
Alpenæ:												
Michigan	53	66	33	23	8	5	3	2	2			271
												15
Huron	7	21	24	40	18	16	14		1			159
	2											204
Zenithicus:												
Nipigon	21	7	2									135
												9
Superior	149	147	110	52	23	10	2	2				758
	1	1										173
Michigan	25	16	7	1			1					111
												10
Huron	19	9	7	6				1	1			84
												69
Reighardi:												
Nipigon	12	3	1		1							69
												15
Superior	4	1	1				1					232
Michigan	7	3	2									301
												102
Ontario	12	5	4	1	1	1	1					76
Nigripinnis:												
Nipigon												226
												4
Superior	36	24	18	18	7		3		1			162
Michigan	7	2	3									51
Huron	2	2	2									130
Kiyi:												
Superior												78
Michigan												126
												44
Huron												18
												188
Ontario	1											132
Hoyi:												
Nipigon												174
Superior												332
Michigan	3	1										138
												992
Huron												865
Ontario	29	22	9	2								255
Artedi:												
Nipigon												13
												69
Superior	36	15	11	7	2	4		2				177
	4	1										77
Michigan	3	4	4	1								136
												143
Huron	9	2	2	3				1				198
												129
Erie	21	25	13	14	7	3						154
	1											124
Ontario	30	19	13	5	3	1						179
	2											46
Nipigon: Nipigon	6	3	7	3	5	3	2		1			42
Clupeaformis: [1]												
Nipigon	2	4		3	3							34
Superior	26	20	14	9	4		1					109
Michigan	13	11	8	10	13	10	6					124
Huron	17	27	19	20	15	12	21	5	4	5		194
Erie		1	3		3	4	3	1	1			18
Ontario	5	5	3	4	3	2	6	3		1		39
Quadrilaterale:												
Nipigon	1											2
Superior	8	10	8	3		2	2	2				63
												17
Michigan	3	8	3	1		1	2					30
												38
Huron	6	7	6	6	3	3						67
Ontario		1	2		1							6

TABLE 10.—*Frequency distribution of the ratio between the length of the pectoral and the pectoral-ventral distance (PV/P) for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the top of the column indicate the classes of ratios; entries beneath these are the numbers of each form, by classes; numbers in the last column give, for each group, the total numbers of specimens included in the table. The various species in each lake often are divided into two size groups. The numbers expressing millimeters, given after the name of the lake, indicate, when preceded by a plus (+) sign, the lower length limit of specimens of the group; when preceded by a minus (−) sign, the upper length limit]

Species and lake	Length, in millimeters	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	Total
Johannæ:																					
Michigan	+200					10	13	16	23	6	4	2									74
Huron	+200			3	9	32	53	60	27	15	5	1									205
	−200		1	2	10	34	22	12	2	2	3										88
Alpenæ:																					
Michigan	+210						2	6	19	43	68	66	43	24	2	2					275
	−210						1	1		7	1	3	1								14
Huron	+210						2	14	30	38	37	25	7	1							154
	−210						4	23	40	42	48	22	4	1	1						185
Zenithicus:																					
Nipigon	+200					11	29	26	33	21	8	2									130
	−200					1	5	7													13
Superior	+200			1	1	26	94	178	220	123	80	20	5	2	1						751
	−200				1	7	12	20	34	33	36	14	8	4	1						170
Michigan	+200							3	8	11	28	28	24	6	3		1				112
	−200									2	5	1									8
Huron	+200						2	2	10	18	27	16	5	2							82
	−200							2	8	9	18	15	13	5	1	1	1				73
Reighardi:																					
Nipigon	+200				7	2	20	21	11	6	1										68
	−200					3	7	2	4												16
Superior	+200					4	8	26	49	57	56	22	7	2	2						233
Michigan	+200							2	4	4	38	64	61	58	34	18	11	2	1		297
	−200					1			3	4	16	19	14	19	8	2	2	1			89
Ontario	+200							1		1	2	3	14	12	14	10	7	2	1	2	69
Nigripinnis:																					
Nipigon	+200		2	17	34	67	47	13		1											181
	−200				1	2															3
Superior	+200				1	17	41	47	36	11	6	2	1								162
Michigan	+200					3	18	11	8	4	4		1								49
Huron	+200		2	6	24	35	31	19	6	2											125
Kiyi:																					
Superior	−200	1	10	15	24	20	6	2													78
Michigan	+200	1		5	10	31	29	28	10	7	5	1									126
	−200			1	9	13	13	5													41
Huron	+200	1		1	3	8	4	3													20
	−200		3	14	35	59	39	19	6	3											178
Ontario [1]						1	3	18	32	26	26	10	4								120
Hoyi:																					
Nipigon [2]			1	8	27	42	52	34	2	2											168
Superior [2]					23	55	74	85	53	27	10	1	1								329
Michigan	+200						6	8	23	34	34	16	7	6							134
	−200			1	3	15	76	153	236	194	146	51	19	6	1	3					904
Huron [2]					6	25	84	174	218	136	121	45	6								815
Ontario [1]					5	11	26	48	63	37	36	17	3								246
Artedi:																					
Nipigon	+225						2	7	4												13
	−225					3	13	23	18	5	4										66
Superior	+225							4	6	18	38	43	39	19	6	4	3		1		181
	−225						2	5	11	6	19	9	15	4							71
Michigan	+225						1	2	5	24	35	24	24	14	4	5	1				139
	−225						3	5	20	23	57	21	10	1		1					141
Huron	+225					1	9	12	13	20	47	43	31	17	2	5	2				202
	−225							4	13	23	40	29	12	6							127
Erie	+225						2	12	21	26	37	25	17	8	6	3					157
	−225						8	17	37	30	25	4	1								122
Ontario	+225							4	21	32	60	38	19	12	3	1					190
	−225						3	3	13	15	12	3	1								50
Nipigon:																					
Nipigon	+200				1	10	9	15	7	1											43
Clupeaformis: [1]																					
Nipigon						4	13	7	6	3	1										34
Superior					3	7	22	21	23	13	9	6	3	2							109
Michigan						3	13	23	20	26	23	7	5	1							121
Huron						2	11	26	43	43	35	15	1								176
Erie							1	3	4	9	1										18
Ontario					1	2	1	5	9	11	6	3	1								39
Quadrilaterale:																					
Nipigon	+200								1	1											2
Superior	+200					3	3	16	21	9	8	2									62
	−200								5	4	3	1									13
Michigan	+200								1	4	7	10	3	1							26
	−200								6	17	15	4									42
Huron	+200					1	2	7	19	13	22	3	1	1							69
Ontario	+200							1	2	2	1										6

[1] Mostly specimens over 200 millimeters long.
[2] Mostly specimens under 200 millimeters long.

TABLE 11.—*Frequency distribution of the ratio between the length of the ventral and the ventral-anal distance (AV/V) for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the top of the columns indicate the classes of ratios; entries beneath these are the numbers of each form, by classes; numbers in the last column give, for each group, the total number of specimens included in the table. The various species in each lake often are divided into two size groups. The numbers expressing millimeters, given after the name of the lake, indicates when preceded by a plus (+) sign, the lower length limit of specimens of the group; when preceded by a minus (−) sign, the upper length limit]

Species and lake	Length, in millimeters	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	Total
Johannæ:																				
Michigan	+200				2	12	13	25	15	5										72
Huron	+200			1	7	35	58	42	13	6										162
	−200	1		1	3	24	17	7	2	1										56
Alpenæ:																				
Michigan	+210					3	12	38	70	73	56	18	4							274
	−210							3	4	4	2									13
Huron	+210						8	32	31	28	32	9	3							143
	−210				2	7	34	63	35	6	2									149
Zenithicus:																				
Nipigon	+200				1	8	31	39	32	13	5									129
	−200					1	5	6	2											14
Superior	+200			1		18	106	234	253	95	16	1	1							725
	−200			3	12	16	32	33	16	2	1									115
Michigan	+200					2	9	30	27	33	11	3		1						116
	−200					1	4	1	3	1										10
Huron	+200					2	5	8	26	18	6	1								66
	−200				1	3	18	24	12	13	2									73
Reighardi:																				
Nipigon	+200				1	1	12	22	19	12	1									68
	−200						2	9	5											16
Superior	+200					2	11	42	67	63	40	7	1							233
Michigan	+200					5	20	47	99	85	30	10	1							297
	−200					3	12	25	32	16	4	1								93
Ontario	+200						1	6	16	29	16	2	2	2	1					75
Nigripinnis:																				
Nipigon	+200				2	24	43	67	20	10	3									169
	−200				1	1	1													3
Superior	+200				1	19	40	37	34	7	2									140
Michigan	+200					9	11	15	10	4										49
Huron	+200			2	13	33	40	12	8	1										109
Kiyi:																				
Superior	−200		1	23	34	15	5	1												79
Michigan	+200		1	16	51	33	23	3												127
	−200			9	23	8	3													43
Huron	+200			1	7	1	3													12
	−200		2	38	86	56	8	2												102
Ontario [1]				1	8	32	37	31	8	1										118
Hoyi:																				
Nipigon [2]				12	36	65	31	4	1											149
Superior [2]			1	24	84	101	84	31	4	1										330
Michigan	+200				1	14	38	47	21	11	1									133
	−200			4	70	267	354	234	54	9										992
Huron [2]				5	75	247	256	193	64	10	1									851
Ontario [1]					8	29	40	62	72	16										227
Artedi:																				
Nipigon	+225							5	4	3	1									13
	−225						2	8	22	27	6									65
Superior	+225						1	0	15	43	53	38	17	8	2		1			178
	−225							3	10	22	14	10	5							64
Michigan	+225							1	13	18	48	31	13	8		2	1			135
	−225						2	7	27	50	37	11	5	1						140
Huron	+225				1	1	7	9	16	31	60	51	11	6	1					194
	−225						1	2	17	41	38	21	7							127
Erie	+225							6	28	35	33	16	16	8	2					144
	−225						7	32	40	28	2	3								112
Ontario	+225						2	8	44	51	42	33	9	5						194
	−225					1	2	12	19	8	6									48
Nipigon:																				
Nipigon	+200						2	12	17	7	3									41
Clupeaformis: [1]																				
Nipigon						1	1	2	13	12	5									34
Superior							1	3	24	36	28	15	2							109
Michigan							2	4	32	40	22	16	8	2						126
Huron								3	25	60	54	33	12	1						188
Erie								1	2	10	3	1								17
Ontario							1	3	4	14	9	7	1							39
Quadrilaterale:																				
Nipigon	+200													1		1				2
Superior	+200												4	19	14	17	5	1	2	62
	−200										1	3	1	6	4	1				16
Michigan	+200														6	7	12	2	1	28
	−200														13	12	3			28
Huron [1]												2	3	10	16	21	10	4		66
Ontario	+200															2	1	1		4

[1] Mostly specimens over 200 millimeters long.

[2] Mostly specimens under 200 millimeters long.

TABLE 12.—*Temperature readings of the waters of Lakes Nipigon, Michigan, and Huron*

Record No.	Location	Date	Time	Depth, in fathoms	Temperature, ° C.
	NIPIGON				
1	2½ miles south of Livingston Point	July 28, 1922	10 a. m.	(1)	16.2
2	do	do		5	14.9
3	do	do		10	10
4	do	do		12	7.8
5	do	do		15	5.9
6	do	do		20	5.2
7	do	do		25	4.9
8	do	do		40	4.4
9	do	do		[2] 56	4
10	Off Blackwater River	do	5 p. m.	(1)	19.5
	MICHIGAN				
11	Green Bay, 8 miles south of Green Island	Aug. 14, 1920		(1)	19
12	do	do		[2] 16	10.9
13	Green Bay, 4 miles west of Boyer Bluff	Aug. 18, 1920		(1)	18.9
14	do	do		[2] 24	6.3
15	10 miles E. by N. of Algoma, Wis	Aug. 24, 1920		31	5.1
16	do	do		49	4.2
17	20 miles N. by W. ¾ W. of Michigan City, Ind	Oct. 11, 1920		(1)	16.8
18	do	do		40	4.2
	HURON				
19	30 miles east of Alpena	Sept. 12, 1917		[2] 65	4
20	11½ miles SE. by S. from Alpena can buoy	Sept. 17, 1917		(1)	14
21	do	do		[2] 15	10.3
22	14 miles N. by E. of Thunder Bay Island	Sept. 18, 1919		[2] 60	4
23	16 miles northeast of Cheboygan	Sept. 29, 1917		(1)	11.8
24	22 miles SE. by E. ½ E. from the can buoy, Alpena	Sept. 13, 1919		(1)	15.6
25	do	do		[2] 35	5.4
26	6 miles NNE. of Thunder Bay	Nov. 16, 1917		(1)	5.6
27	do	do		[2] 8	5.6

[1] Surface. [2] Bottom.

TABLE 13.—*Temperature readings of the waters of Lake Superior*

Record No.	Location	Date	Time	Depth, fathoms	Temperature, ° C.
1	7 miles WNW. of Point Iroquois Light	June 14, 1922	4 p. m.	(1)	7.7
2	do	do		[2] 25	4
3	6 miles northeast off east end light of Michipicoten Island	June 19, 1922	9 a. m.	(1)	3
4	do	do		20	3.6
5	do	do	2 p. m.	(1)	4
6	Below Leach Island	June 23, 1922		(1)	3.5
7	12 miles off Coppermine Point	June 26, 1922	8.30 a. m.	(1)	6.4
8	12 miles off Alona Bay	do	12 m.	(1)	3.8
9	Black Bay, off Demers Point	July 20, 1922	2 p. m.	(1)	14.4
10	do	do		[2] 8	12.9
11	South of Thunder Cape Light	do	4.30 p. m.	(1)	8.5
12	Off Crow Point	Aug. 5, 1922	10 a. m.	(1)	12.4
13	do	Aug. 10, 1922	9 a. m.	(1)	12.1
14	Simpson Channel	Aug. 5, 1922	10.30 a. m.	(1)	16.3
15	do	do	4.45 p. m.	5	6.6
16	do	do		10	5
17	do	Aug. 10, 1922	10.30 a. m.	(1)	15.8
18	Morn Point	Aug. 5, 1922	4.15 p. m.	(1)	15.4
19	do	Aug. 10, 1922	5.30 p. m.	(1)	14.2
20	Armour Harbor	Aug. 5, 1922	1.15 p. m.	(1)	15
21	do	Aug. 10, 1922	2.30 p. m.	(1)	14.6
22	do	do		[2] 4	9.8
23	Moffat Strait	Aug. 5, 1922	11.15 a. m.	(1)	16.3
24	do	Aug. 10, 1922	12.30 p. m.	(1)	15.2
25	do	do		[2] 4	9.7
26	21 miles west of Ontonagon, Mich	Aug. 24, 1921		(1)	18.1
27	do	do		54	4
28	6 miles NNW. of Ontonagon, Mich	Aug. 25, 1921		34	5

[1] Surface. [2] Bottom.

TABLE 14.—*Total weight of chubs taken by each of five tugs on Lake Huron, the number of lifts of the gill nets, and the average weight of each lift, for each month of the fishing season*

Locality and date	Total weight	Number of lifts	Average weight per lift	Locality and date	Total weight	Number of lifts	Average weight per lift
Cheboygan, Mich., 1915:	*Pounds*		*Pounds*	Duck Islands, Ontario, 1915:	*Pounds*		*Pounds*
May	8,510	6	1,418	May	4,470	3	1,490
June	21,980	13	1,690	June	22,920	12	1,910
July	26,258	24	1,094	July	36,610	18	2,034
August	29,010	22	1,318	August	13,553	8	1,694
September	64,655	24	2,693	Southampton, Ontario, 1917:			
October [1]	31,200	14	2,228	May	4,620	2	2,310
Alpena, Mich., 1915:				June	12,565	7	1,795
April	41,325	23	1,796	July	9,075	7	1,296
May	33,755	23	1,467	August	9,475	9	1,052
June	43,305	18	2,405	September	5,910	7	844
July	45,225	22	2,055	Harbor Beach, Mich., 1916:			
August	46,275	19	2,435	June	4,870	2	2,435
September	29,790	24	1,241	July	21,263	10	2,126
October	18,485	15	1,232	August	30,910	13	2,377
November	32,930	15	2,195	September	18,405	9	2,045
December	8,780	4	2,195	October	27,740	14	1,981

[1] Nothing after Oct. 20.

TABLE 15.—*Total weight of chubs taken by each of three tugs on Lake Michigan, the number of lifts of the gill nets, and the average weight of each lift, for each month of the fishing season*

Locality and date	Total weight	Number of lifts	Average weight per lift	Locality and date	Total weight	Number of lifts	Average weight per lift
Charlevoix, Mich., 1914:	*Pounds*		*Pounds*	Northport, Mich., 1916—Con.	*Pounds*		*Pounds*
May	6,023	14	430	October	8,435	18	468
June	10,753	18	597	November	29,532	20	1,476
July	12,657	22	575	December	14,190	13	1,091
August	14,846	22	674	Michigan City, Ind., 1917:			
September	13,293	23	577	March	4,600	5	920
October	14,428	19	758	April	14,200	11	1,290
November	5,496	11	499	May	18,000	13	1,380
December	5,578	11	507	June	19,550	22	860
Northport, Mich., 1916:				July	40,200	23	1,740
April	5,520	10	552	August	64,700	27	2,390
May	11,799	23	513	September	40,400	21	1,920
June	2,620	8	327	October	59,200	17	3,480
September	9,842	20	492	November	63,400	21	3,010

TABLE 16.—*Records of the occurrence of Leucichthys johannæ in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of johannæ	Preserved specimens examined: +200	Preserved specimens examined: −200
Washington Harbor, Wis.	1	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅝	71–90	Clay, mud	900	30	11	------
Sturgeon Bay, Wis.	2	Aug. 23, 1920	12 miles E. by S. of ship channel mouth.	2⅝, 2¾	60–70	Mud	50	22	4	1
Algoma, Wis.	3	Aug. 24, 1920	10 miles E. by N.	2½	35–50	Gravel, mud.	310	(1)	1	------
Sheboygan, Wis.	4	Oct. 1, 1920	11 miles southeast	2½	60	Clay	200	(2)	2	------
Port Washington, Wis.	5	Sept. 25, 1920	18 miles E. ½ S.	2½	65–48	do	285	(1)	3	------
	6	May 26, 1922	24 miles E. by N.	3½	60–80	Mud	--------	(2)	1	------
Milwaukee, Wis.	7	Sept. 23, 1920	27 miles ESE	2½	60	Red clay	250	(1)	2	------
Michigan City, Ind.	8	Sept. 31, 1920	22 miles NW. by N. ½ N.	2½	30–40	Clay	--------	(1)	4	------
	9	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Clay, mud	535	(1)	------	------
Grand Haven, Mich.	10	Mar. 20, 1919	12 miles west	2¾	50–55	Clay	--------	(2)	9	1
Ludington, Mich.	11	Aug. 30, 1920	17 miles W. ½ S.	2¾	60–70	do	--------	(2)	8	------
	12	do	12 miles W. ½ S.	2¾	45–50	do	--------	(2)	5	------
Frankfort, Mich.	13	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60–70	Blue clay	1,400	7	1	------
Northport, Mich.	14	June 22, 1920	5 miles northwest of Cathead Light.	2¾	40–60	Mud	200	(1)	1	------
	15	July 31, 1923	do	2¾	40–60	do	--------	(1)	15	------
Charlevoix, Mich.	16	June 29, 1920	5 miles N. by E.	2¾	40–55	Clay, mud	--------	(1)	1	------
	17	Aug. 11, 1923	3 miles NW. ½ W.	2¾	35–60	Red clay	375	(1)	1	------
Manistique, Mich.	18	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60–70	------------	200	(1)	1	------
Racine, Wis.[3]	----	------------	------------	------	------	------------	--------	--------	1	------
Sturgeon Bay, Wis.[3]	----	------------	------------	------	------	------------	--------	--------	3	------

[1] Rare. [2] Lift not examined or percentage not ascertained. [3] Wisconsin Geological Survey collection, borrowed specimens.

TABLE 17.—*Numerical expressions of certain systematic characters for the type of Leucichthys johannæ and for nine other specimens from Lake Michigan, selected according to size and locality*

Field No.	Locality	Length, millimeters	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
87353[1]	Racine, Wis.	265	10+19	♂	82	4.2	5.8	9.1	8.4	2.7	8.0	3.6	7.7	2.1	2.2	3.0	3.2
1570	Grand Haven, Mich.	254	11+18	♂	81	4.1	5.6	8.4	8.2	2.7	7.6	3.6	7.2	2.0	2.0	2.8	3.0
1593	do	280	12+18	♂	88	4.3	5.9	10.1	10.3	2.8	7.3	4.2	7.7	1.8	2.1	2.9	3.3
2949	Manistique, Mich.	265	11+17	♂	87	4.0	5.4	8.8	9.6	2.7	6.9	3.9	8.2	2.0	2.0	2.8	3.0
3218	Washington Harbor, Wis.	268	11+19	♂	85	4.1	5.8	8.9	8.7	2.8	7.2	3.7	7.4	2.0	2.0	2.8	3.1
3292	Sturgeon Bay, Wis.	245	12+20	♂	91	4.2	5.6	9.8	9.7	2.7	7.0	4.3	8.4	1.9	2.1	2.8	3.2
3301	do	231	12+20	♀	84	4.1	5.5	8.8	8.8	2.7	8.1	4.0	7.7	1.9	2.0	2.7	3.1
3402	Ludington, Mich.	262	10+20	♀	83	4.2	5.9	9.7	8.7	2.7	7.1	3.9	8.7	2.2	2.1	2.9	3.2
3471	do	288	11+17	♀	87	4.0	5.4	9.3	8.4	3.0	9.2	3.8	7.7	2.0	2.0	2.7	3.1
3668	Port Washington, Wis.	252	10+17	♀	82	4.2	5.7	9.4	9.0	2.8	9.1	3.8	8.4	2.1	2.0	2.8	3.1

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
87353[1]	Racine, Wis.	4.5	4.5	2.5	3.4	2.0	3.4	6.7	3.3	1.8	2.6	2.0	1.5	10	12	11	17	1.6	0.87	9
1570	Grand Haven, Mich.	4.1	4.5	2.7	3.5	2.0	3.3	6.8	3.3	2.0	2.5	1.6	1.2	10	14	12	17	1.4	.89	9
1593	do	4.5	4.8	2.8	3.8	2.1	3.4	6.0	3.4	2.0	2.7	1.7	1.4	10	11	11	15	1.4	1.0	8
2949	Manistique, Mich.	4.1	4.4	2.7	3.4	1.9	3.6	6.0	3.2	2.0	2.5	1.6	1.2	10	11	12	17	1.4	1.0	8
3218	Washington Harbor, Wis.	4.4	4.6	2.6	3.6	2.0	3.6	7.2	3.2	1.8	2.5	1.7	1.3	11	12	12	17	1.5	.94	8
3292	Sturgeon Bay, Wis.	4.3	4.4	2.7	3.5	2.0	3.0	6.4	3.3	2.0	2.6	1.8	1.3	9	11	11	17	1.6	1.0	9
3301	do	4.2	4.3	2.8	3.6	2.0	4.3	6.0	3.2	2.1	2.7	1.6	1.3	10	11	12	17	1.5	.98	8
3402	Ludington, Mich.	4.5	4.6	2.6	3.5	2.0	3.3	7.8	3.3	1.9	2.5	1.8	1.5	10	16	12	20	1.5	.88	9
3471	do	4.3	4.8	2.7	3.7	2.0	4.1	6.4	3.5	2.0	2.7	1.7	1.5	11	13	11	15	1.5	.82	9
3668	Port Washington, Wis.	4.3	4.6	2.7	3.5	2.0	3.7	6.0	3.3	2.0	2.5	1.8	1.4	10	14	11	16	1.5	.91	8

[1] Type: U. S. National Museum number.

Table 18.—*Records of the occurrence of Leucichthys johannæ in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Lake Huron proper:										
Cheboygan, Mich.	1	July 21, 1917	5 miles north of Spectacle Reef.	2¾	35–50	Clay		(1)	10	1
	2	Sept. 29, 1917	2 miles northeast of Spectacle Reef.	2¾	35–50	do	1,850	(2)	1	
	3	Oct. 1, 1917		2¾						1
Rogers, Mich.	4	July 24, 1917		2¾	60–70	Clay		(1)	18	
	5	Oct. 14, 1917	12 miles E. by N. ½ N.	2¾	35–50	do	1,500	(2)		
Alpena, Mich.	6	Aug. 13, 1917	38 miles east of can buoy	2¾	70–80	do	1,470	(1)	12	1
	7	Sept. 7, 1917	26 miles SE. by E. ¼ E. of can buoy.	4½	16–20			(2)	1	
	8	do	Center of lake, east of can buoy.	2¾	70–80	Clay	3,250	50	5	1
	9	Sept. 8, 1917	22 miles SE. by E. ½ E. of can buoy.	1½	30			(2)		1
	10	Sept. 10, 1917	Center of lake, northeast of can buoy.	2¾	60–70	Clay	1,300	80		
	11	Sept. 12, 1917	Center of lake, east of can buoy.	2¾	65–80	do	2,610	60	2	2
	12	Sept. 14, 1917	Center of lake, northeast of can buoy.	2¾	65–80	do	1,200	80		2
	13	Sept. 17, 1917	do	2¾	60–70	do		75	2	
	14	Sept. 18, 1917	17½ miles N. by E. of Thunder Bay Island.	2¾	60	do	825	(1)	9	11
	15	Sept. 19, 1917	Center of lake, northeast of can buoy.	2¾	65–80	do		(1)	3	6
	16	Sept. 20, 1917	14 miles NE. by E. of Thunder Bay Island.	2¾	65	do		(1)	3	5
	17	Sept. 21, 1917	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–75	do		(1)	3	10
	18	do	Center of lake, east of can buoy.	2¾	65–70	do		42	14	8
	19	Sept. 24, 1917	do	2¾	65–80	do		30		
	20	Sept. 26, 1917	do	2¾	65–80	do		60	2	
	21	Oct. 17, 1917	do	2¾	65–80	do		50	1	
	22	Oct. 20, 1917	do	2¾	65–80	do		40	4	
	23	Aug. 30, 1919	18 miles N. by E. ½ E. of Thunder Bay Island.	2¾	60–64	do		53		
	24	Sept. 3, 1919	28 miles E. ¼ S. of can buoy.	2¾	60–64	do		53		
	25	Sept. 18, 1919	14 miles N. by E. of Thunder Bay Island.	2¾	65	do		(1)		5
	26	do		2¾				(1)	14	20
	27	Aug. 7, 1920	19 miles NE. ½ N. of Thunder Bay Island.	2¾	60–65		3,500	90		
	28	June 28, 1923	19 miles northeast of Thunder Bay Island.	2¾	60–70		2,100	20		
	29	June 30, 1923	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–70	Clay	1,600	63	8	4
	30	July 2, 1923	20 miles E. by N. of can buoy.	2¾	60–70	do	2,000	12	3	
	31	July 5, 1923	18 miles NE. ¾ E. of Thunder Bay Island.	2¾	80–100	do	6,000	8	10	1
	32	July 7, 1923	13 miles NE. ½ N. of Thunder Bay Island.	2¾	60	do	1,400	47	10	1
Harbor Beach, Mich.	33	Oct. 27, 1917	35 miles NE. by N. ¾ N. of city.	2¾	50	do	1,183	50	15	
Georgian Bay:										
Lion's Head, Ontario.	34	July 30, 1919	21 miles east of Surprise Shoal.	3	60	Mud	400	50	12	1
	35	Oct. 6, 1919	Off White Bluff	3	70	do	425	(4)	8	
Wiarton, Ontario.	36	Nov. 6, 1917	6½ miles northeast of Griffith Island.	3	45–60	do		(1)	4	
	37	July 28, 1919	Off Cape Croker	3	52	do	500	50	6	
	38	June 10, 1922	do	3				(1)	8	
	39	June 26, 1923	do	3				(1)	24	
Borrowed specimens:										
Detour, Mich.[3]									1	

[1] Lift not examined or percentage not ascertained.
[2] Rare.
[3] Field Museum collection.
[4] Few.

TABLE 19.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys johannæ from Lake Huron, 10 of them more than 200 millimeters long and 10 less than 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	51	Cheboygan, Mich.	245	♂	11+19	80	3.8	5.4	10.2	9.6	2.7	8.0	4.0	8.0	2.0	1.9	2.6
	79	Rogers, Mich.	257	Im. ♀	10+16	83	4.1	5.8	9.5	8.6	2.8	9.4	4.0	8.0	1.9	2.0	2.8
	86	do	262	♀	10+18	82	4.0	5.8	9.8	8.9	2.7	8.7	3.9	8.8	2.1	1.9	2.7
	90	do	250	♀	11+18	80	4.2	5.8	10.0	9.2	2.7	8.0	4.2	8.4	2.0	2.0	2.7
	140	Alpena, Mich.	281	♀	11+17	87	4.0	5.7	9.6	9.0	2.7	7.8	3.6	7.0	1.9	1.9	2.7
	150	do	260	♀	11+18	85	4.1	5.9	9.9	9.0	2.8	8.1	4.2	8.5	2.0	2.0	2.9
	201	do	254	♂	11+19	83	4.0	5.7	9.4	8.4	2.8	8.2	4.2	8.0	1.9	1.9	2.7
	773	do	256	♀	12+19	82.	4.2	5.9	9.6	9.7	2.8	8.2	4.3	8.0	1.8	2.1	2.9
	777	do	282	♀	11+18	88	4.1	5.8	10.1	8.6	2.7	7.7	3.7	8.5	2.3	2.0	2.8
	805	do	305	♀	11+18	82	4.0	5.6	9.2	10.0	2.7	7.8	4.0	8.2	2.1	1.9	2.7
Under 200 millimeters.	195	do	158	Im. ♂	10+16	83	3.9	5.3	9.2	8.2	2.9	7.9	4.3	9.8	2.2	1.9	2.6
	376	do	198	Im. ♂	12+18	87	3.8	5.5	10.1	8.5	2.8	8.1	4.2	9.0	2.1	1.9	2.7
	478	do	165	Im. ♂	11+18	80	3.8	5.5	9.5	9.0	2.9	7.8	4.6	9.4	2.0	1.9	2.7
	458	do	182	Im. ♀	11+18	81	3.9	5.4	9.5	8.6	2.8	7.9	4.4	9.1	2.0	1.9	2.7
	551	do	187	Im. ♀	11+16	85	3.8	5.5	9.9	8.9	2.6	8.1	4.5	8.1	1.8	1.8	2.6
	553	do	190	Im. ♀	12+19	82	4.0	5.6	9.9	9.4	2.9	7.6	4.8	9.5	1.9	1.9	2.7
	550	do	182	Im. ♀	11+18	79	3.9	5.3	8.0	9.3	2.6	7.7	4.9	9.1	1.8	1.9	2.6
	579	do	170	♂	11+19	76	3.8	5.2	9.1	8.0	2.8	8.7	4.7	9.1	1.9	1.9	2.6
	666	do	199	Im. ♂	11+16	81	4.0	5.5	9.3	8.0	2.7	8.1	4.2	9.5	2.2	2.0	2.7
	673	do	184	♂	12+18	73	4.0	5.5	9.5	8.9	2.8	8.1	4.2	8.0	1.8	2.0	2.7

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	51	2.9	4.1	4.5	2.7	3.5	2.0	3.4	6.6	3.2	1.9	2.5	1.6	1.3	8	13	11	18	1.6	1.0	8
	79	3.1	4.4	4.6	2.6	3.5	2.0	3.4	6.7	3.2	1.8	2.5	1.8	1.4	10	13	11	17	1.6	.90	9
	86	3.2	4.5	4.7	2.7	3.6	2.0	3.7	7.0	3.3	1.9	2.6	1.7	1.5	10	12	11	18	1.7	1.0	9
	90	3.2	4.4	4.5	2.7	3.5	2.0	3.6	7.3	3.3	2.0	2.6	1.6	1.4	9	12	11	17	1.6	1.0	8
	140	3.1	4.4	4.6	2.6	3.4	1.9	3.4	6.5	3.3	1.9	2.4	1.8	1.4	9	12	11	19	1.5	.92	9
	150	3.1	4.5	4.5	2.6	3.5	2.0	3.4	6.0	3.1	1.8	2.4	1.6	1.4	10	12	11	18	1.5	.91	9
	201	3.1	4.3	4.5	2.5	3.3	2.0	3.7	5.7	3.2	1.8	2.3	1.6	1.4	10	12	11	17	1.5	.90	9
	773	3.2	4.4	4.6	2.6	3.4	2.0	3.5	6.8	3.3	1.9	2.5	1.8	1.4	10	11	12	17	1.6	1.0	9
	777	3.1	4.5	4.6	2.6	3.3	1.9	3.3	5.7	3.2	1.8	2.3	1.8	1.4	9	11	11	17	1.6	.89	9
	805	3.1	4.3	4.5	2.5	3.3	1.9	3.5	6.8	3.2	1.8	2.4	1.8	1.5	10	11	11	17	1.5	1.0	8
Under 200 millimeters.	195	2.9	4.0	4.0	2.6	3.4	1.9	3.6	6.0	2.9	1.9	2.5	1.5	1.3	10	12	11	17	1.6	.89	8
	376	3.0	4.3	4.2	2.7	3.6	2.1	3.9	7.3	2.9	1.8	2.5	1.7	1.4	10	13	11	18	1.7	.98	9
	478	2.9	4.1	4.1	2.5	3.4	1.9	3.8	6.8	2.9	1.8	2.4	1.5	1.3	10	11	11	17	1.7	1.0	9
	458	2.9	4.1	4.2	2.6	3.4	1.9	4.1	6.9	3.0	1.9	2.4	1.6	1.3	10	12	11	17	1.6	.92	9
	551	2.9	4.1	4.3	2.7	3.4	1.9	3.6	6.6	3.0	1.9	2.4	1.6	1.2	10	12	11	16	1.8	.93	8
	553	3.0	4.2	4.1	2.5	3.5	1.9	3.7	5.9	2.9	1.7	2.4	1.5	1.4	10	11	12	19	1.5	.93	8
	550	3.0	4.0	4.1	2.8	3.5	1.9	4.1	6.0	3.0	2.0	2.6	1.4	1.2	10	11	11	18	1.8	.94	9
	579	2.8	3.9	4.0	2.5	3.3	1.9	4.1	6.2	2.9	1.8	2.4	1.6	1.3	11	14	11	17	1.5	.89	8
	666	2.9	4.0	4.2	2.7	3.3	1.9	3.2	5.9	3.1	2.0	2.4	1.6	1.2	10	13	12	17	1.4	.80	9
	673	2.9	4.1	4.1	2.4	3.5	2.0	3.7	6.3	3.0	1.7	2.5	1.6	1.2	10	12	11	17	-----	1.0	9

TABLE 20.—*Records of the occurrence of Leucichthys alpenæ in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of alpenæ	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Washington Harbor, Wis.	1	Aug. 18, 1920	4 miles west of Boyer Bluff.	2⅜	18–24			[1]	2	
	2	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅝	71–90	Clay, mud	900	[1]	2	
Sturgeon Bay, Wis.	3	Aug. 23, 1920	12 miles E. by S. of channel mouth.	2⅝, 2¾	60–70	Mud	50	[1]		
Algoma, Wis.	4	Aug. 24, 1920	10 miles E. by N.	2½	35–50	Gravel, mud	310	[1]	1	
Sheboygan, Wis.	5	Oct. 1, 1920	11 miles southeast	2½	60	Clay	200	[2]	2	
Port Washington, Wis.	6	Sept. 25, 1920	18 miles E. ½ S.	2½	65–48	do	285	[1]	1	
	7	do	5 miles E. ½ S.	1½	30			[1]		1
D. H. Smith [3]	8	1892–1894	Sheboygan Reef, about halfway between Port Washington and Muskegon.							
Milwaukee, Wis.	9	Sept. 23, 1920	27 miles ESE.	2½	60	Red clay	250	[1]	1	
	10	Nov. 15, 1920	20 miles ESE.	2½	28–35		700	[1]	4	
Michigan City, Ind.	11	Sept. 3, 1920	22 miles NW. by N. ½ N.	2½	30–40	Clay		10	9	
	12	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Clay, mud	535	20	3	
	13	Nov. 8, 1920	18 miles NNW.	2½	30–38	Clay	1,000	33	4	
	14	Nov. 19, 1920	17 miles NNW.	2½	28–32	do	700	30	5	
	15	do	17½ miles NW. by N. ¾ N.	2½	32	do		15	2	
	16	do	10 miles NNW.	2½	18			[1]		
	17	Mar. 2, 1921	21 miles NNW.	2½	30	Clay	1,000	[1]		
	18	Mar. 4, 1921	15 miles NW. by N. ½ N.	2½	28			[1]		
Grand Haven, Mich.	19	Mar. 20, 1919	12 miles west	2¾	50–55	Clay		[2]	7	
Frankfort, Mich.	20	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60–70	Blue clay	1,400	22	5	
Platte Bay, Mich. (field station).	21	July 21, 1923	1½ miles south of Otter Creek.	1½	8–12	Sand		[4]		1
	22	July 23, 1923	do	1½	15–25	do		[4]		1
South Manitou Island, Mich.	23	July 30, 1923	Off the lighthouse	[5]	5				3	
Northport, Mich.	24	June 22, 1920	5 miles northwest of Cathead Light.	2¾	40–60	Mud	200	98	8	
	25	June 23, 1920	Off Northport Point	1½	28–40	do		[6]	1	9
	26	July 31, 1923	5 miles northwest of Cathead Light.	2¾	40–60		400	45	156	
Hans Anderson, Peter Anderson, Walter Wilson	27	Nov., 1923	Grand Traverse Bay	2¾	10–25	Mud, stone				
Traverse City, Mich.	28	July 18, 1923	West Bay	1½	30–40	Clay		[1]		
	29	July 25, 1923	Off Lees Point	1½	6–16			[4]		1
Will Hopkins	30	Nov., 1923	Grand Traverse Bay	2¾	10–25	Mud, clay				
Beaver Island, Mich., James Martin.	31	do	Sandy Bay	2¾	10–25	Mud, stone				
Charlevoix, Mich.	32	June 29, 1920	5 miles N. by E.	2¾	40–55	Clay, mud		98	8	
	33	June 15, 1923	Off Ile Aux Galets	2¾	25–47				2	
	34	Aug. 10, 1923	8 miles NNW. of Big Rock Point.	2¾	45–50	Clay	477	90	1	
	35	Aug. 11, 1923	3 miles NW. ½ W.	2¾	35–60	Red clay	375	69	3	
	36	Aug. 21, 1923		2¾			100	91	52	
John Nordrum, Chas. Hendrickson, sr.	37	Nov., 1923	Grand and Little Traverse Bays.	2¾	10–25	Mud, stone				
Manistique, Mich.	38	Aug. 11, 1920	13 miles SE. ½ E.	4½	20	Sand, mud		[1]	1	
	39	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60–70		200	50	5	

[1] Rare.
[2] *Lift not examined or percentage not ascertained.*
[3] Where fishermen's names or other sources appear opposite the record number the data entered in the table were obtained from these sources.
[4] Only specimens taken in lift.
[5] Pound.
[6] Occasional.

TABLE 21.—*Numerical expressions of certain systematic characters for the type of Leucichthys alpenæ and for nine cotypes from Lake Michigan over 200 millimeters long and for nine under 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length, millimeters	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	[1]87352	Charlevoix, Mich	269	14+25	♀	75	4.4	5.9	9.1	9.9	2.7	8.1	4.2	7.6	1.8	2.2	2.9
	1587	Grand Haven, Mich	275	14+24	♀	80	4.3	6.0	9.6	10.1	2.8	8.0	3.9	7.2	1.8	2.1	2.9
	2864	Charlevoix, Mich	284	15+25	♀	81	4.2	5.7	9.4	9.4	2.7	9.1	3.9	7.2	1.8	2.1	2.8
	2879	do	285	16+28	♀	74	4.1	5.5	8.9	8.9	2.7	10.0	4.0	7.9	1.9	2.0	2.8
	2938	Manistique, Mich	275	14+25	♀	83	4.2	5.9	8.9	8.8	2.9	8.8	4.3	8.3	1.9	2.1	2.9
	2940	do	301	15+28	♀	76	4.4	6.1	9.4	10.0	2.7	8.8	4.1	7.5	1.8	2.2	3.0
	2941	do	317	13+25	♀	76	4.2	5.7	9.1	9.9	2.8	7.9	3.8	7.8	2.0	2.1	2.9
	2951	do	276	16+26	♂	80	4.2	5.8	8.4	10.6	2.6	7.4	3.5	7.8	2.2	2.1	2.8
	4378	Michigan City, Ind	245	12+22	♀	83	4.5	5.9	8.7	9.8	2.6	8.1	3.9	7.4	1.8	2.2	2.9
	4395	do	291	14+22	♀	75	4.4	5.7	10.3	11.4	2.9	7.9	4.2	8.0	1.9	2.1	2.8
Under 200 millimeters.	1779	Northport, Mich	178	16+27	Im. ♀	76	4.2	5.8	11.4	10.4	2.9	8.0	5.1	9.3	1.8	2.0	2.7
	1785	do	165	14+24	Im. ♀	84	4.1	5.3	10.3	9.8	2.9	8.0	4.8	8.6	1.7	1.9	2.5
	1793	do	178	15+24	Im. ♀	84	4.3	5.9	9.4	9.4	2.7	8.4	4.5	9.3	2.0	2.0	2.8
	1813	do	174	15+26	Im. ♀	79	4.0	5.6	10.4	10.4	3.1	7.5	4.5	10.2	2.2	1.9	2.6
	2707	do	182	14+24	Im. ♂	81	4.1	5.5	9.6	10.7	2.8	7.2	4.9	9.5	1.9	2.0	2.6
	2717	do	170	14+24	Im. ♀	80	4.0	5.6	10.3	9.8	2.9	8.9	5.1	9.7	1.8	1.9	2.7
	2749	do	173	16+28	Im. ♂	86	4.2	5.5	10.8	9.7	2.9	7.2	5.0	10.1	2.0	1.9	2.6
	2769	do	160	15+24	Im. ♂	79	4.1	5.5	10.6	10.5	3.0	8.3	4.8	9.4	1.9	2.0	2.7
	2780	do	193	15+27	Im. ♂	83	4.2	5.8	9.6	10.2	2.8	8.3	4.8	9.6	2.0	2.1	2.8

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	[1]87352	3.5	4.7	4.6	2.7	3.7	1.9	3.3	5.9	3.4	2.0	2.6	2.2	1.8	10	11	11	16	1.3	0.91	8
	1587	3.3	4.6	4.5	2.5	3.7	1.9	3.1	6.8	3.2	1.8	2.6	2.2	1.6	11	11	10	15	1.5	.98	9
	2864	3.2	4.3	4.5	2.5	3.5	2.0	3.9	6.5	3.3	1.8	2.6	2.1	1.5	10	12	11	16	1.3	.88	9
	2879	3.2	4.4	4.5	2.6	3.6	2.0	4.0	5.8	3.3	1.9	2.7	2.2	1.6	11	12	12	17	1.4	.88	9
	2938	3.3	4.6	4.5	2.6	3.6	1.9	3.5	5.5	3.2	1.9	2.6	1.9	1.6	11	13	11	17	1.4	1.0	9
	2940	3.4	4.7	4.5	2.6	3.1	2.0	3.8	5.6	3.2	1.8	2.2	2.1	1.8	10	11	11	16	1.4	.96	8
	2941	3.3	4.4	4.9	2.6	3.0	2.0	3.5	5.7	3.6	1.9	2.2	2.0	1.8	11	12	11	17	1.3	.94	10
	2951	3.2	4.3	4.6	2.5	3.5	1.8	3.7	6.3	3.3	1.8	2.6	2.0	1.5	10	11	11	16	1.3	1.0	9
	4378	3.4	4.5	4.2	2.5	3.8	1.8	3.4	6.4	3.2	1.9	2.9	2.0	1.5	11	11	11	16	1.4	1.1	9
	4395	3.4	4.4	4.7	2.5	3.3	1.9	3.1	7.3	3.6	2.0	2.5	2.2	1.7	10	9	11	15	1.4	1.1	9
Under 200 millimeters.	1779	3.1	4.3	4.2	2.6	3.5	1.9	3.7	6.0	3.0	1.9	2.5	2.1	1.6	9	11	11	15	1.6	.94	9
	1785	3.2	4.1	4.2	2.6	3.5	2.0	3.7	6.4	3.2	2.0	2.7	2.1	1.7	10	11	11	16	1.5	------	9
	1793	3.3	4.5	4.1	2.6	3.4	1.9	3.4	6.0	3.0	1.9	2.5	2.1	1.5	11	12	11	16	1.5	.92	9
	1813	3.0	4.2	4.3	2.7	3.8	2.0	3.8	6.2	3.1	2.0	2.8	2.2	1.7	11	12	11	16	1.5	1.0	9
	2707	3.0	4.1	4.3	2.7	3.3	1.9	3.6	6.7	3.2	2.0	2.5	1.9	1.5	10	10	11	15	1.5	1.0	9
	2717	3.0	4.1	4.3	2.6	3.7	1.8	3.8	6.1	3.1	1.8	2.6	1.9	1.4	9	11	11	16	1.6	.98	9
	2749	3.1	4.1	4.0	2.5	3.6	1.9	3.6	6.6	3.0	1.9	2.7	1.9	1.6	10	12	11	17	1.6	.91	9
	2769	3.1	4.2	4.2	2.6	3.8	1.8	3.6	6.2	3.1	1.9	2.8	1.9	1.4	9	11	11	15	1.7	1.0	9
	2780	3.2	4.3	4.1	2.7	3.6	1.9	3.7	5.7	3.0	2.0	2.7	1.9	1.6	10	12	12	17	1.5	1.0	9

[1] Type, U. S. National Museum number.

TABLE 22.—*Records of the occurrence of Leucichthys alpenæ in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined +200 mm.	Preserved specimens examined −200 mm.
Lake Huron proper:										
Cheboygan, Mich.	1	July 21, 1917	5 miles north of Spectacle Reef.	2¾	35–50	Clay			6	6
	2	Sept. 29, 1917	2 miles northeast of Spectacle Reef.	2¾	35–50	do	1,850	(1)		3
	3	Oct. 15, 1919		1½	35			(2)		42
Rogers, Mich.	4	July 24, 1917		2¾	60–70	Clay		(3)	9	
Emil Schmekel.	5	Sept. 17–30, 1917		4½	12–15	Rock		(2)		
	6	Oct. 14, 1917	12 miles E. by N. ½ N.	2¾	35–50	Clay	1,500	(1)	1	4
Alpena, Mich.	7	Aug. 13, 1917	38 miles east of can buoy.	2¾	70–80	do	1,470		12	7
	8	Sept. 7, 1917	Center of lake, east of can buoy.	2¾	70–80	do	3,250	(1)		
	9	do	26 miles SE. by E. ¼ E. of can buoy.	4½	16–20			(5)		2
	10	Sept. 8, 1917	22 miles SE. by E. ½ E. of can buoy.	1½	30			(1)		1
	11	Sept. 10, 1917	8 miles E. by N. of can buoy.	4½	20			(5)	1	
	12	do	Center of lake, northeast of can buoy.	2¾	60–70	Clay	1,300	(1)		
	13	Sept. 12, 1917	Center of lake, east of can buoy.	2¾	65–80	do	2,610	(1)		
	14	Sept. 14, 1917	24 miles SE. by E. ½ E. of can buoy.	4½	24			(5)	1	5
	15	do	Center of lake, northeast of can buoy.	2¾	65–80	Clay	1,200	(1)	1	5
	16	Sept. 17, 1917	do	2¾	60–70	do		(1)	1	
	17	Sept. 18, 1917	17½ miles N. by E. of Thunder Bay Island.	2¾	60	do	825	(3)	4	12
	18	Sept. 19, 1917	23 miles SE. by E. ½ E. of can buoy.	2¾	30	Rock		(1)	1	
	19	do	Center of lake, northeast of can buoy.	2¾	65–80	Clay		(3)		1
	20	Sept. 20, 1917	14 miles NE. by E. of Thunder Bay Island.	2¾	65	do		(3)		4
	21	Sept. 21, 1917	Center of lake, east of can buoy.	2¾	65–70	do		(1)	3	6
	22	do	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–75	do		(3)		1
	23	Sept. 22, 1917	15 miles SE. by S. ½ S. of can buoy.	4½	17			(5)		1
	24	Sept. 24, 1917	Center of lake, east of can buoy.	2¾	65–80	Clay		(1)		
	25	Sept. 26, 1917	do	2¾	65–80	do		(1)		
	26	do	13 miles SE. by S. of can buoy.	2¾	17			(1)	1	
	27	Oct. 17, 1917	Center of lake, east of can buoy.	2¾	65–80	Clay		(1)	4	
	28	Oct. 20, 1917	do	2¾	65–80	do		(1)		
	29	Aug. 30, 1919	18 miles N. by E. ½ E. of Thunder Bay Island.	2¾	60–64	do		20		
	30	Sept. 3, 1919	28 miles E. ¼ S. of can buoy.	2¾	60–64	do		20		
	31	Sept. 16, 1919	40 miles ESE. of can buoy.	4½	20–30			(1)		1
	32	Sept. 18, 1919	14 miles N. by E. of Thunder Bay Island.	2¾	65	Clay		(3)		1
	33	Aug. 7, 1920	19 miles NE. ½ N. of Thunder Bay Island.	2¾	60–65		3,500	(1)		
	34	June 28, 1923	19 miles northeast of Thunder Bay Island.	2¾	60–70		2,100	(1)		
	35	June 30, 1923	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–70	Clay	1,600	7		13
	36	July 2, 1923	20 miles E. by N. of can buoy.	2¾	60–70	do	2,000	3	5	
	37	July 5, 1923	18 miles NE. ¾ E. of Thunder Bay Island.	2¾	80–100	do	6,000	(1)		4
	38	July 7, 1923	13 miles NE. ½ N. of Thunder Bay Island.	2¾	60	do	1,400	22	2	11
	39	July 10, 1923	3 miles E. ½ S. of North Point.	4½	14–20	Rock, mud.		(5)		8

[1] Rare.
[2] Occasional.
[3] Lift not examined or percentage not ascertained.
[4] See note, Table 20.
[5] Only specimens taken in lift.

TABLE 22.—*Records of the occurrence of Leucichthys alpenæ in Lake Huron*—Continued

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined	
									+200 mm.	−200 mm.
Lake Huron proper—Continued.										
Tug records	40	April-November, 1923.		4½	20-30			(1)		
Bay City, Mich.	41	Oct. 29, 1921	Saginaw Bay at Tobico	(6)	3			(1)	1	
	42	Nov. 25, 1925	Saginaw Bay at Nayanquing.	(6)	3			(1)		3
Harbor Beach, Mich.	43	Oct. 27, 1917	35 miles NE. by N. ¾ N. of city.	2¾	50	Clay	1,183	48	6	7
	44	Mar. 15, 1919		1½	31	do		21		46
Duck Islands, Ontario, A. Purvis.	45	May-August, 1919.	Off the islands	4½	20-30	Rock and gravel.				
North Channel:										
John Merrylees	46	August, 1919	Off Gore Bay Light	4½	20-25					
D. Beneteau	47	January-February, 1919.	North Channel	4½	20-25					
Georgian Bay:										
Lions Head, Ontario.	48	July 30, 1919	21 miles east of Surprise Shoal.	3	60	Mud	400	48	16	12
	49	Oct. 6, 1919	Off White Bluff	3	70	do	425	(1)	4	2
Wiarton, Ontario	50	Nov. 6, 1927	6½ miles northeast of Griffith Island.	3	45-60	do		(3)	13	1
	51	July 28, 1919	Off Cape Croker	3	52	do	500	50	21	4
	52	July 30, 1919		3						5
Stanley Boyd	53	Nov. 19, 1919	Colpoys Bay	3						
	54	Nov. 28, 1919	do	3	10-25	Mud, rock	755	100	10	2
	55	Dec. 3, 1919	do	1½-3	10-25	do	380	100	6	2
	56	June 10, 1922	Off Cape Croker	3					49	
	57	June 26, 1923	do	3						
Owen Sound to Meaford, D. McInnis.	58	November and early December, 1923.	In sound and along shore.		10-25					

[1] Rare. [3] Lift not examined or percentage not ascertained. [6] Pound net.

TABLE 23.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys alpenæ from Lake Huron, 10 of them more than 200 millimeters long and 10 less than 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length, millimeters	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	DW	SD/H	SD/O
Over 200 millimeters.	844	Cheboygan, Mich.	315	♀	14+25	82	4.2	6.1	10.0	10.7	2.8	7.8	4.0	8.5	2.1	2.2	3.1
	62	do	260	♀	14+24	79	4.1	5.7	8.8	9.1	2.8	8.2	4.1	8.9	2.1	2.0	2.8
	141	Alpena, Mich.	305	♀	13+24	78	4.1	6.1	10.0	10.1	2.8	8.2	4.0	8.0	2.0	2.2	3.0
	143	do	296	♀	14+24	74	3.9	5.5	10.0	9.8	2.8	7.8	4.3	9.2	2.1	2.0	2.8
	142	do	337	♂	14+25	81	4.1	5.7	8.3	9.3	2.8	8.4	4.0	8.4	2.1	2.0	2.8
	147	do	310	♀	13+23	75	4.1	5.9	10.0	10.2	2.8	8.8	3.7	7.4	2.0	2.1	3.0
	144	do	274	♀	13+24	82	4.2	6.1	9.2	10.4	2.7	8.6	4.2	7.7	1.8	2.0	2.9
	137	do	299	♂	15+23	80	4.2	6.0	10.0	9.2	2.7	8.2	3.8	7.6	1.9	2.0	2.9
	146	do	289	♀	15+25	80	4.1	5.6	9.0	10.5	2.7	8.4	3.7	7.8	2.0	2.0	2.8
	136	do	342	♀	13+24	78	4.2	6.0	10.3	11.0	2.9	8.1	3.9	7.6	1.9	2.1	3.0
Under 200 millimeters.	42B	Harbor Beach, Mich.	169	Im. ♀	13+23	77	4.1	5.6	9.3	8.8	2.8	8.0	4.3	8.2	1.9	2.0	2.7
	49B	do	178	♀	13+22	79	4.2	5.7	10.0	9.6	2.8	8.0	4.5	7.9	1.7	2.0	2.7
	57B	do	173	♀	13+23	84	4.1	5.7	10.2	10.0	2.8	7.8	4.4	8.4	1.8	2.0	2.8
	59B	do	189	Im. ♀	13+23	83	4.1	5.8	10.0	10.9	3.0	7.8	4.2	8.2	1.9	2.0	2.8
	60B	do	161	Im. ♂	12+21	79	4.1	5.3	8.8	10.0	2.8	8.0	4.1	7.6	1.8	2.0	2.6
	61B	do	157	Im. ♂	12+21	77	3.9	5.2	11.2	9.2	2.9	7.9	4.1	8.3	2.0	1.9	2.6
	72B	do	161	Im. ♂	11+20	72	4.0	5.4	9.0	9.2	2.8	8.0	4.6	8.2	1.7	1.9	2.6
	73B	do	165	Im. ♂	13+23	76	3.9	5.3	9.7	9.1	2.9	7.1	4.3	9.0	2.0	1.9	2.6
	74B	do	156	Im. ♂	12+21	76	4.2	5.6	10.0	9.6	2.9	8.2	4.3	8.8	2.0	2.0	2.8
	75B	do	164	Im. ♀	12+20	76	3.9	5.2	9.1	9.7	2.9	8.5	4.2	7.6	1.8	1.9	2.5

TABLE 23.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys alpenæ from Lake Huron, 10 of them more than 200 millimeters long and 10 less than 200 millimeters long, selected according to size*—Continued

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	844	3.2	4.7	4.7	2.6	3.8	1.9	4.2	5.7	3.2	1.8	2.6	2.1	1.7	11	11	11	15	1.3	0.91	9
	62	3.2	4.5	4.8	2.6	3.4	2.0	3.6	6.2	3.4	1.8	2.5	1.9	1.7	11	12	11	16	1.3	.87	8
	141	3.4	4.8	4.6	2.7	3.6	1.9	3.7	5.6	3.3	1.9	2.6	2.1	1.8	10	11	11	16	1.4	.98	8
	143	3.1	4.3	4.5	2.4	3.5	1.9	4.7	7.1	3.2	1.7	2.5	1.8	1.6	10	12	11	16	1.6	.98	9
	142	3.2	4.5	4.7	2.6	3.4	1.8	3.2	5.7	3.4	1.8	2.4	1.9	1.6	11	11	11	16	1.2	.94	9
	147	3.3	4.7	4.8	2.5	3.5	1.8	3.5	7.2	3.4	1.7	2.4	2.2	1.6	10	10	11	16	1.4	1.0	10
	144	3.2	4.7	4.6	2.5	3.4	1.9	3.7	5.8	3.2	1.7	2.4	2.0	1.7	10	12	11	16	1.3	.99	9
	137	3.3	4.7	4.6	2.5	3.5	2.0	3.5	6.6	3.3	1.7	2.5	2.0	1.5	10	11	11	16	1.6	.98	8
	146	3.2	4.4	4.8	2.6	3.4	2.1	3.7	6.3	3.5	1.9	2.4	2.0	1.6	10	11	11	16	1.2	.92	9
	136	3.3	4.7	4.8	2.5	3.4	1.9	3.5	6.2	3.3	1.6	2.4	2.2	1.8	10	10	11	15	1.3	1.0	10
Under 200 millimeters.	42B	3.1	4.1	4.0	2.5	3.6	1.9	3.4	6.6	2.9	1.8	2.6	2.0	1.4	11	13	11	16	1.5	.90	9
	49B	3.2	4.3	3.8	2.5	3.7	1.8	3.8	6.3	2.9	1.8	2.8	2.2	1.6	10	11	11	16	1.5	.87	9
	57B	3.1	4.3	3.8	2.4	3.7	1.8	3.4	5.9	2.7	1.7	2.6	2.1	1.3	10	11	11	16	1.6	1.0	9
	59B	3.1	4.4	3.8	2.3	3.6	1.8	3.7	6.3	2.7	1.6	2.6	2.1	1.4	9	9	11	15	1.5	1.0	9
	60B	3.1	4.1	3.9	2.4	3.5	1.7	3.8	6.7	3.0	1.9	2.6	2.0	1.4	11	12	10	16	1.4	1.0	8
	61B	2.9	4.0	3.8	2.5	3.4	1.8	3.8	7.3	2.8	1.8	2.6	1.8	1.4	10	12	12	16	1.8	1.0	9
	72B	3.0	4.0	3.9	2.4	3.6	1.9	3.5	8.0	2.9	1.8	2.7	2.0	1.5	11	12	10	16	1.4	.90	10
	73B	3.0	4.0	3.9	2.4	3.9	1.8	3.7	6.9	2.9	1.8	2.9	2.0	1.4	10	11	11	17	1.6	1.0	9
	74B	3.1	4.2	3.7	2.5	4.0	1.8	3.1	6.1	2.7	1.8	2.9	2.0	1.4	11	12	11	15	1.5	.88	9
	75B	3.1	4.1	4.0	2.3	3.6	1.8	3.5	6.9	3.0	1.7	2.9	2.0	1.5	10	11	11	16	1.5	1.0	8

TABLE 24.—*Records of the occurrence of Leucichthys zenithicus in Lake Superior*

[For each record is given, if known, the date and locality, the kind and quantity of gear used to make it, the depth of the water and character of the bottom where made, the number of fish gilled in the netting, the percentage of this species among them, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms
Sault Ste. Marie, Mich.	1	June 14, 1922	10 miles NW. by W. ¼ W. of Point Iroquois Light in Whitefish Bay.	2½, 2¾	38
Grand Marais, Mich.	2	Oct. 3, 1917		4½	+65
Marquette, Mich.	3	Aug. 5, 1921	31 miles N. ¾ E.	4½	100
	4	Aug. 8, 1921	6 miles NE. ¾ N.	1½, 2½, 2¾	42–65
	5	Aug. 11, 1921	18 miles NE. by N.	2½, 2¾	100–80
	6	Dec. 5, 1922	Off Granite Island	4½	
	7	1923			
	8	November, 1925			
W. J. Parker [1]	9	Nov. 25–Dec. 1	10 miles N. by W. ¼ W.	2¾	20–40
Ontonagon, Mich.	10	Aug. 16, 1921	54 miles W. by N.	4½	25–80
	11	Aug. 24, 1921	21 miles west	2½, 2¾	15–45
	12	Aug. 25, 1921	6 miles NNW.	2½, 2¾	20–38
Apostle Islands, Wis.	13	July 11, 1922	Between Cat and South Twin Island	2½, 2¾	15–20
	14	July 14, 1922	25 miles north of South Twin Island	4½	50–90
	15	July 15, 1922	14–18 miles NW. by N. of South Twin Island	4½	40–90
	16	do	20 miles northwest of Rocky Island	4½	35–65
Duluth, Minn.	17	July 17, 1922	20 miles NE. by E.	2⅝	30–40
Grand Marais, Minn.	18	Sept. 14, 1921	Off Terrace Point	2½, 2¾	30–65
	19	July 17, 1922	do	4½	30–65
Port Arthur, Ontario	20	Sept. 15, 1923	North of Silver Island	2½	14
	21	do	Thunder Bay, off Thunder Cape	2½	31
	22	Sept. 17, 1923	Thunder Bay, north of Welcome Islands	2½	11
	23	do	Thunder Bay, south of Welcome Islands	2½	23
	24	Sept. 19, 1923	Thunder Bay, off Sawyer Bay	2½	49
Rossport, Ontario	25	Oct. 4, 1921	Off Bread Rock	2½, 2¾	80–90
	26	Sept. 25, 1923	Simpson Channel	2½	74
	27	Sept. 29, 1923	Off Salter Island	2½	42
Port Coldwell, Ontario	28	Oct. 22, 1923		4½	
Michipicoten Island, Ontario	29	June 19, 1922	6 miles northeast of East End Light	4½	15–35
	30	June 22, 1922	3 miles SE. ½ E. of Quebec Harbor Light	2½, 2¾	80
Coppermine Point, Ontario	31	June 24, 1922	Agawa Bay	4½	40–50
	32	June 26, 1922	Off Alona Bay	2½, 2¾, 4½	60

TABLE 24.—*Records of the occurrence of Leucichthys zenithicus in Lake Superior*—Continued

Port from which nets were set	Record No.	Bottom	Length of net, in feet	Nights set	Number of fish gilled	Percentage of zenithicus	Preserved specimens examined	
							+200 mm.	−200 mm.
Sault Ste. Marie, Mich	1		1,800	2	200	99	79	9
Grand Marais, Mich	2						27	25
Marquette, Mich	3	Reddish-brown clay					18	52
	4	Red clay	2,500	5	250	96	57	36
	5		2,500	7	200	88	19	2
	6						16	50
	7						1	
	8						2	
W. J. Parker [1]	9	Clay				(2)		
Ontonagon, Mich	10						11	
	11	Red clay	2,500	7	700	99	39	3
	12	Sand and clay	2,500	7	500	97	53	6
Apostle Islands, Wis	13	Sand	2,200	1	300	99	185	
	14	Red and yellow clay					2	2
	15	Clay					3	8
	16	do					4	7
Duluth, Minn	17	Sand					48	3
Grand Marais, Minn	18	Clay	3,500	7	2,000	98	39	1
	19	do					17	4
Port Arthur, Ontario	20	Mud	500	1	32	3	1	
	21	Brownish-gray clay	500	2	70	50	32	
	22	Clay	500	2	16	(3)	1	
	23	Brownish-gray clay	1,000	2	121	6	8	
	24	do	1,000	2	50	62	26	
Rossport, Ontario	25	Grayish-brown clay	1,000	4	210	89	42	
	26	Clay	1,000	1	4	100	4	
	27	do	1,000	4	25	92	22	
Port Coldwell, Ontario	28						1	
Michipicoten Island, Ontario	29						24	7
	30	Blue clay	2,500	3	75	79	30	1
Coppermine Point, Ontario	31	Mud						2
	32		1,800	5	200	87	68	8
Marquette, Mich. [4]							7	
Devil Island [4]							1	
Knife River, Minn. [5]							3	
Duluth, Minn. [5]							1	

[1] See note, Table 20.
[2] Abundant.
[3] Rare.
[4] Field Museum collection, borrowed specimens.
[5] U. S. National Museum collection, borrowed specimens.

TABLE 25.—*Numerical expressions of certain systematic characters for the type of Leucichthys zenithicus and for 19 other specimens from Lake Superior, 9 of them over 200 millimeters long and 10 under 200 millimeters, selected according to size*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	[1] 62517	Isle Royale, Mich.	278	17+28	♂	74	3.7	5.1	10.0	8.7	2.8	9.0	4.7	9.0	1.9	1.8	2.5
	53882	Rossport, Ontario.	265	16+25	♀	80	3.9	5.3	9.4	9.3	2.8	7.3	4.0	7.1	1.7	2.0	2.7
	53888	do	254	15+25	♀	80	4.0	5.3	9.0	9.4	2.8	8.1	4.2	7.8	1.8	2.0	2.7
	53894	do	266	16+27	♀	76	4.0	5.4	9.4	9.8	2.8	7.6	4.1	8.0	1.9	2.0	2.7
	53897	do	286	15+27	♀	79	4.1	5.5	8.7	9.2	2.8	8.1	4.4	8.2	1.8	2.0	2.7
	53901	do	277	15+25	♂	74	3.8	4.9	8.9	9.2	2.8	8.3	4.3	9.3	2.1	1.9	2.4
	57033	Michipicoten Island, Ontario.	263	16+28	♂	82	4.0	5.4	9.7	9.0	2.7	8.2	4.1	8.2	1.9	2.0	2.7
	57067	Alona Bay	233	15+24	♀	83	4.0	5.2	9.7	9.7	2.8	6.7	4.2	8.6	2.0	2.0	2.6
	58095	Apostle Islands.	263	15+25	♀	75	4.0	5.2	10.0	9.7	2.7	7.7	4.6	9.3	2.0	2.0	2.6
	58104	do	257	14+25	♀	80	4.0	5.1	10.0	9.6	2.7	7.4	4.5	8.0	1.7	1.9	2.5
Under 200 millimeters.	53380	Marquette, Mich.	155	14+23	♂	86	3.7	4.8	9.8	8.5	2.9	7.4	4.4	9.3	2.1	2.0	2.5
	53651	Ontonagon, Mich.	170	15+23	Im. ♀	81	4.0	5.6	10.4	10.4	2.8	7.4	5.3	8.9	1.6	1.9	2.7
	53655	do	185	13+24	Im. ♂	75	3.8	5.1	9.7	9.7	2.8	7.5	4.4	9.2	2.0	1.9	2.5
	53661	do	195	16+26	♂	79	4.0	5.4	8.5	9.3	2.7	8.4	4.4	8.1	1.8	2.0	2.6
	53805	Grand Marais, Minn.	168	16+24	♀	79	4.0	5.2	9.8	9.7	2.9	7.3	4.0	8.4	2.1	2.0	2.7
	57059	Alona Bay	188	13+23	♂	80	4.0	5.1	9.0	8.2	2.8	7.8	4.5	8.7	1.9	1.9	2.5
	57820	Michipicoten Island, Ontario.	191	14+24	♀	80	4.0	5.4	9.0	10.1	2.7	7.3	4.5	8.6	1.9	2.0	2.6
	57832	do	171	14+23	♂	72	4.0	4.6	10.5	8.6	3.1	7.7	4.7	9.5	2.0	1.9	2.4
	57944	Whitefish Bay.	189	15+24	♀	69	3.9	5.0	9.8	9.4	3.0	8.5	5.2	9.9	1.8	1.9	2.5
	58471	Grand Marais, Minn.	183	14+23	♀	76	3.8	5.0	9.1	8.7	2.9	8.3	4.4	8.1	1.8	1.8	2.4

[1] Type, U. S. National Museum number.

TABLE 25.—*Numerical expressions of certain systematic characters for the type of Leucichthys zenithicus and for 19 other specimens from Lake Superior, 9 of them over 200 millimeters long and 10 under 200 millimeters, selected according to size*—Continued

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	[1] 62517	2.9	4.0	4.6	2.5	3.5	2.0	4.2	6.2	3.3	1.8	2.5	1.6	1.3	10	12	12	16	1.7	1.0	10
	53882	3.0	4.1	4.4	2.4	3.4	2.0	3.6	5.9	3.3	1.8	2.6	2.0	1.4	10	12	11	16	1.5	.94	9
	53888	3.1	4.2	4.4	2.5	3.3	1.9	3.4	5.7	3.3	1.8	2.5	2.1	1.5	11	12	11	16	1.4	.95	9
	53894	3.0	4.2	4.4	2.4	3.7	2.0	3.4	6.6	3.2	1.8	2.7	1.8	1.6	10	10	11	15	1.4	.96	9
	53897	3.2	4.3	4.6	2.3	3.4	1.9	3.5	4.8	3.4	1.7	2.5	1.8	1.5	11	12	11	18	1.4	1.0	9
	53901	3.0	3.8	4.8	2.4	3.6	1.9	4.4	5.7	3.8	1.9	2.8	1.7	1.4	10	12	11	16	1.4	.94	9
	57033	3.0	4.1	4.7	2.5	3.5	2.0	3.6	5.9	3.4	1.8	2.5	1.7	1.5	10	11	11	17	1.5	.93	9
	57067	3.0	3.9	4.0	2.5	3.5	1.9	3.4	6.4	3.0	1.9	2.7	1.6	1.3	11	12	11	16	1.6	1.0	9
	58095	3.0	3.9	4.3	2.4	3.3	1.9	3.1	6.5	3.3	1.9	2.5	1.7	1.3	10	13	11	16	1.5	1.0	9
	58104	3.0	3.9	4.2	2.3	3.5	1.9	3.1	5.9	3.2	1.8	2.7	1.6	1.4	10	12	11	16	1.6	.98	9
Under 200 millimeters.	53380	2.9	3.7	3.7	2.6	3.6	2.1	4.0	7.0	2.9	2.0	2.8	2.0	1.2	11	13	11	16	1.6	.93	8
	53651	3.0	4.3	4.2	2.6	3.7	2.1	3.4	7.0	3.0	1.8	2.6	1.7	1.5	10	11	11	17	1.6	1.0	9
	53655	2.9	3.9	4.0	2.5	3.6	2.0	4.7	6.0	3.0	1.8	2.7	1.6	1.4	10	11	11	16	1.5	1.0	9
	53661	3.0	4.1	4.0	2.5	3.7	2.0	3.9	8.7	3.0	1.8	2.8	2.1	1.4	11	11	11	16	1.4	.96	9
	53805	3.0	4.0	3.8	2.5	3.5	1.9	3.0	7.0	2.9	1.9	2.6	1.5	1.3	10	10	11	16	1.7	1.0	9
	57059	3.0	4.0	4.2	2.4	3.5	2.0	3.4	7.5	3.2	1.8	2.7	1.9	1.3	10	12	11	16	1.5	.92	8
	57820	3.1	4.2	3.9	2.6	3.6	1.9	3.5	7.5	2.9	1.9	2.6	1.7	1.4	11	11	11	16	1.6	1.1	8
	57832	2.7	3.5	3.9	2.6	3.4	2.1	4.2	8.1	3.1	2.0	2.6	1.7	1.1	10	12	11	17	1.5	.94	8
	57944	2.8	3.7	4.1	2.6	3.4	2.0	4.1	8.0	3.1	2.0	2.6	1.5	1.1	10	12	11	17	1.7	1.1	9
	58471	3.0	3.9	3.8	2.4	3.4	1.8	3.6	7.8	2.9	1.8	2.6	1.8	1.4	11	12	11	15	1.6	.92	9

[1] Type, U. S. National Museum number.

TABLE 26.—*Records of the occurrence of Leucichthys zenithicus in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.[1]	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined	
					+200 mm.	−200 mm.
1	July 26, 1922	Off Macdiarmid	2½, 2¾	30	101	7
2	Sept. 10, 1923	do			2	1
3	July 21, 1924	do			3	
4	July 29, 1924	do		15	1	
5	July 25, 1924	Off Blackwater River		54	1	
6	Sept. 6, 1923	Off Selwyn Island			1	
7	Sept. 5, 1923	Off McKellar Island				1
8	Sept. 3, 1923	Humboldt Bay		6–35	1	1
9	Aug. 15, 1922	Off Murchison Island		25	5	
10	Aug. 23, 1923	Ombabika Bay		10	5	
11	July 19, 1924	do		10	5	
12	Aug. 17, 1922	Off Whitesand River		25	3	0
13	Aug. 1, 1922	Grand Bay	4½	15–20	1	
14	Aug. 25, 1921	Off source of Nipigon River		12	2	
15	June 15, 1922	do		15	1	
16	July 25, 1922	do	2½, 2¾	10–15	19	
17	Aug. 28, 1923	Off Virgin Island		10–15		5
18	Aug. 15, 1922	Unknown		25	3	
19	Oct. 26, 1922	do	4½		5	
20	June 14, 1924	do	4½		1	

[1] All but records 1, 13, 16, and 19 are from University of Toronto collections.

TABLE 27.—*Numerical expression of certain systematic characters for 20 specimens of Leucichthys zenithicus from Lake Nipigon, half of them over 200 millimeters long and half under 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	57454	Macdiarmid, Ontario.	247	♀	13+24	72	3.8	5.1	10.2	9.5	3.0	8.4	4.2	8.5	2.0	1.9	2.5
	57482	do	234	♀	12+23	70	3.8	4.8	8.9	8.6	2.9	8.5	3.9	8.6	2.2	1.9	2.5
	57484	do	252	♀	14+25	72	4.2	5.3	9.4	9.1	3.2	7.6	4.5	9.8	2.1	2.0	2.6
	57519	do	256	♀	14+25	71	3.9	5.2	9.5	9.0	3.0	9.8	4.4	8.2	1.8	2.0	2.6
	57531	do	274	♀	14+24	72	4.0	5.5	8.5	7.8	3.0	9.3	4.2	9.4	2.2	2.0	2.8
	57548	do	246	♀	13+24	76	3.9	5.2	9.1	10.4	3.1	8.2	4.3	9.1	2.0	1.9	2.5
	57575	do	259	♀	13+22	76	4.0	5.3	8.9	8.6	3.0	8.9	4.5	9.5	2.1	2.0	2.7
	57611	do	252	♀	13+24	77	4.0	5.3	8.3	9.6	2.9	8.3	4.5	9.3	2.0	2.0	2.6
	57617	do	265	♀	14+22	72	4.0	5.3	9.1	8.3	2.9	8.5	4.2	8.5	2.0	2.0	2.7
	57622	do	257	♀	14+26	74	4.0	5.1	9.1	10.2	2.7	9.1	4.0	8.8	2.1	2.1	2.6
Under 200 millimeters.	57510	do	186	Im. ♀	13+26	72	3.6	4.6	8.5	9.7	3.2	8.0	4.7	10.3	2.1	1.8	2.3
	57625	do	190	♂	14+25	70	3.8	5.0	8.2	9.4	2.9	8.4	4.4	10.5	2.3	1.8	2.4
	57633	do	196	♂	13+25	70	3.8	5.1	8.5	9.3	2.9	7.8	4.3	10.3	2.3	1.9	2.5
	57650	do	184	Im. ♀	15+26	77	3.9	5.2	9.6	10.2	2.9	7.0	5.1	10.2	2.0	2.0	2.7
	57673	do	192	Im. ♀	15+25	78	3.8	5.1	8.8	9.3	3.0	7.6	4.8	9.1	1.9	2.0	2.7
	57695	do	157	Im. ♀	13+24	76	3.8	5.0	8.3	8.3	2.8	8.3	5.1	9.3	1.8	1.9	2.5
	N840	Virgin Islands, Ontario.	199	♂	14+23	69	3.9	5.3	9.8	9.7	3.0	8.1	4.7	11.0	2.3	2.0	2.7
	N459	(?)	172	♂	13+22	73	3.8	4.8	8.6	9.0	2.9	9.0	4.0	10.1	2.4	2.0	2.5
	N460	(?)	161	Im. ♂	13+23	78	3.8	5.1	9.9	9.0	2.8	8.4	4.3	9.4	2.1	2.0	2.7
	[1] N461	(?)	155	Im. ♀	14+23	74	3.6	4.7	8.7	9.6	2.9	9.1	5.0	11.0	2.2	1.8	2.4

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	57454	3.0	4.0	4.5	2.5	3.2	1.9	3.5	7.1	3.4	1.8	2.4	1.8	1.4	10	11	10	16	1.7	1.0	9
	57482	2.9	3.7	4.1	2.4	3.2	1.9	3.4	5.8	3.2	1.9	2.5	1.6	1.5	10	12	11	16	1.6	.97	9
	57484	3.3	4.2	4.0	2.4	3.3	1.9	3.0	6.0	3.1	1.9	2.6	2.0	1.7	11	11	11	15	1.5	.92	10
	57519	3.1	4.1	4.4	2.3	3.2	1.9	3.6	5.9	3.3	1.7	2.4	1.8	1.6	10	12	11	16	1.6	1.0	9
	57531	3.1	4.4	4.5	2.4	3.4	1.9	4.0	6.6	3.2	1.7	2.4	1.9	1.6	10	12	10	16	1.3	.82	9
	57548	3.0	4.1	4.4	2.3	3.3	1.9	3.1	4.8	3.2	1.7	2.4	1.7	1.4	11	10	12	17	1.6	1.1	10
	57575	3.2	4.2	4.2	2.4	3.3	1.9	3.3	5.7	3.2	1.8	2.4	1.9	1.5	10	12	12	17	1.5	.93	9
	57611	3.1	4.1	4.1	2.3	3.4	1.9	3.4	5.5	3.1	1.7	2.6	1.9	1.6	11	11	12	17	1.3	1.0	9
	57617	3.1	4.1	4.2	2.4	3.2	1.8	3.5	7.2	3.1	1.8	2.4	2.0	1.6	10	11	12	16	1.5	.94	9
	57622	3.0	3.8	4.2	2.6	3.3	1.8	4.5	5.8	3.3	2.0	2.6	1.8	1.4	9	10	11	16	1.6	1.1	9
Under 200 millimeters.	57510	2.7	3.5	4.1	2.5	3.3	1.9	3.5	7.5	3.2	1.9	2.6	1.6	1.2	10	11	11	17	1.6	1.1	9
	57625	2.9	3.8	4.1	2.5	3.5	1.9	3.5	6.2	3.1	1.9	2.6	1.7	1.4	11	12	11	17	1.5	1.0	9
	57633	2.9	3.9	4.0	2.3	3.4	1.9	3.6	5.7	3.0	1.7	2.5	1.7	1.4	10	11	12	17	1.6	1.1	9
	57650	3.0	4.0	3.8	2.5	3.5	1.9	2.9	5.8	2.9	1.9	2.6	1.7	1.3	10	11	11	17	1.6	1.0	9
	57673	3.0	4.1	4.2	2.6	3.5	2.0	3.6	6.4	3.1	1.9	2.6	1.7	1.4	11	11	12	17	1.6	1.0	9
	57695	2.8	3.8	3.6	2.4	3.6	1.9	4.1	5.4	2.7	1.8	2.7	1.7	1.3	10	12	12	16	1.6	.96	9
	N840	3.0	4.1	4.1	2.5	3.5	1.9	3.4	6.2	3.0	1.8	2.6	1.7	1.5	9	11	11	16	1.6	1.0	9
	N459	3.0	3.8	3.8	2.4	3.4	1.8	3.4	6.9	3.0	1.9	2.7	1.7	1.3	10	11	11	16	1.6	1.0	9
	N460	2.9	3.9	3.8	2.4	3.7	1.8	3.9	5.3	2.9	1.8	2.8	1.6	1.2	11	13	11	17	1.8	1.0	9
	[1] N461	2.8	3.6	3.8	2.5	3.5	1.9	3.5	8.4	3.0	1.9	2.7	1.6	1.3	11	12	11	16	1.6	1.1	10

[1] University of Toronto collection.

TABLE 28.—*Records of the occurrence of Leucichthys zenithicus in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of zenithicus	Preserved specimens examined: +200 mm	Preserved specimens examined: −200 mm
Washington Harbor, Wis.	1	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅝	71–90	Clay, mud	900	([1])	------	------
Sturgeon Bay, Wis.	2	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60–70	Mud	50	([1])	2	------
Algoma, Wis.	3	Aug. 24, 1920	10 miles E. by N.	2½	35–50	Gravel, mud.	310	20	2	------
Sheboygan, Wis.	4	Sept. 28, 1920	5 miles SE. by E.	1½	30–32	------	------	([2])	------	7
	5	Oct. 1, 1920	11 miles southeast	2½	60	Clay	200	([3])	5	------
Port Washington, Wis.	6	Sept. 25, 1920	18 miles E. ½ S.	2½	65–48	do	285	([1])	7	------
	7	do	5 miles E. ½ S.	1½	30	------	------	([1])	------	2
	8	May 26, 1921	8 miles northeast	2½	20–35	Mud	------	([3])	2	------
Milwaukee, Wis.	9	Mar. 24, 1919	------	2½	50	------	------	([3])	3	------
	10	Sept. 23, 1920	27 miles ESE	2½	60	Red clay	250	35	5	------
	11	Sept. 24, 1920	9 miles NNE	2½	22–25	Clay	------	([3])	9	------
	12	Nov. 15, 1920	20 miles ESE	2½	28–35	------	700	99	13	------
	13	do	5 miles E. by S. ½ S.	2½	12	------	------	([3])	2	------
Michigan City, Ind.	14	Sept. 3, 1920	22 miles NW. by N. ½ N.	2½	30–40	Clay	------	29	11	------
	15	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Mud, clay	535	44	5	------
	16	Nov. 8, 1920	18 miles NNW	2½	30–38	Clay	1,000	54	11	------
	17	Nov. 19, 1920	17 miles NNW	2½	28–32	do	700	15	6	------
	18	do	10 miles NNW	2½	18	------	------	93	10	------
	19	do	17½ miles NW. by N. ¾ N.	2½	32	Clay	------	70	3	------
	20	Mar. 2, 1921	21 miles NNW	2½	30	do	1,000	([1])	------	------
	21	Mar. 4, 1921	15 miles NW. by N. ½ N.	2½	28	------	1,000	([1])	3	------
	22	Apr. 1, 1921	------	2½	30	Clay	500	([3])	2	------
Grand Haven, Mich.	23	Mar. 20, 1919	12 miles west	2¾	50–55	do	------	([3])	3	------
Frankfort, Mich.	24	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60–70	Blue clay	1,400	6	2	------
Northport, Mich.	25	July 31, 1923	5 miles northwest of Cathead Light.	2¾	40–60	Mud	------	([1])	5	------
Charlevoix, Mich.	26	June 29, 1920	5 miles N. by E.	2¾	40–50	Clay, mud	------	([1])	2	------
Manistique, Mich.	27	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60–70	------	200	40	1	------
Lake Michigan [4]	------	------	------	------	------	------	------	6	1	------
Milwaukee, Wis.[5]	------	------	------	------	------	------	------	1	------	------
Kenosha, Wis.[6]	------	------	------	------	------	------	------	1	------	------
Sturgeon Bay, Wis.[6]	------	------	------	------	------	------	------	1	------	------

[1] Rare.
[2] Occasional.
[3] Lift not examined or percentage not ascertained.
[4] Field Museum collection, borrowed specimens.
[5] U. S. National Museum collection, borrowed specimens.
[6] Wisconsin Geological Survey collection, borrowed specimens.

94995—29——19

TABLE 29.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys zenithicus from Lake Michigan over 200 millimeters long and for 7 specimens under 200 millimeters long, selected according to size and locality*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT
Over 200 millimeters	2828	Charlevoix, Mich.	280	13+25	♀	84	4.2	5.7	10.0	9.9	2.8	8.7
	2936	Manistique, Mich.	271	15+26	♀	79	4.3	5.7	10.4	11.1	2.8	8.7
	3992	Frankfort, Mich.	271	14+27	♀	84	4.1	5.4	10.2	10.5	3.0	9.3
	4208	Michigan City, Ind.	259	14+26	♀	73	4.1	5.7	8.9	9.8	2.8	8.3
	4332	do	252	15+26	♀	86	4.5	6.0	9.7	9.7	2.8	7.0
	4375	do	272	16+25	♀	87	4.3	5.9	10.2	9.7	2.9	7.5
	4379	do	271	14+25	♀	79	4.5	6.0	10.3	10.1	2.8	8.2
	4380	do	264	13+23	♀	81	4.3	5.8	9.4	10.1	2.7	8.3
	4386	do	245	16+26	♂	76	4.1	5.6	9.7	9.8	2.9	9.0
	4397	do	257	14+24	♂	75	4.1	5.5	9.1	9.1	3.0	8.8
Under 200 millimeters	3701	Port Washington, Wis.	175	14+23	Im. ♀	83	4.1	5.3	10.2	11.0	2.8	8.1
	3711	do	185	15+26	Im. ♂	84	4.2	5.6	10.8	8.8	2.8	7.9
	3777	Sheboygan, Wis.	171	13+26	Im. ♀	82	4.1	5.4	11.2	11.4	3.1	7.2
	3830	do	192	13+24	♂	74	4.0	5.4	9.6	10.2	2.8	7.8
	3852	do	170	14+24	Im. ♂	77	4.0	5.3	10.0	10.7	2.8	7.7
	3874	do	162	14+25	Im. ♂	80	4.0	5.5	9.5	10.0	2.7	7.3
	3881	do	168	15+24	Im. ♂	76	4.0	5.2	10.8	10.8	3.1	6.7

Size	Field No.	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R
Over 200 millimeters	2828	4.3	8.0	1.8	2.1	2.8	3.2	4.3	4.5	2.5	3.2	2.0	3.5	7.2
	2936	4.6	8.4	1.8	2.1	2.9	3.4	4.6	4.5	2.4	3.5	2.0	3.5	7.8
	3992	4.3	7.9	1.8	2.1	2.7	3.3	4.3	4.3	2.3	3.5	2.0	3.9	6.5
	4208	4.1	8.0	1.9	2.2	3.0	3.2	4.5	4.4	2.5	3.6	2.0	3.5	7.5
	4332	4.6	7.8	1.6	2.2	2.9	3.5	4.6	4.3	2.5	3.5	2.0	3.2	5.8
	4375	4.0	7.5	1.8	2.2	2.9	3.3	4.5	4.5	2.4	3.4	1.9	3.2	6.8
	4379	4.1	8.2	2.0	2.2	2.9	3.5	4.7	4.5	2.5	3.5	2.1	3.1	5.9
	4380	3.8	7.3	1.8	2.2	3.0	3.3	4.5	4.5	2.5	3.5	2.0	3.0	6.1
	4386	4.6	9.0	1.9	2.1	2.9	3.2	4.4	4.4	2.4	3.6	2.1	3.6	6.9
	4397	4.2	7.7	1.8	2.1	2.8	3.2	4.2	4.4	2.3	3.4	2.0	3.4	7.2
Under 200 millimeters	3701	4.6	9.7	2.1	2.0	2.5	3.2	4.0	4.1	2.6	3.5	2.0	4.1	6.0
	3711	4.5	10.2	2.2	2.1	2.8	3.1	4.1	4.2	2.6	3.6	2.1	3.6	6.2
	3777	5.3	9.5	1.7	2.0	2.6	3.1	4.1	4.0	2.5	3.5	2.0	3.4	6.6
	3830	4.4	10.6	2.3	2.1	2.8	3.1	4.1	4.2	2.6	3.5	2.0	3.4	7.2
	3852	4.7	10.0	2.1	2.0	2.7	3.0	4.0	4.0	2.7	3.6	2.1	3.5	6.3
	3874	5.2	9.0	1.7	2.0	2.8	3.0	4.2	4.2	2.7	3.6	2.0	3.3	6.6
	3881	5.2	11.2	2.1	1.9	2.5	3.0	3.9	4.1	2.6	3.5	2.1	3.2	6.1

Size	Field No.	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	MS/E
Over 200 millimeters	2828	3.3	1.9	2.4	2.1	1.6	10	12	11	17	1.5	0.98	9	3.1
	2936	3.3	1.9	2.6	2.0	1.6	10	11	10	15	1.6	1.1	9	3.0
	3992	3.3	1.7	2.7	2.2	1.8	10	10	11	15	1.4	.93	9	3.1
	4208	3.2	1.8	2.7	2.3	1.7	10	11	11	15	1.3	.95	9	2.8
	4332	3.2	1.9	2.6	2.1	1.7	9	11	11	15	1.4	.92	9	2.9
	4375	3.4	1.8	2.5	2.3	1.7	11	12	11	15	1.4	.93	9	3.1
	4379	3.4	1.9	2.6	2.4	2.0	11	11	11	15	1.3	.89	9	3.0
	4380	3.3	1.8	2.6	2.2	1.6	10	12	11	15	1.4	.96	9	3.0
	4386	3.2	1.7	2.6	2.1	1.4	10	11	11	15	1.5	.96	8	3.0
	4397	3.3	1.7	2.5	2.0	1.4	10	11	11	17	1.3	.91	9	3.1
Under 200 millimeters	3701	3.2	2.0	2.7	2.1	1.6	10	11	11	16	1.5	1.0	9	2.7
	3711	3.2	2.0	2.7	2.0	1.2	9	13	11	15	1.6	.96	9	2.7
	3777	3.0	1.9	2.7	2.0	1.5	10	10	11	14	1.6	1.1	8	2.7
	3830	3.2	2.0	2.7	2.0	1.3	10	10	11	15	1.5	1.1	8	2.8
	3852	3.0	2.0	2.7	2.0	1.3	10	11	11	14	1.6	1.0	8	2.6
	3874	3.0	1.9	2.5	1.9	1.3	9	11	11	16	1.5	1.0	9	2.7
	3881	3.1	2.0	2.6	1.9	1.3	10	11	11	15	1.8	1.1	9	2.7

TABLE 30.—*Records of the occurrence of Leucichthys zenithicus in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined +200 mm.	Preserved specimens examined −200 mm.
Lake Huron proper:										
Cheboygan, Mich.	1	July 21, 1917	5 miles north of Spectacle Reef.	2¾	35–50	Clay		(1)	8	3
	2	Sept. 28, 1917	2 miles northeast of Spectacle Reef.	2¾	35–50	do	1,800	99		
	3	Sept. 29, 1917	do	2¾	35–50	do	1,850	99	9	2
	4	Oct. 15, 1919		1½	35			(2)	1	11
Rogers, Mich.	5	July 24, 1917		2¾	60–70	Clay		(1)	5	
	6	Oct. 14, 1917	12 miles E. by N. ½ N. of city.	2¾	35–50	do	1,500	99	10	1
Alpena, Mich.	7	Aug. 13, 1917	38 miles east of can buoy	2¾	70–80	do	1,470	(1)	2	
	8	Sept. 7, 1917	Center of lake east of can buoy.	2¾	70–80	do	3,250	(3)	2	
	9	do	26 miles SE. by E. ¼ E. of can buoy.	4½	16–20			(4)	2	2
	10	Sept. 8, 1917	22 miles SE. by E. ½ E. of can buoy.	1½	30			(5)	2	11
	11	Sept. 10, 1917	8 miles E. by N. of can buoy.	4½	20			(4)	1	
	12	do	13½ miles SE. by S. of can buoy.	4½	15	Mud		(4)	4	1
	13	Sept. 12, 1917	11 miles SE. ¾ E. of can buoy.	4½	15–17			(4)	2	2
	14	Sept. 14, 1917	24 miles SE. by E ½ E. of can buoy.	4½	24			(4)	2	1
	15	do	Center of lake northeast of can buoy.	2¾	65–80	Clay	1,200	(3)	1	1
	16	Sept. 17, 1917	13½ miles SE. by S. of can buoy.	2¾	15			(4)	1	
	17	do	Center of lake northeast of can buoy.	2¾	60–70	Clay		(3)	1	
	18	Sept. 18, 1917	17½ miles N. by E. of Thunder Bay Island.	2¾	60		825	(1)	5	3
	19	Sept. 19, 1917	23 miles SE. by E. ½ E. of can buoy.	2¾	30	Rock		(3)	1	
	20	Sept. 20, 1917	14 miles NE. by E. of Thunder Bay Island.	2¾	65	Clay		(1)		2
	21	Sept. 21, 1917	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–75	do		(1)		1
	22	Sept. 22, 1917	15 miles SE. by S. ½ S. of can buoy.	4½	17			(4)	3	3
	23	Sept. 26, 1917	13 miles SE. by S. of can buoy.	2¾	17			(4)	1	
	24	Oct. 17, 1917	Center of lake east of can buoy.	2¾	65–80	Clay		(3)	1	
	25	Oct. 20, 1917	do	2¾	65–80	do		(3)	4	
	26	Aug. 30, 1919	18 miles N. by E. ½ E. of Thunder Bay Island.	2¾	60–64	do		17	2	
	27	Sept. 3, 1919	28 miles E. ¼ S. of can buoy.	2¾	60–64	do		17	2	
	28	Sept. 13, 1919	Off Presque Isle Light	1½	60			(4)		1
	29	Sept. 16, 1919		1½				(5)		1
	30	Aug. 7, 1920	19 miles NE. ½ N. of Thunder Bay Island.	2¾	60–65	Clay	3,500	3		
	31	June 30, 1923	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–70	do	1,600	5		1
	32	July 2, 1923	20 miles E. by N. of can buoy.	2¾	60–70	do	2,000	3	4	
	33	July 5, 1923	18 miles NE. ¾ E. of Thunder Bay Island.	2¾	80–100	do	6,000	(3)	4	
	34	July 7, 1923	13 miles NE. ½ N. of Thunder Bay Island.	2¾	60	do	1,400	14	4	1
	35	July 10, 1923	3 miles E. ½ S. of North Point.	4½	14–20	Rock, mud		(4)	1	1
Harbor Beach, Mich.	36	Oct. 27, 1917	35 miles NE. by N. ¾ N. of city.	2¾	50	Clay		(3)	3	
	37	Mar. 15, 1919		1½	31			12		30
Georgian Bay:										
Wiarton, Ontario	38	Nov. 6, 1917	6½ miles northeast of Griffith Island.	3	45–60	Mud		(1)	1	
Lion's Head, Ontario.	39	July 30, 1919	21 miles east of Surprise Shoal.	3	60	do	400	(4)		2
Borrowed specimens:										
Cheboygan, Mich.[6]									2	

[1] Lift not examined or percentage not ascertained.
[2] Occasional.
[3] Rare.
[4] Only specimens taken in the lift.
[5] Few.
[6] U. S. National Museum collection.

TABLE 31.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys zenithicus from Lake Huron, 10 of them more than 200 millimeters long and 10 less than 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	44	Cheboygan, Mich.	287	Im. ♂	14+25	72	4.1	5.7	10.0	11.0	2.6	9.2	3.8	9.2	2.4	2.1	2.9
	46	do	260	♀	14+26	71	4.1	5.5	8.8	9.5	2.7	9.4	4.1	9.6	2.3	2.1	2.8
	56	do	269	♀	14+25	80	4.5	6.2	9.9	10.0	2.5	8.4	4.0	7.9	1.9	2.2	3.0
	855	do	282	♀	14+25	75	4.3	5.8	9.7	10.4	2.6	7.2	3.8	6.9	1.8	2.1	2.9
	856	do	275	♀	14+24	82	4.1	5.7	10.5	9.8	2.7	8.0	3.5	6.4	1.8	2.1	3.0
	942	Rogers, Mich.	257	♀	13+23	74	4.2	5.8	9.5	9.3	2.7	8.2	3.5	8.5	2.3	2.0	2.9
	224	Alpena, Mich.	236	♂	14+23	77	4.1	5.6	10.0	10.0	2.8	7.3	4.9	9.0	1.8	2.0	2.7
	423	do	277	♂	14+26	81	4.4	6.2	9.8	9.0	2.8	8.9	5.1	9.3	1.8	2.1	3.0
	433	do	261	Evis.	14+27	82	4.2	5.7	9.5	9.8	2.7	8.0	4.4	9.3	2.1	2.1	2.9
	540	do	270	Evis.	13+24	72	4.2	6.0	9.3	10.8	2.8	7.9	4.3	9.3	2.1	2.1	2.9
Under 200 millimeters.	58	Cheyboygan, Mich.	186	Im. ♀	13+25	77	4.1	5.5	9.9	9.5	3.1	8.7	4.8	10.0	2.0	2.1	2.8
	841	do	167	♀	13+22	79	4.2	5.7	9.8	9.9	2.9	8.3	3.9	.77	1.9	2.1	2.9
	897	do	191	♀	13+23	82	4.1	5.4	10.4	10.9	2.8	7.6	3.8	7.7	2.0	2.1	2.7
	230	Alpena, Mich.	191	♂	14+23	79	4.2	5.8	11.2	11.2	2.9	8.2	4.7	8.7	1.8	2.1	3.0
	249	do	167	Im. ♀	12+23	74	4.1	5.6	11.5	9.8	3.0	8.0	4.5	8.0	1.7	2.1	2.8
	253	do	188	Im. ♀	14+25	78	4.2	5.7	9.0	10.3	2.7	9.6	4.2	8.1	1.9	2.1	2.9
	255	do	170	Im. ♀	13+24	77	4.1	5.7	9.4	9.8	2.8	8.2	4.3	8.5	1.9	2.0	2.7
	269	do	171	Im. ♂	13+23	75	4.0	5.7	9.4	9.5	2.8	8.2	4.8	9.0	1.8	2.0	2.8
	270	do	180	Im. ♂	14+24	80	4.0	5.7	9.2	10.0	2.8	8.2	4.5	8.7	1.9	2.0	2.9
	273	do	190	Im. ♂	14+26	79	4.2	5.8	10.5	9.1	2.8	8.6	4.5	10.0	2.2	2.1	2.9

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	44	3.2	4.4	4.6	2.5	3.3	2.1	4.0	6.8	3.3	1.8	2.4	2.0	1.5	9	10	10	16	1.4	0.93	9
	46	3.3	4.4	4.4	2.6	3.4	2.0	4.0	6.8	3.3	1.9	2.5	2.1	1.5	11	11	11	16	1.3	.96	9
	56	3.4	4.8	4.4	2.5	3.5	2.1	3.5	7.0	3.1	1.8	2.5	1.9	1.5	10	10	12	17	1.5	1.0	9
	855	3.3	4.4	4.4	2.3	3.4	2.0	3.8	6.0	3.2	1.7	2.5	2.1	1.6	10	11	12	17	1.3	.92	10
	856	3.2	4.4	4.7	2.4	3.3	2.0	3.4	6.4	3.3	1.7	2.3	2.0	1.6	10	11	11	16	1.5	.93	9
	942	3.3	4.5	4.5	2.4	3.3	2.0	3.1	6.6	3.2	1.7	2.4	2.0	1.5	10	11	11	17	1.4	.86	8
	224	3.1	4.2	4.4	2.5	3.5	2.0	3.8	6.5	3.2	1.8	2.6	1.8	1.5	10	11	11	17	1.5	1.0	9
	423	3.4	4.8	4.4	2.5	3.3	2.0	3.8	5.5	3.2	1.8	2.4	1.9	1.5	10	12	11	16	1.5	.93	8
	433	3.2	4.4	4.2	2.5	3.4	2.1	3.5	7.6	3.1	1.8	2.5	2.1	1.6	10	12	11	17	1.3	.93	9
	540	3.4	4.7	4.2	2.5	3.7	2.1	3.7	5.6	3.0	1.8	2.6	2.0	1.6	10	11	11	16	1.4	1.0	9
Under 200 millimeters.	58	3.2	4.3	3.7	2.6	3.6	2.0	3.7	6.9	2.8	1.9	2.9	2.1	1.4	9	11	11	17	1.5	1.0	9
	841	3.2	4.4	4.1	2.8	3.5	2.0	3.4	7.5	3.0	2.0	2.6	2.4	1.4	10	11	11	16	1.5	.98	9
	897	3.1	4.1	4.0	2.6	3.5	2.0	3.8	11.7	3.0	2.0	2.7	2.2	1.4	10	11	11	16	1.5	.97	8
	230	3.2	4.4	4.0	2.6	3.5	2.1	3.3	6.4	2.9	1.8	2.6	2.1	1.5	10	10	10	16	1.6	1.0	9
	249	3.3	4.4	3.7	2.6	4.0	2.1	3.8	6.4	2.7	1.9	2.9	2.3	1.5	9	11	11	17	1.6	1.0	9
	253	3.2	4.4	4.2	2.5	3.5	2.2	4.1	6.8	3.0	1.8	2.6	2.0	1.6	11	11	11	16	1.3	.98	9
	255	3.1	4.3	4.1	2.5	3.6	2.1	4.0	6.0	3.9	1.9	2.6	1.8	1.5	10	12	11	17	1.4	.92	9
	269	3.1	4.3	4.1	2.5	3.7	2.0	3.8	6.4	3.0	1.9	2.6	1.9	1.4	10	11	11	16	1.4	.94	10
	270	3.1	4.4	4.1	2.6	3.7	2.1	4.0	6.5	2.9	1.8	2.6	1.9	1.5	10	12	11	17	1.4	1.0	9
	273	3.3	4.5	4.2	2.5	3.6	2.1	3.8	6.5	3.0	1.8	2.6	2.0	1.6	9	11	11	16	1.6	.96	9

TABLE 32.—*Records of the occurrence of Leucichthys reighardi in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of reighardi	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Washington Harbor, Mich.	1	Aug. 18, 1920	4 miles west of Boyer Bluff.	2⅜	18–24			(1)	7	
	2	do.	14 miles E. ¾ N. of Rock Island.	2½	30–50			(2)	1	
	3	do.	5 miles west of Boyer Bluff.	4	20	Rock		(3)		3
	4	do.	3 miles WNW. of Boyer Bluff.	4	20–24			(1)	1	
	5	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅝	71–90	Clay-mud	900	(1)	1	1
Sturgeon Bay, Wis.	6	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60–70	Mud	50	(1)	3	
Algoma, Wis.	7	Aug. 24, 1920	10 miles E. by N.	2½	35–50	Gravel-mud	310	(4)	12	4
Sheboygan, Wis.	8	Sept. 28, 1920	40 miles SE. by E.	3½	35–40				3	1
	9	do.	5 miles SE. by E.	1½	30–32			20	1	31
	10	Oct. 1, 1920	11 miles southeast	2½	60	Clay	200	(2)	12	
Port Washington, Wis.	11	Sept. 25, 1920	18 miles E. ½ S.	2½	65–48	do.	285	(1)	4	2
	12	do.	5 miles E. ½ S.	1½	30			(4)		
	13	May 26, 1921	8 miles northeast	2½	20–35	Mud		(2)	8	
Milwaukee, Wis.	14	Mar. 24, 1919		2½	50			(2)	2	
	15	Sept. 23, 1920	27 miles ESE.	2½	60	Red clay	250	(1)	2	
Racine, Wis.	16	Oct. 8, 1920		1½	30	Clay		(2)		
Michigan City, Ind.	17	Sept. 3, 1920	22 miles NW. by N. ½ N.	2½	30–40	do.		(1)	4	
	18	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Mud-clay	535	(1)	15	
	19	Nov. 8, 1920	18 miles NNW.	2½	30–38	Clay	1,000	(1)	6	1
	20	Nov. 19, 1920	17 miles NNW.	2½	28–32		700	(4)	8	
	21	Nov. 19, 1920	17½ miles NW. by N. ¾ N.	2½	32	Clay		(4)		
	22	Mar. 2, 1921	21 miles NNW.	2½	30	do.	1,000	16		
	23	do.	14 miles NNW.	1½	26	do.		(1)		3
	24	Mar. 4, 1921	15 miles NW. by N. ½ N.	2½	28		1,000	(1)	8	
	25	Apr. 1, 1921		2½	30	Clay	500	30	47	
Grand Haven, Mich.	26	Mar. 20, 1919	12 miles west	2¾	50–55	do.		(2)	6	1
Ludington, Mich.	27	Aug. 30, 1920	7 miles NW. by N.	4½	14–26			(3)	1	
Manistee, Mich.	28	Aug. 27, 1920	4 miles west	1½	28–35			(2)		3
	29	Aug. 28, 1920	9 miles northwest	4½	28–32			(1)	1	
Frankfort, Mich.	30	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60–70	Blue clay	1,400	(1)	4	1
Platte Bay, Mich. (field station).	31	July 21, 1923	1½ miles south of Otter Creek.	1½	8–12	Sand		(1)		
Northport, Mich.	32	June 22, 1920	5 miles northwest of Cathead Light.	2¾	40–60	Mud	200	(1)	8	
	33	June 23, 1920	Off Northport Point	1½	28–40	do.		30		48
	34	July 31, 1923	5 miles northwest of Cathead Light.	2¾	40–60	do.		41	92	2
Traverse City, Mich.	35	July 18, 1923	West Bay	1½	30–40	Clay				
	36	July 25, 1923	Off Lees Point	1½	6–16			(3)	1	3
Charlevoix, Mich.	37	June 29, 1920	5 miles N. by E.	2¾	40–55	Clay-mud		(1)	9	
	38	June 30, 1920	3 miles northwest	2¾	40–65	Clay		(2)	1	1
	39	Aug. 10, 1923	8 miles NNW. of Big Rock Point.	2¾	45–50	do.	480	(4)		
	40	Aug. 11, 1923	3 miles NW. ½ W.	2¾	35–60	Red clay	375	21	35	
	41	Aug. 21, 1923					100	(4)	3	
	42	May 3, 1924		2¾					43	
Manistique, Mich.	43	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60–70		200	(4)	5	1

1 Rare.
2 Lift not examined or percentage not ascertained.
3 Only specimens taken in lift.
4 Occasional.

TABLE 33.—*Numerical expressions of certain systematic characters for the type of Leucichthys reighardi and for 9 other specimens from Lake Michigan, 4 of them cotypes, over 200 millimeters long and for 10 other specimens under 200 millimeters long, selected according to size and locality*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	[1] 87351	Michigan City, Ind.	210	14+23	♀	74	4.4	6.0	10.9	9.9	3.1	7.2	4.2	6.7	1.6	2.3	3.1
	53080	do	223	14+25	♂	75	4.2	5.4	9.4	9.7	2.6	6.9	4.1	6.9	1.6	2.1	2.7
	53094	do	220	14+24	♀	77	4.4	5.9	11.2	9.6	2.9	7.5	4.4	7.3	1.6	2.2	2.9
	53104	do	234	13+22	♀	76	4.4	5.8	9.7	11.0	2.8	6.9	3.9	6.9	1.7	2.3	3.0
	53111	do	233	13+23	♀	75	4.3	5.8	10.0	10.0	2.7	7.0	4.0	6.6	1.6	2.1	2.9
	4684	Charlevoix, Mich.	226	14+22	♀	75	4.2	5.6	9.8	9.8	2.8	5.7	4.2	7.2	1.7	2.1	2.8
	4685	do	240	14+23	♀	71	4.6	5.9	10.0	9.4	3.0	7.5	4.1	7.5	1.8	2.3	3.0
	4686	do	238	13+24	♀	73	4.2	5.6	9.8	9.0	2.8	8.8	3.8	6.6	1.7	2.1	2.9
	4687	do	227	12+22	♀	74	4.2	5.5	9.0	9.8	2.9	7.5	4.3	7.5	1.7	2.0	2.7
	4688	do	233	13+22	♀	81	4.3	5.7	10.4	10.9	2.9	8.3	4.3	7.2	1.6	2.2	2.9
Under 200 millimeters.	3375	Manistee, Mich.	161	14+23	Im. ♂	73	4.2	5.6	10.5	8.9	2.9	8.9	4.2	10.5	2.1	2.1	2.8
	3376	do	166	14+26	♀	80	4.2	5.6	11.2	9.7	3.1	7.4	4.7	9.7	2.0	2.1	2.8
	3656	Port Washington, Wis.	182	14+25	♂	76	4.1	5.3	9.6	9.1	3.0	7.2	4.3	9.1	2.1	2.1	2.7
	3781	Sheboygan, Wis.	198	14+22	♂	79	4.6	6.2	11.3	9.0	3.0	7.3	4.7	8.4	1.7	2.2	3.0
	3786	do	186	13+21	♂	78	4.4	6.0	11.4	10.0	2.9	7.9	4.7	10.0	2.1	2.1	2.9
	3822	do	168	13+23	♀	68	4.4	6.0	11.2	11.0	3.1	8.0	4.4	9.3	2.1	2.2	3.0
	3825	do	191	13+23	♂	75	4.2	5.6	10.6	9.6	2.9	8.6	4.5	9.5	2.1	2.1	2.8
	3854	do	172	13+22	♂	74	4.4	5.9	10.1	10.1	2.9	8.0	4.1	10.1	2.4	2.1	2.8
	3856	do	183	14+23	♂	77	4.5	6.2	10.7	9.6	2.9	7.6	4.5	9.1	2.0	2.2	3.0
	4656	Michigan City, Ind.	172	13+23	♀	77	4.3	5.7	10.1	9.4	2.9	7.7	4.3	7.1	1.6	2.1	2.8

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	[1] 87351	3.4	4.6	3.8	2.7	3.8	2.1	3.1	6.7	2.8	2.0	2.8	2.1	1.4	9	10	11	16	1.6	1.0	9
	53080	3.1	3.9	4.0	2.6	3.7	2.1	3.2	6.5	3.1	2.0	2.9	2.0	1.5	9	11	10	16	1.4	1.0	9
	53094	3.5	4.6	4.1	2.8	3.7	2.1	3.7	5.9	3.1	2.1	2.8	2.3	1.7	9	11	11	16	1.5	.92	10
	53104	3.3	4.5	4.3	2.6	3.7	2.1	3.3	6.6	3.2	2.0	2.8	2.4	1.6	9	10	10	16	1.3	.90	10
	53111	3.2	4.3	4.1	2.7	3.8	2.1	3.3	6.7	3.0	2.0	2.8	2.1	1.7	10	11	12	17	1.4	.95	9
	4684	3.3	4.3	4.1	2.7	3.8	2.1	3.2	5.1	3.1	2.0	2.8	2.0	1.5	10	12	11	16	1.5	1.0	8
	4685	3.5	4.5	3.9	2.7	3.6	2.0	3.0	6.1	3.0	2.0	2.8	2.2	1.5	9	11	11	16	1.4	.90	9
	4686	3.3	4.4	4.0	2.8	3.8	2.1	3.6	6.0	3.0	2.1	2.8	2.3	1.5	10	11	12	15	1.3	.90	9
	4687	3.3	4.3	4.0	2.7	3.6	2.0	3.3	7.0	3.1	2.0	2.7	2.0	1.6	9	12	11	16	1.4	.86	9
	4688	3.5	4.6	4.0	2.8	3.7	2.1	3.7	5.4	3.1	2.1	2.8	2.5	1.6	9	11	12	16	1.4	1.0	9
Under 200 millimeters.	3375	3.1	4.1	3.8	2.6	3.7	2.1	3.4	6.0	2.9	2.0	2.8	2.0	1.4	9	11	11	16	1.6	.84	9
	3376	3.2	4.3	3.8	2.7	4.1	2.0	3.2	5.6	2.8	2.0	3.1	2.3	1.4	9	11	10	16	1.7	.92	8
	3656	3.1	4.0	3.8	2.5	3.6	2.0	3.1	5.5	2.9	2.0	2.8	1.9	1.2	9	11	11	16	1.6	1.0	8
	3781	3.4	4.6	4.0	2.6	3.9	2.0	3.0	6.1	3.0	1.9	2.9	2.4	1.5	9	11	11	16	1.6	.86	8
	3786	3.3	4.5	3.9	2.7	3.8	2.1	3.7	6.9	2.9	2.0	2.8	2.2	1.7	9	11	11	15	1.6	.91	9
	3822	3.5	4.7	3.8	2.8	4.0	2.1	3.7	6.3	2.8	2.0	2.9	2.1	1.6	10	10	11	15	1.7	1.1	9
	3825	3.3	4.4	3.9	2.8	4.0	2.1	4.0	6.9	2.9	2.1	3.0	2.0	1.5	9	11	11	17	1.5	1.0	9
	3854	3.3	4.4	3.9	2.7	3.6	2.0	3.5	6.2	2.9	2.0	2.7	2.3	1.6	10	11	11	15	1.4	.95	8
	3856	3.2	4.4	3.8	2.7	4.3	2.0	3.3	5.8	2.7	1.9	3.1	2.0	1.4	9	11	11	17	1.6	1.1	9
	4656	3.2	4.3	4.0	2.8	4.0	2.1	3.7	6.4	3.0	2.1	3.0	2.2	1.6	10	11	10	16	1.5	.94	9

[1] Type, U. S. National Museum number.

TABLE 34.—*Records of the occurrence of Leucichthys reighardi dymondi in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.[1]	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined	
					+200 mm.	−200 mm.
1	Aug. 9, 1921	Off Macdiarmid		10–15	1	2
2	July 26, 1922	do	2½, 2¾	30	35	1
3	Aug. 4, 1923	do		7	2	
4	Sept. 8, 1923	do		6		1
5	Sept. 10, 1923	do				1
6	Sept. 6, 1923	Off Selwyn Island				1
7	Sept. 3, 1923	Humboldt Bay		6–35	2	1
8	Sept. 5, 1923	Off McKellar Island			1	1
9	June 19, 1924	Ombabika Bay		10	1	
10	Aug. 17, 1921	Off Whitesand River		25	3	1
11	June 30, 1921	Off Frog Island		25		1
12	Aug. 23, 1921	Grand Bay		10		1
13	Aug. 1, 1922	do	4½	15–20	1	1
14	July 17, 1924	do		20	2	
15	Aug. 25, 1921	Off source of Nipigon River		12	3	
16	July 25, 1922	do	2½, 2¾	10–15	27	1
17	July 19, 1924	do		15	4	
18	Aug. 27, 1921	Sandy Bay		5–8	1	2
19	July 23, 1924	do		11	2	
20	Aug. 15, 1922	Unknown		20–25	1	
21	Oct. 26, 1922	do	4½		3	2

[1] All but records 2, 13, 16, and 21 are from University of Toronto collections.

TABLE 35.—*Numerical expressions of certain systematic characters for the type of the dymondi form of Leucichthys reighardi from Lake Nipigon and for 17 cotypes, half over 200 millimeters and half under 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	57273	Nipigon River source.	211	13+22	♀	72	3.9	5.1	8.7	9.5	2.7	7.8	3.8	8.1	2.1	1.9	2.5
	57301	do	238	12+22	♂	73	3.9	4.8	8.8	9.0	3.0	8.0	4.0	8.8	2.1	2.0	2.4
	57304	do	268	13+21	♂	71	3.9	5.1	9.7	9.9	2.9	7.4	3.8	9.2	2.4	2.0	2.6
	57309	do	261	12+21	♂	68	3.8	5.1	8.0	9.0	2.9	8.7	3.7	8.4	2.2	1.9	2.5
	[1] 57467	Macdiarmid, Ontario.	227	12+20	♀	69	3.7	4.9	9.0	9.1	2.9	8.4	3.8	8.7	2.2	1.8	2.4
	57499	do	225	12+23	♂	71	4.0	5.1	8.3	8.2	2.8	9.3	3.8	8.3	2.1	1.9	2.5
	57501	do	238	13+22	♀	70	3.7	5.1	8.5	8.5	3.0	7.6	3.9	8.8	2.2	1.9	2.6
	57595	do	223	13+22	♀	64	3.5	4.6	9.6	9.7	3.0	8.2	3.7	8.2	2.2	1.8	2.4
	57657	do	225	13+21	♀	70	3.7	5.1	9.6	8.8	2.7	9.0	3.7	8.0	2.1	1.9	2.6
Under 200 millimeters.	57267	Nipigon River source.	197	13+23	♂	68	3.6	4.6	8.7	8.2	2.7	7.8	3.9	8.5	2.1	1.8	2.4
	57667	Macdiarmid, Ontario.	169	13+21	Im. ♂	71	3.8	4.9	8.6	8.8	2.8	8.0	4.1	8.8	2.1	1.9	2.5
	57721	do	200	13+23	Im. ♀	74	3.9	5.0	10.5	9.5	2.9	8.6	4.3	9.3	2.1	2.0	2.6
	63069	(?)	190	11+21	♂	67	3.9	5.0	9.5	9.5	3.0	8.2	4.2	7.0	1.6	1.9	2.5
	63076	(?)	195	13+21	♀	70	3.7	4.7	8.8	9.2	2.9	7.8	3.8	6.7	1.7	1.9	2.3
	N70	Orient Bay	181	12+23	♂	66	3.6	5.0	8.9	9.5	2.9	8.6	3.9	9.0	2.3	1.8	2.5
	N105	Sandy Bay	185	13+22	♀	72	3.9	5.4	10.0	9.8	2.9	7.4	4.0	9.2	2.3	1.9	2.6
	N1019	Humboldt Bay.	175	13+22	♂	73	3.9	5.1	9.7	10.1	2.9	8.3	3.8	9.2	2.3	2.0	2.5
	N1077	Orient Bay	145	13+21	Im. ♀	74	3.6	4.8	10.3	10.2	3.0	7.6	4.8	9.0	1.8	1.8	2.4

[1] Type, U. S. National Museum No. 88353.

TABLE 35.—*Numerical expressions of certain systematic characters for the type of the dymondi form of Leucichthys reighardi from Lake Nipigon and for 17 cotypes, half over 200 millimeters and half under 200 millimeters long, selected according to size*—Continued

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	57273	3.0	3.9	4.0	2.6	3.5	1.8	3.1	5.3	3.1	2.0	2.7	1.7	1.6	11	11	10	15	1.4	1.1	9
	57301	3.0	3.7	4.0	2.4	3.5	2.0	3.3	5.3	3.2	1.9	2.8	1.7	1.3	11	12	11	16	1.6	1.1	9
	57304	3.0	3.9	4.5	2.5	3.5	1.9	3.0	5.6	3.4	1.9	2.7	1.6	1.3	11	12	11	16	1.7	1.1	9
	57309	3.0	4.0	4.4	2.5	3.6	2.0	3.3	6.5	3.4	1.9	2.8	1.5	1.6	11	11	11	15	1.4	1.0	9
	[1] 57467	2.9	3.9	4.2	2.3	3.5	1.9	3.2	5.0	3.2	1.7	2.6	1.6	1.5	10	12	11	16	1.5	1.0	9
	57499	3.1	4.0	4.0	2.5	3.4	1.9	3.5	6.0	3.1	1.9	2.6	1.8	1.6	11	12	11	16	1.4	.96	9
	57501	2.9	4.0	4.2	2.5	3.6	1.9	4.0	5.6	3.1	1.8	2.6	1.9	1.5	11	12	11	16	1.5	.99	10
	57595	2.8	3.7	4.1	2.4	3.6	1.9	3.4	5.6	3.2	1.9	2.7	1.8	1.5	10	11	11	16	1.6	1.0	10
	57657	2.9	4.0	4.0	2.5	4.0	2.0	3.6	5.8	2.9	1.9	2.9	1.5	1.5	9	11	11	16	1.6	1.0	10
Under 200 millimeters.	57267	2.8	3.7	3.8	2.4	3.6	1.8	3.3	4.8	3.0	1.8	2.8	1.6	1.4	10	11	11	16	1.6	1.0	9
	57667	2.9	3.7	3.7	2.4	3.7	1.8	3.6	5.6	2.8	1.8	2.8	1.5	1.4	10	12	11	17	1.6	1.0	9
	57721	3.0	4.0	3.9	2.4	3.6	1.9	3.9	5.3	3.0	1.8	2.8	1.7	1.4	10	10	11	16	1.9	1.1	10
	63069	3.1	3.7	3.9	2.4	3.6	1.9	3.2	5.1	3.1	1.8	2.8	1.5	1.5	10	11	10	15	1.8	1.1	9
	63076	3.0	3.8	3.7	2.3	3.4	1.8	3.6	5.0	3.0	1.9	2.7	1.8	1.5	10	10	11	16	1.5	1.0	9
	N70	2.8	3.8	4.0	2.4	3.8	2.0	3.5	4.8	2.9	1.8	2.8	1.6	1.4	10	11	11	16	1.4	1.1	9
	N105	3.0	4.1	3.9	2.5	3.9	1.9	3.0	5.7	2.8	1.8	2.8	1.8	1.5	10	12	11	16	1.9	1.1	8
	N1019	3.0	4.0	3.7	2.5	3.7	1.9	3.6	5.1	2.8	1.9	2.8	1.8	1.4	10	10	11	15	1.8	1.1	10
	N1077	2.8	3.7	3.7	2.6	3.7	2.0	3.5	5.1	2.7	1.9	2.7	1.6	1.3	9	10	11	16	2.0	1.2	10

[1] Type, U. S. National Museum No. 88353.

TABLE 36.—*Records of the occurrence of Leucichthys reighardi dymondi in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water and character of the bottom where made, the abundance of this species in the lift, and the number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Percentage of reighardi	Preserved specimens examined, +200 mm.
Ontonagon, Mich.	1	Aug. 24, 1921	21 miles west	2½, 2¾	15–45	Red clay	(1)	4
	2	Aug. 25, 1921	6 miles NNW	2½, 2¾	20–38	Sand, clay	(1)	1
Apostle Islands, Wis.	3	July 11, 1922	Between Cat and South Twin Islands.	2½, 2¾	15–20	Sand	(1)	2
Duluth, Minn.	4	July 17, 1922	20 miles NE. by E.	2⅝	30–40	do	(2)	
Grand Marais, Minn.	5	Sept. 14, 1921	Off Terrace Point	2½, 2¾	30–65	Clay	(1)	2
Port Arthur, Ontario.	6	July 20, 1922	Black Bay	(3)	8	Mud	(1)	3
	7	Nov. 25, 1922	Thunder Bay, between Pie and Welcome Islands.	2½			(4)	199
	8	Sept. 15, 1923	North of Silver Island	2½	14	Mud	65	21
	9	do	Thunder Bay, off Thunder Cape.	2½	31	Brownish-gray clay.	50	33
	10	Sept. 17, 1923	Thunder Bay, north of Welcome Islands.	2½	11	do	81	14
	11	do	Thunder Bay, south of Welcome Islands.	2½	23	Clay	92	28
	12	Sept. 19, 1923	Thunder Bay, off Sawyer Bay.	2½	49	Brownish-gray clay.	32	15
Rossport, Ontario	13	Mar. 10, 1922		2½			(4)	1
	14	Aug. 5, 1922	Moffat Strait	(3)	4		(1)	7
	15	do	Armour Harbor	(3)	4		(1)	1
	16	Aug. 10, 1922	Moffat Strait	(3)	4		(1)	5
	17	do	Crow Point	(3)	4		(1)	1
	18	Sept. 25, 1923	Moffat Strait	2½	13–14	Clay, sand	17	5
	19	Sept. 29, 1923	Off Salter Island	2½	42	Clay	(1)	4

[1] Only specimens taken in lift. [2] Rare. [3] Pound net. [4] Lift not examined.

Table 37.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys reighardi dymondi from Lake Superior, selected at random*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
59139	Port Arthur, Ontario	225	13+23	♂	68	4.0	5.5	9.7	8.6	2.8	8.5	4.2	7.7	1.8	1.9	2.6	3.0
59162	do	215	14+23	♀	68	3.9	5.5	9.6	9.7	2.9	7.4	3.7	7.6	2.0	1.9	2.7	3.0
59174	do	235	13+24	♂	72	4.1	5.8	10.9	10.6	2.6	7.1	4.4	8.3	1.8	2.0	2.8	3.2
59180	do	223	13+21	♂	69	3.9	5.3	8.5	9.7	2.7	7.1	4.3	7.1	1.6	2.0	2.6	2.9
59181	do	223	13+24	♀	73	4.0	5.3	9.6	8.9	2.6	7.3	4.1	8.2	2.0	1.8	2.4	3.0
59186	do	217	13+23	♂	71	3.8	5.2	9.8	9.0	2.9	7.9	3.9	7.4	1.8	1.9	2.6	3.0
59197	do	222	12+24	♀	74	3.8	5.1	8.7	10.0	2.7	8.5	4.0	8.2	2.0	2.0	2.6	2.9
59198	do	235	13+21	♀	74	4.1	5.5	9.4	9.8	2.7	7.5	4.1	8.7	2.1	2.0	2.7	3.1
59208	do	211	13+21	♂	73	4.0	5.3	8.7	8.3	2.8	9.1	3.9	7.5	1.9	2.0	2.6	3.1
59218	do	237	12+23	♂	73	3.8	5.6	9.1	8.5	2.8	8.7	4.0	7.4	1.8	1.9	2.7	3.0

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AO	Br
59139	Port Arthur, Ontario	4.1	4.0	2.5	3.7	2.1	3.5	6.3	2.9	1.8	2.7	1.8	1.5	10	12	11	16	1.6	0.89	9
59162	do	4.2	3.9	2.6	4.1	2.0	3.8	5.5	2.8	1.8	2.9	1.7	1.5	11	12	12	16	1.7	1.0	9
59174	do	4.5	4.0	2.5	3.8	2.0	3.5	5.6	2.8	1.8	2.7	1.9	1.4	11	12	12	17	1.8	1.0	10
59180	do	3.9	3.9	2.5	3.8	2.0	3.2	5.5	2.9	1.9	2.8	1.7	1.4	11	11	11	17	1.4	1.0	9
59181	do	4.0	4.1	2.5	3.7	2.0	4.2	5.6	3.0	1.8	2.8	2.0	1.5	10	13	12	17	1.4	.86	10
59186	do	4.1	4.1	2.4	3.6	2.1	3.7	5.9	3.0	1.8	2.7	1.7	1.3	11	12	11	15	1.7	1.0	9
59197	do	3.9	4.0	2.5	3.5	2.0	4.0	5.7	3.0	1.8	2.6	1.8	1.3	10	11	11	14	1.4	1.0	9
59198	do	4.3	4.0	2.5	3.8	2.0	3.6	5.7	3.0	1.8	2.8	1.9	1.5	10	12	11	15	1.4	.91	9
59208	do	4.1	3.9	2.5	3.7	2.0	3.6	5.7	2.9	1.9	2.8	1.8	1.6	10	11	12	17	1.4	1.0	8
59218	do	4.4	4.3	2.5	4.0	2.1	4.0	5.4	3.0	1.7	2.7	1.6	1.6	10	12	11	16	1.4	.92	9

Table 38.—*Records of the occurrence of Leucichthys reighardi in Lake Ontario*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the abundance of this species in the lift, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Brighton, Ontario	1	June 10, 1921	20 miles S. by W. from the light.	2½	40–50	Mud	Common	18	------
	2	June 16, 1921	do	2½	40–50	do	do	16	------
Sandy Pond, N. Y.	3	Aug. 24, 1923	9 miles west	3	25–30	do	Occasional	13	------
	4	Aug. 30, 1923	14 miles west	2½, 3½	60	Clay and mud.	do	10	------
Selkirk, N. Y.	5	July 11, 1921	5 miles NNW. off Nine-Mile Point.	3	25–35	Blue clay	Rare	4	------
Oswego, N. Y.	6	Sept. 1, 1923	Off Nine-Mile Point	3	30	Brown clay	Common	1	------
Sodus Point, N. Y.	7	July 12, 1921	8½ miles NNW	2½, 2¾	60	Mud and clay.	Rare	3	------
Charlotte, N. Y.	8	July 4, 1921	7 miles off Braddock Point Light.	2½, 2¾	65	Blue and brown clay	do	1	------
Wilson, N. Y.	9	June 23, 1921	3 miles north	2½, 2¾	30	Brown clay	do	2	------
	10	July 19, 1921	6½ miles N. by W. ½ W	2½, 2¾	65	do	do	2	------
	11	July 21, 1921	2 miles north	2½	20	------------	Common	6	2

TABLE 39.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys reighardi from Lake Ontario, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O
53166	Brighton, Ontario	225	13+25	♂	85	4.7	6.4	9.6	10.0	2.8	7.7	4.5	9.0	1.9	2.3	3.1	3.7	4.9
53179	do	228	12+22	♂	80	4.6	6.1	9.9	9.8	2.9	7.3	4.6	8.7	1.8	2.2	3.0	3.5	4.7
53934	do	216	13+23	♂	76	4.5	6.3	9.7	9.1	2.7	7.4	4.4	8.6	1.9	2.3	3.1	3.5	4.8
53937	do	240	14+23	♀	76	4.7	6.4	10.3	10.0	2.7	8.0	4.2	8.0	1.9	2.4	3.3	3.6	4.9
53942	do	215	14+23	♂	75	4.3	5.9	10.2	9.3	3.0	7.6	4.0	7.6	1.8	2.0	2.7	3.4	4.7
53952	do	240	12+21	♂	74	4.5	6.1	10.4	10.9	2.7	8.0	4.1	8.5	2.0	2.3	3.2	3.4	4.7
53956	do	257	13+23	♂	78	4.6	6.4	10.7	9.1	2.8	8.2	3.7	7.3	1.9	2.3	3.2	3.7	5.1
53982	Wilson, N.Y.	208	14+24	♀	72	4.3	5.9	10.9	9.5	2.8	7.1	4.3	7.4	1.7	2.2	3.0	3.3	4.5
53996	do	203	14+24	♀	80	4.5	6.0	10.5	9.2	2.9	7.8	4.6	7.2	1.5	2.2	2.9	3.5	4.7
54080	do	240	13+24	♂	75	4.6	5.9	10.5	9.5	2.8	8.4	4.0	7.5	1.8	2.4	3.1	3.4	4.5

Field No.	Locality	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
53166	Brighton, Ontario	4.2	2.8	3.9	2.1	3.3	5.7	3.1	2.1	2.9	2.5	1.8	11	10	11	15	1.2	0.92	9
53179	do	4.1	2.8	3.8	2.2	2.7	7.9	3.1	2.1	2.8	2.2	1.6	11	11	11	16	1.4	1.0	9
53934	do	4.0	2.9	3.6	2.1	3.1	6.7	2.9	2.1	2.6	2.3	1.5	10	12	11	17	1.4	.89	7
53937	do	4.2	2.8	3.8	2.1	4.2	7.0	3.1	2.0	2.8	2.7	1.5	10	11	11	17	1.4	1.0	9
53942	do	4.2	2.9	4.0	2.1	3.2	6.1	3.1	2.1	3.0	2.3	1.7	9	11	11	15	1.4	.94	9
53952	do	4.4	2.8	3.7	2.3	3.3	7.0	3.2	2.0	2.7	2.1	1.4	9	9	11	16	1.6	1.1	8
53956	do	4.2	2.7	3.9	2.1	3.6	7.6	3.0	2.0	2.8	2.3	1.6	8	11	12	16	1.5	.96	9
53982	Wilson, N. Y.	4.2	2.9	4.2	2.1	3.4	6.8	3.1	2.1	3.1	2.3	1.5	9	12	10	16	1.6	.96	8
53996	do	4.2	2.8	3.7	2.1	3.1	6.5	3.0	2.1	2.8	2.4	1.6	11	12	10	16	1.4	.90	9
54080	do	4.3	2.6	3.4	2.1	3.2	6.4	3.3	2.0	2.6	2.4	1.4	9	10	11	15	1.4	.90	8

TABLE 40.—*Records of the occurrence of Leucichthys nigripinnis in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of nigripinnis	Preserved specimens examined
Washington Harbor, Wis.	1	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅝	71–90	Clay, mud.	900	(1)	2
Sturgeon Bay, Wis	2	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60–70	Mud	50	(1)	1
Port Washington, Wis.	3	Sept. 25, 1920	18 miles E. ½ S	2½	65–48	Clay	285	(1)	2
	4	May 26, 1922	24 miles E. by N	3½	60–80	Mud		(2)	5
Milwaukee, Wis	5	Mar. 24, 1919		2½	50			(2)	5
	6	Sept. 23, 1920	27 miles ESE	2½	60	Red clay	250	(1)	2
Wm. Lahmann [3]	7	December–January.	40 miles ESE		80–90				
C. Tamms	8	April–June	do	3½	80–90				
Racine, Wis.; C. Hyttel, sr.	9	January	Off city	3½	60				
Michigan City, Ind	10	Sept. 3, 1920	22 miles NW. by N. ½ N.	2½	30–40	Clay		(1)	1
	11	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Mud, clay	535	(1)	
Grand Haven, Mich	12	Mar. 20, 1919	12 miles west	2¾	50–55	Clay		(2)	5
Ludington, Mich	13	Aug. 30, 1920	17 miles W. ½ S	2¾	60–70	do		(2)	4
Manistee, Mich., Peter Petersen; Hans P. Petersen.	14	December–January.	5–8 miles west	4⅛	40–80	do			
Frankfort, Mich	15	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60–70	Blue clay	1,400	(1)	1
Northport, Mich	16	June 22, 1920	5 miles northwest of Cathead Light.	2¾	40–60	Mud	200	(1)	4
	17	July 31, 1923	do	2¾	40–60	do		(1)	13
Charlevoix, Mich	18	June 30, 1920	3 miles northwest	2¾	40–65	Clay		(2)	1
	19	Aug. 11, 1923	3 miles NW. ½ W	2¾	35–60	Red clay	375	(1)	3
Manistique, Mich	20	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60–70		200	(1)	1
Chicago, Ill. [4]									1

[1] Rare.
[2] Lift not examined or percentage not ascertained.
[3] See note, Table 20.
[4] Field Museum collection, borrowed specimens.

TABLE 41.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys nigripinnis from Lake Michigan, selected according to locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
1564	Grand Haven, Mich.	272	18+31	♀	81	4.3	5.7	8.0	9.0	2.5	8.3	3.4	6.4	1.9	2.1	2.8	3.2
1684	Milwaukee, Wis.	274	18+32	Im. ♂	86	4.4	6.0	9.4	8.8	2.7	7.7	3.4	6.8	2.0	2.1	3.0	3.3
1686	do	265	19+31	Im. ♀	81	4.4	6.3	9.8	9.2	2.9	7.6	3.8	6.4	1.6	2.1	3.0	3.3
2891	Charlevoix, Mich.	286	16+30	♀	77	4.1	5.6	9.1	8.6	2.8	8.1	3.5	7.1	2.0	2.0	2.7	3.2
3203	Washington Harbor, Wis.	262	16+30	♂	81	4.3	5.6	9.7	8.4	2.7	8.8	3.9	8.4	2.1	2.1	2.7	3.2
3305	Sturgeon Bay, Wis.	254	19+29	♂	78	4.1	5.4	8.7	8.7	2.7	7.6	4.1	7.9	1.9	2.0	2.7	3.1
3397	Ludington, Mich.	294	19+32	♂	85	4.2	6.0	9.7	8.8	2.9	7.3	4.2	8.9	2.0	2.0	2.8	3.2
3550	Michigan City, Ind.	259	18+34	Im. ♀	83	4.3	6.1	9.5	8.6	2.7	7.6	4.1	8.0	1.9	2.1	3.0	3.3
3684	Port Washington, Wis.	294	16+28	♀	82	4.4	6.2	8.9	9.2	2.7	7.7	3.8	7.7	2.0	2.1	3.0	3.3
3987	Frankfort, Mich.	300	17+30	♀	87	4.4	6.0	8.8	9.4	2.6	7.7	3.9	7.9	1.9	2.2	3.0	3.4

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
1564	Grand Haven, Mich.	4.3	4.3	2.7	3.8	2.0	3.9	5.1	3.2	2.0	2.9	1.8	1.3	11	12	12	17	1.3	1.0	8
1684	Milwaukee, Wis.	4.6	4.2	2.6	3.7	2.0	3.3	5.6	3.1	1.8	2.7	1.8	1.4	10	12	12	17	1.5	1.0	9
1686	do	4.7	4.4	2.6	3.7	2.0	3.2	4.9	3.1	1.8	2.6	1.8	1.4	10	11	12	15	1.7	1.0	8
2891	Charlevoix, Mich.	4.3	4.4	2.7	3.7	2.0	3.4	6.8	3.2	2.0	2.7	1.7	1.4	10	12	11	18	1.6	.99	10
3203	Washington Harbor, Wis.	4.2	4.0	2.7	3.5	2.0	3.5	5.5	3.1	2.0	2.7	1.6	1.5	10	13	11	17	1.8	.94	8
3305	Sturgeon Bay, Wis.	4.2	4.2	2.6	3.6	2.0	3.3	5.0	3.1	2.0	2.8	1.6	1.3	11	12	12	18	1.5	1.0	8
3397	Ludington, Mich.	4.5	4.3	2.7	3.9	2.0	3.2	5.5	3.0	1.9	2.8	1.6	1.4	10	12	11	15	1.7	1.0	9
3550	Michigan City, Ind.	4.7	4.3	2.7	3.9	2.0	3.3	5.9	3.0	1.9	2.7	1.6	1.4	10	13	11	16	1.6	.93	9
3684	Port Washington, Wis.	4.7	4.4	2.6	4.1	1.9	2.9	5.4	3.1	1.8	2.9	1.8	1.3	10	12	11	17	1.5	1.0	9
3987	Frankfort, Mich.	4.6	4.4	2.6	3.7	2.0	3.3	6.0	3.2	1.9	2.7	1.7	1.5	10	11	12	17	1.5	.99	9

TABLE 42.—*Records of the occurrence of Leucichthys nigripinnis in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined, +200 mm.
Lake Huron proper:									
Cheboygan, Mich.	1	July 21, 1917	5 miles north of Spectacle Reef	2¾	35- 50	Clay		(1)	1
Rogers, Mich.	2	July 24, 1917		2¾	60- 70	do		(2)	3
Alpena, Mich.	3	Aug. 13, 1917	38 miles east of can buoy	2¾	70- 80	do	1,470	(2)	10
	4	Sept. 7, 1917	Center of lake east of can buoy	2¾	70- 80	do	3,250	45	3
	5	Sept. 10, 1917	Center of lake northeast of can buoy.	2¾	60- 70	do	1,300	12	
	6	Sept. 12, 1917	Center of lake east of can buoy	2¾	65- 80	do	2,610	30	
	7	Sept. 14, 1917	Center of lake northeast of can buoy.	2¾	65- 80	do	1,200	10	1
	8	Sept. 17, 1917	do	2¾	60- 70	do		18	
	9	Sept. 21, 1917	Center of lake east of can buoy	2¾	65- 70	do		55	9
	10	Sept. 24, 1917	do	2¾	65- 80	do		63	
	11	Sept. 26, 1917	do	2¾	65- 80	do		30	
	12	Oct. 17, 1917	do	2¾	65- 80	do		45	4
	13	Oct. 20, 1917	do	2¾	65- 80	do		55	8
	14	Aug. 30, 1919	18 miles N. by E. ½ E. of Thunder Bay Island.	2¾	60- 64	do		10	2
	15	Sept. 3, 1919	28 miles E.¼ S. of can buoy	2¾	60- 64	do		10	2
	16	Aug. 7, 1920	19 miles NE.½N. of Thunder Bay Island.	2¾	60- 65	do	3,500	5	
	17	June 28, 1923	19 miles northeast of Thunder Bay Island.	2¾	60- 70		2,100	75	

[1] Rare.
[2] Lift not examined or percentage not ascertained.

TABLE 42.—*Records of the occurrence of Leucichthys nigripinnis in Lake Huron*—Continued

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined, +200 mm.
Lake Huron proper—Continued.									
Alpena, Mich	18	June 30, 1923	17 miles NE. by N.¾N. of Thunder Bay Island.	2¾	65– 70	Clay	1,600	24	7
	19	July 2, 1923	20 miles E. by N. of can buoy	2¾	60– 70	do	2,000	82	3
	20	July 5, 1923	18 miles NE.¾E. of Thunder Bay Island.	2¾	80–100	do	6,000	90	7
	21	July 7, 1923	13 miles NE.½N. of Thunder Bay Island.	2¾	60	do	1,400	15	2
Harbor Beach, Mich.	22	Oct. 27, 1917	35 miles NE. by N.¾N. of city	2¾	50	do	1,183	(1)	1
Georgian Bay:									
Lions Head, Ontario.	23	July 30, 1919	21 miles east of Surprise Shoal	3	60	Mud	400	(1)	5
	24	Oct. 6, 1919	Off White Bluff	3	70	do	425	95	10
Wiarton, Ontario	25	Nov. 6, 1917	6½ miles northeast of Griffith Island.	3	45–60	do		(2)	2
	26	July 28, 1919	Off Cape Croker	3	52	do	500	(1)	4
	27	June 10, 1922	do	3				(2)	47
	28	June 26, 1923	do	3				(2)	3

[1] Rare. [2] Lift not examined or percentage not ascertained.

TABLE 43.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys nigripinnis from Lake Huron, selected according to size*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
129	Alpena, Mich	320	♀	16+28	78	4.3	6.0	9.3	9.3	2.9	8.0	3.5	7.2	2.0	2.1	2.9	3.4
130	do	340	♀	19+32	80	4.2	5.6	8.9	9.7	2.6	8.5	3.4	6.1	1.7	2.1	2.8	3.3
204	do	290	♂	18+33	77	4.1	5.6	8.0	8.3	2.7	8.2	4.1	8.0	1.9	2.0	2.8	3.1
205	do	312	♀	16+30	79	4.1	5.5	8.7	9.6	2.6	7.8	3.6	7.4	1.9	2.0	2.7	3.1
763	do	304	♂	16+31	82	3.9	5.5	8.7	9.3	2.8	8.3	3.8	8.0	2.1	1.8	2.6	3.0
770	do	297	♂	17+30	83	4.1	5.5	8.7	8.2	2.8	7.7	3.5	7.4	2.1	2.0	2.6	3.0
771	do	302	♀	17+30	78	4.0	5.5	7.7	7.3	2.5	7.7	3.6	7.4	2.0	1.9	2.7	2.9
772	do	303	♀	18+32	85	4.0	5.7	8.8	8.3	2.7	8.1	3.9	7.9	2.0	2.0	2.8	3.1
800	do	255	♀	18+32	77	4.0	5.6	8.9	9.1	2.9	9.0	4.2	7.8	1.8	2.0	2.7	3.1
965	do	314	♀	17+30	85	4.1	5.7	9.5	9.3	2.7	7.8	4.0	6.5	1.6	1.9	2.7	3.1

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
129	Alpena, Mich	4.7	4.1	2.6	3.6	1.9	3.6	4.7	3.0	1.8	2.6	1.7	1.4	10	11	12	16	1.6	1.0	9
130	do	4.4	4.2	2.7	3.6	2.0	3.7	5.3	3.2	2.0	2.7	1.8	1.6	10	11	11	18	1.3	.97	10
204	do	4.3	4.0	2.5	3.7	1.9	3.6	4.6	3.0	1.9	2.7	1.6	1.3	11	13	12	16	1.4	.94	8
205	do	4.2	4.1	2.6	3.5	2.0	3.5	5.1	3.0	1.9	2.6	1.7	1.5	10	11	12	15	1.4	1.0	9
763	do	4.3	4.1	2.7	3.7	2.1	3.7	4.2	2.9	1.9	2.6	1.6	1.5	10	12	11	18	1.5	.98	9
770	do	4.1	3.9	2.5	3.5	1.9	3.2	4.5	2.9	1.8	2.6	1.6	1.0	11	12	11	17	1.5	.97	9
771	do	4.1	4.0	2.5	3.7	1.9	3.4	4.5	2.8	1.8	2.7	1.5	1.3	11	13	11	17	1.3	.84	10
772	do	4.3	4.2	2.6	3.8	2.0	3.2	4.2	3.0	1.9	2.7	1.7	1.3	11	11	12	17	1.4	.92	10
800	do	4.4	4.1	2.4	3.6	1.9	3.9	6.2	3.0	1.8	2.6	1.7	1.3	10	11	11	16	1.5	.92	9
965	do	4.3	4.1	2.6	3.8	2.0	3.6	4.8	3.0	1.9	2.8	1.7	1.3	10	11	12	17	1.6	1.0	8

TABLE 44.—*Records of the occurrence of Leucichthys nigripinnis cyanopterus in Lake Superior*

[For each record is given, if known, the date and locality, the kind and quantity of gear used to make it, the depth of the water and the character of bottom where made, the number of the fish gilled in the netting, the percentage of this species among them, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth in fathoms	Bottom	Length of net, in feet	Nights set	Number of fish gilled	Percentage of nigripinnis	Preserved specimens examined[1]
Sault Ste. Marie, Mich.	1	June 14, 1922	10 miles NW. by W. ¼ W. of Point Iroquois Light in Whitefish Bay.	2½, 2¾	38		1,800	2	200	1	2
Grand Marais, Mich.	2	Oct. 3, 1917		4½	+65						25
Chas. Macdonald,[2] Joseph Desjardins.	3	April – October, up to about 1907.		3¼	+65	Clay					
Marquette, Mich.	4	Aug. 5, 1921	31 miles N. ¾ E	4½	100	Reddish-brown clay.					10
	5	Aug. 8, 1921	6 miles NE. ¾ N	2½, 2¾	42–65	Red clay	2,500	5	250	3	7
	6	Aug. 11, 1921	18 miles NE. by N	2½, 2¾	100–80		2,500	7	200	10	20
	7	1923									10
	8	November, 1925									2
W. J. Parker	9	April–August		3¼	60–100	Clay					
Ontonagon, Mich.	10	Aug. 16, 1921	54 miles W. by N	4½	25–80						1
	11	Aug. 25, 1921	6 miles NNW	2½, 2¾	20–38	Sand, clay	2,500	7	500	0.2	1
K. McLean	12	April–Nov. 1	Off city	3½	60–100	Clay					
Apostle Islands, Wis.	13	July 11, 1922	Between Cat and South Twin Islands.	2½, 2¾	15–20	Sand	2,200	1	300	.3	1
	14	July 14, 1922	25 miles north of South Twin Island.	4½	50–90	Red and yellow clay.					2
	15	July 15, 1922	20 miles northwest of Rocky Island.	4½	35–65	Clay					1
Duluth, Minn	16	July 17, 1922	20 miles NE. by E	2⅝	30–40	Sand					2
Grand Marais, Minn.	17	Sept. 14, 1921	Off Terrace Point	2½, 2¾	30–65	Clay	3,500	7	2,000	.15	3
	18	July 17, 1922	do	4½	30–65	do					1
James Scott	19	April – October, 1903–1906.	5–6 miles off the coast	3½	80–90	do					
Rossport, Ontario.	20	Oct. 4, 1921	Off Bread Rock	2½, 2¾	80–90	Grayish-brown clay.	1,000	4	210	10	23
Port Coldwell, Ontario.	21	Oct. 22, 1923		4½							5
Michipicoten Island, Ontario.	22	June 19, 1922	6 miles northeast of East-End Light.	4½	15–35						6
	23	June 22, 1922	3 miles SE. ½ S. of Quebec Harbor Light.	2½, 2¾	80	Blue clay	2,500	3	75	21	16
John McMillan. Luther McArthur.	24	1900–1903	Northwest and south of the island.	3½	60–110	Clay					
Coppermine Point, Ontario.	25	June 24, 1922	Agawa Bay	4½	40–50	Mud					1
	26	June 26, 1922	Off Alona Bay	2½, 2¾	60		1,800	5	200	13	27
Marquette, Mich.[3]											2

[1] All over 200 millimeters except 1 specimen 198 millimeters long under record 22.
[2] See note, Table 20.
[3] U. S. National Museum collection, borrowed specimens.

TABLE 45.—*Numerical expressions of certain systematic characters of the types of the cyanopterus and prognathus forms of Leucichthys nigripinnis from Lakes Superior and Ontario, respectively, and for nine other specimens of that species from Lake Superior, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
646721[1]	Marquette, Mich.	345	14+25	♀	77	4.0	5.6	8.9	9.6	2.8	7.5	3.8	8.0	2.0	1.9	2.7	3.1
866	Grand Marais, Mich.	284	14+24	♀	87	4.1	5.6	9.0	9.2	2.7	7.7	3.7	8.4	2.2	2.0	2.7	3.2
1293	do	289	16+26	♂	80	3.9	5.2	9.6	8.3	2.8	8.6	4.0	9.0	2.2	1.9	2.6	3.0
1295	do	292	16+28	♂	85	4.2	5.8	10.0	8.8	2.7	7.8	4.2	8.8	2.0	2.0	2.8	3.2
1296	do	298	14+24	♀	84	4.1	5.5	9.2	8.5	2.7	7.5	3.5	8.0	2.2	2.0	2.7	3.0
1322	do	330	15+25	♂	85	4.1	5.2	8.6	8.6	2.7	7.8	3.7	8.0	2.1	1.9	2.4	3.2
57001	Michipicoten Island, Ontario	272	14+26	♂	82	4.1	5.4	9.0	7.7	2.9	8.2	4.1	8.3	2.0	2.0	2.6	3.0
57028	do	287	15+24	♀	85	4.0	5.3	9.1	8.7	3.0	7.7	4.1	7.9	1.9	2.0	2.6	3.0
57146	Alona Bay	246	15+24	♀	88	4.0	5.4	9.6	8.7	2.8	8.2	3.8	7.6	2.0	2.0	2.6	3.0
57188	Apostle Islands, Wis.	267	15+25	♀	88	4.1	5.6	8.3	7.8	2.8	7.9	3.8	7.6	2.0	2.0	2.7	3.0
45568[1]	"Lake Ontario"	297	[2]14+28	Ev.	77	4.1	5.7	9.3	8.7	2.8	8.3	3.4	7.4	2.1	2.0	2.8	3.2

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
646721[1]	Marquette, Mich.	4.2	4.7	2.7	3.9	1.9	3.8	5.6	3.4	1.9	2.8	1.6	1.4	11	12	12	17	1.4	1.0	9
866	Grand Marais, Mich.	4.4	4.5	2.6	3.7	2.0	3.9	5.6	3.3	1.9	2.7	1.8	1.4	11	12	12	17	1.5	1.0	9
1293	do	4.0	4.3	2.6	3.6	2.0	4.1	4.2	3.2	2.0	2.7	1.5	1.3	10	11	11	18	1.5	.95	9
1295	do	4.0	4.4	2.5	3.7	2.0	3.3	5.6	3.2	1.9	2.7	1.7	1.3	10	13	11	17	1.7	.97	9
1296	do	4.1	4.7	2.6	3.6	2.0	4.2	5.6	3.5	2.0	2.7	1.6	1.3	10	12	12	17	1.5	.93	9
1322	do	4.0	4.4	2.5	3.6	1.9	3.6	5.2	3.5	2.0	2.8	1.9	1.3	11	14	11	17	1.3	.85	9
57001	Michipicoten Island, Ontario	3.9	4.4	2.7	3.8	2.0	3.8	5.4	3.3	2.0	2.9	1.7	1.3	10	13	12	17	1.4	.86	9
57028	do	4.0	4.4	2.7	3.7	2.0	3.6	5.8	3.3	2.0	2.8	1.6	1.4	10	12	12	18	1.4	.88	9
57146	Alona Bay	4.1	4.2	2.6	3.6	1.9	3.8	5.6	3.2	1.9	2.7	1.6	1.4	10	12	11	19	1.6	.93	9
57188	Apostle Islands, Wis.	4.3	4.4	2.6	3.7	2.0	3.5	6.4	3.2	1.9	2.7	1.6	1.3	11	12	11	17	1.5	.94	9
45568[1]	"Lake Ontario"	4.5	4.6	2.4	3.6	1.8	4.1	5.1	3.3	1.7	2.6	2.1	1.4	11	13	12	16	-----	-----	9

[1] Types, U. S. National Museum catalogue number.
[2] The count of 14 is not complete, because some of the rakers have been lost.

TABLE 46.—*Records of the occurrence of Leucichthys nigripinnis regalis in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.[1]	Date	Location	Gill net mesh, in inches	Depth, in fathoms	Preserved specimens examined	
					+200 mm.	−200 mm.
1	July 26, 1921	Off Macdiarmid	------	15	2	------
2	July 26, 1922	do	2½, 2¾	30	96	2
3	Sept. 8, 1923	do	------	6	------	1
4	Sept. 10, 1923	do	------	------	2	------
5	Aug. 21, 1921	Off Blackwater River	------	50	2	------
6	July 28, 1922	Off Livingston Point	2½, 2¾	56	------	------
7	Sept. 6, 1923	Off Selwyn Island	------	------	1	------
8	Sept. 3, 1923	Humboldt Bay	------	------	9	1
9	Sept. 5, 1923	Off McKellar Island	------	------	4	------
10	Aug. 10, 1921	Off Murchison Island	------	15	5	------
11	Aug. 15, 1922	do	------	25	17	------
12	Aug. 21, 1923	Ombabika Bay	------	14	7	------
13	June 19, 1924	do	------	10	5	------
14	Aug. 17, 1922	Off Whitesand River	------	25	4	------
15	June 21, 1924	Off Caribou Island	------	25	3	------
16	Aug. 1, 1922	Grand Bay	4½	15–20	2	------
17	Aug. 27, 1921	Off Gros Cap	------	20	1	------
18	Sept. 3, 1923	do	------	10	1	------
19	July 25, 1922	Off Source of Nipigon River	2½, 2¾	10–15	42	1
20	Aug. 28, 1923	Off Virgin Island	------	10–15	3	------
21	Aug. 30, 1923	do	------	19	1	------
22	July 23, 1924	Sandy Bay	------	10	------	1
23	Aug. 15, 1922	Unknown	------	------	10	------
24	Oct. 26, 1922	do	------	------	5	------
25	June 14, 1924	do	4½	------	2	------

[1] All but records 2, 6, 16, 19, and 24 from University of Toronto collections.

TABLE 47.—*Numerical expressions of certain systematic characters for the type of the regalis form of Leucichthys nigripinnis from Lake Nipigon and for 11 cotypes, 10 over 200 mm. long and 2 under 200 mm. long, selected according to size*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 mm.	57235	Nipigon River source.	236	16+31	Im. ♂	75	4.0	5.4	7.9	9.1	2.8	7.5	3.8	8.7	2.2	1.9	2.6
	57248	do	240	17+29	Im. ♂	74	4.0	5.4	8.0	8.2	2.8	8.5	3.8	8.2	2.1	2.0	2.7
	57319	do	294	18+33	♀	76	3.9	5.7	9.8	10.4	3.1	7.9	4.0	8.4	2.0	2.0	2.9
	57414	Macdiarmid, Ontario.	280	18+32	♂	71	4.1	5.4	8.6	9.4	2.7	8.0	4.0	9.0	2.2	2.0	2.7
	[1] 57416	do	326	18+30	♀	72	4.1	5.8	7.7	8.5	2.7	9.0	3.5	7.7	2.1	2.0	2.9
	57422	do	278	16+28	♀	74	3.9	5.4	8.6	9.5	2.6	8.1	3.8	8.1	2.1	1.9	2.7
	57431	do	326	19+32	♀	69	4.0	5.3	7.4	8.4	2.7	9.5	3.1	7.7	2.5	2.0	2.6
	57502	do	298	18+31	♀	71	4.1	5.9	8.0	9.0	2.6	8.2	3.8	8.0	2.1	2.0	2.9
	57516	do	249	18+31	Im. ♀	71	4.0	5.6	8.3	8.8	2.7	8.3	3.6	7.7	2.1	2.0	2.8
	57616	do	277	18+32	♀	79	4.0	5.6	8.9	9.6	2.8	8.9	3.9	8.1	2.0	2.0	2.7
Under 200 mm.	[2] N1025	Humboldt Bay.	174	17+31	Im. ♂	72	3.8	5.3	9.1	8.7	2.9	7.5	4.3	9.1	2.2	1.9	2.6
	[2] N1168	Sandy Bay	159	17+30	Im. ♀	76	3.7	5.1	8.8	7.9	2.8	8.8	4.6	8.8	1.8	1.8	2.5

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 mm.	57235	3.0	4.2	3.8	2.5	3.8	1.9	3.0	5.4	2.8	1.8	2.7	1.4	1.5	11	12	12	16	1.6	1.0	9
	57248	3.1	4.2	3.9	2.6	3.7	1.9	3.2	4.9	2.8	1.9	2.7	1.3	1.4	12	13	12	16	1.6	1.0	8
	57319	3.1	4.5	4.1	2.6	4.0	2.0	3.2	5.2	2.8	1.8	2.7	1.6	1.5	9	11	11	16	1.6	1.1	9
	57414	3.2	4.3	3.7	2.5	3.6	1.8	3.2	4.8	2.8	1.9	2.7	1.5	1.4	11	11	11	16	1.6	1.0	9
	[1] 57416	3.2	4.5	4.1	2.6	3.9	1.9	3.4	4.3	2.9	1.8	2.7	1.6	1.4	10	12	12	16	1.4	1.0	8
	57422	3.1	4.2	3.8	2.5	3.6	1.8	3.5	5.0	2.8	1.8	2.6	1.6	1.3	10	12	12	16	1.5	1.2	9
	57431	3.2	4.2	4.0	2.7	3.8	1.9	3.2	5.0	3.0	2.1	2.9	1.6	1.6	11	12	11	16	1.4	1.1	9
	57502	3.2	4.6	4.0	2.5	4.0	2.0	3.4	5.1	2.7	1.7	2.7	1.6	1.4	10	11	12	16	1.5	1.1	8
	57516	3.1	4.3	4.0	2.6	3.9	1.9	3.6	4.9	2.8	1.8	2.7	1.4	1.3	11	12	11	16	1.6	1.0	9
	57616	3.2	4.4	3.9	2.7	4.0	2.0	3.6	5.3	2.8	1.9	2.8	1.6	1.5	10	11	12	17	1.5	1.0	8
Under 200 mm.	[2] N1025	2.9	4.0	3.7	2.6	4.0	2.0	3.6	5.0	2.7	1.8	2.9	1.4	1.3	10	12	12	17	-----	1.1	8
	[2] N1168	2.9	3.9	3.3	2.6	3.8	1.9	3.7	5.1	2.4	1.9	2.8	1.4	1.3	10	12	11	16	1.6	1.0	9

[1] Type, U. S. National Museum catalogue number 88354.

[2] University of Toronto collection.

TABLE 48.—*Records of the occurrence of Leucichthys kiyi in Lake Michigan*

For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Ports from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of kiyi	Preserved specimens examined	
									+200 mm.	−200 mm.
Washington Harbor, Wis.	1	Aug. 18, 1920	14 miles E. ¾ N. of Rock Island.	2½	30-50	------	------	(1)	------	1
	2	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅝	71-90	Clay-mud	900	65	9	12
Sturgeon Bay, Wis.	3	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60-70	Mud	50	65	9	11
Algoma, Wis.	4	Aug. 24, 1920	10 miles E. by N.	2½	35-50	Gravel-mud.	310	(2)	4	2
Sheboygan, Wis.	5	Oct. 1, 1920	11 miles southeast	2½	60	Clay	200	(1)	11	1
Port Washington, Wis.	6	Sept. 25, 1920	18 miles E. ½ S.	2½	65-48	do	285	35	7	1
	7	May 26, 1922	8 miles northeast	2½	20-35	Mud	------	(1)	------	1
Milwaukee, Wis.	8	Sept. 23, 1920	27 miles ESE	2½	60	Red clay	250	60	5	------
Michigan City, Ind.	9	Sept. 3, 1920	22 miles NW. by N. ½ N.	2½	30-40	Clay	------	6	4	------
	10	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30-40	Mud, clay	535	(2)	2	------
	11	Nov. 8, 1920	18 miles NNW	2½	30-38	Clay	1,000	(2)	------	------
	12	Nov. 19, 1920	30 miles NNW	4½	48-50	do	------	(2)	1	------
Grand Haven, Mich.	13	Mar. 20, 1919	12 miles west	2¾	50-55	do	------	(1)	11	1
Ludington, Mich.	14	Aug. 30, 1920	17 miles W. ½ S.	2¾	60-70	do	------	(1)	13	------
	15	do	12 miles W. ½ S.	2¾	45-50	do	------	(1)	10	------
Manistee, Mich.	16	Aug. 28, 1920	9 miles northwest	4½	28-32	------	------	(2)	------	1
Frankfort, Mich.	17	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60-70	Blue clay	1,400	38	5	2
Northport, Mich.	18	July 31, 1923	5 miles northwest of Cathead Light.	2¾	40-60	Mud	------	9	32	4
Charlevoix, Mich.	19	June 29, 1920	5 miles N. by E.	2¾	40-55	Clay, mud	------	(2)	1	1
	20	June 30, 1920	3 miles northwest	2¾	40-65	Clay	------	(1)	------	4
	21	Aug. 11, 1923	3 miles NW. ½ W.	2¾	35-60	do	375	(2)	7	------
Manistique, Mich.	22	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60-70	------	200	(2)	------	1

[1] Lift not examined or percentage not ascertained.

[2] Rare.

TABLE 49.—*Numerical expressions of certain systematic characters for the type and for nine cotypes of Leucichthys kiyi from Lake Michigan, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
84100[1]	Sturgeon Bay, Wis	191	15+25	♀	85	4.0	5.4	9.1	9.9	2.9	8.1	4.0	7.3	1.8	2.0	2.5	3.1
2858	Charlevoix, Mich	227	15+25	♀	82	3.9	5.3	9.8	8.3	3.0	8.7	3.9	8.4	2.1	2.0	2.5	2.9
3276	Sturgeon Bay, Wis	169	14+26	♂	80	3.9	5.2	8.9	8.4	2.8	7.6	4.1	9.9	2.4	2.0	2.7	2.9
3295	Washington Harbor, Wis	179	15+23	♀	77	3.9	5.4	9.9	10.0	3.1	8.4	4.4	9.9	2.2	2.0	2.7	2.9
3370	Algoma, Wis	190	14+24	♀	83	4.1	5.5	9.0	9.8	2.8	7.7	3.9	8.2	2.1	2.1	2.8	3.1
3483	Ludington, Mich	222	14+23	♀	86	4.1	5.5	9.0	8.4	3.0	7.9	3.5	8.2	2.2	2.1	2.9	3.2
3597	Milwaukee, Wis	219	14+25	♀	84	4.1	5.7	9.8	10.0	2.7	8.1	3.5	8.4	2.3	2.1	3.0	3.1
3898	Sheboygan, Wis.	201	13+25	♀	79	3.9	5.4	9.1	9.1	2.9	8.5	3.9	8.0	2.0	2.0	2.7	3.0
3972	Frankfort, Mich	204	14+23	♀	82	3.7	5.1	8.9	9.7	2.8	8.8	3.8	8.1	2.1	2.0	2.7	2.8
4008	Michigan City, Ind	210	14+24	♂	80	4.0	5.7	9.3	9.1	2.8	8.3	4.0	9.3	2.3	2.0	3.0	3.0

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
84100[1]	Sturgeon Bay, Wis	4.2	3.9	2.7	3.6	1.9	3.6	6.5	2.9	2.0	2.7	1.6	1.2	10	11	11	15	1.5	-----	9
2858	Charlevoix, Mich	4.0	4.1	2.5	3.4	1.8	3.8	8.0	3.0	1.8	2.5	1.5	1.1	10	13	12	17	1.7	1.0	9
3276	Sturgeon Bay, Wis	3.9	3.8	2.3	3.5	1.9	3.5	7.1	2.8	1.7	2.6	1.4	1.1	10	11	12	16	1.7	1.0	9
3295	Washington Harbor, Wis	4.0	3.8	2.6	3.6	1.9	3.6	6.2	2.7	1.9	2.7	1.5	1.1	10	11	11	16	1.8	1.1	9
3370	Algoma, Wis	4.1	3.9	2.4	3.6	1.9	3.0	7.0	2.9	1.8	2.7	1.4	1.2	10	10	11	16	1.6	1.1	9
3483	Ludington, Mich	4.3	3.8	2.4	3.5	1.9	3.1	6.0	2.8	1.8	2.6	1.5	1.1	10	12	12	16	1.8	1.0	8
3597	Milwaukee, Wis	4.3	4.3	2.6	3.5	1.9	3.1	7.9	3.1	1.9	2.5	1.6	1.1	10	10	11	18	1.7	1.2	9
3898	Sheboygan, Wis	4.2	4.0	2.5	3.6	1.9	3.9	6.0	2.9	1.8	2.6	1.3	1.1	10	11	12	17	1.8	1.2	9
3972	Frankfort, Mich	3.8	4.0	2.5	3.8	2.0	3.9	7.2	2.9	1.9	2.8	1.4	1.0	10	11	12	16	1.7	1.1	9
4008	Michigan City, Ind	4.3	4.3	2.6	3.7	2.1	3.2	6.7	2.9	1.8	2.6	1.5	1.0	10	11	11	17	1.8	1.2	9

[1] Type, U. S. National Museum number.

TABLE 50.—*Records of the occurrence of Leucichthys kiyi in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined	
								+200 mm.	−200 mm.
Lake Huron proper: Alpena, Mich	1	Sept. 7, 1917	Center of lake east of can buoy.	2¾	70-80	Clay	Only specimen taken in lift.	------	1
	2	Sept. 12, 1917	do	2¾	65-80	do	do	------	3
	3	Sept. 14, 1917	Center of lake northeast of can buoy.	2¾	65-80	do	do	1	8
	4	Sept. 18, 1917	17½ miles N. by E. of Thunder Bay Island.	2¾	60	do	do	------	18
	5	Sept. 19, 1917	Center of lake northeast of can buoy.	--------	65-80	do	do	2	3
	6	Sept. 20, 1917	14 miles NE. by E. of Thunder Bay Island.	2¾	65	do	do	------	16
	7	Sept. 21, 1917	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65-75	do	do	------	36
	8	do	Center of lake east of can buoy.	2¾	65-70	do	do	------	8
	9	Oct. 17, 1917	do	2¾	65-80	do	do	2	------
	10	Oct. 20, 1917	do	2¾	65-80	do	do	2	1
	11	Sept. 13, 1919	Off Presque Isle Light	1½	60	do	Rare	------	8

TABLE 50.—*Records of the occurrence of Leucichthys kiyi in Lake Huron*—Continued

Ports from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined +200 mm.	Preserved specimens examined −200 mm.
Lake Huron proper—Continued.									
Alpena, Mich.	12	Sept. 18, 1919	14 miles N. by E. of Thunder Bay Island.	2¾	65	----------	Only specimens taken in lift.	------	5
	13	-----do-------	----------------------------	2¾	---------	----------	-----do---------	------	18
	14	June 30, 1923	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65-70	Clay----	-----do---------	3	32
	15	July 2, 1923	20 miles E. by N. of can buoy.	2¾	60-70	---do----	-----do---------	1	6
	16	July 5, 1923	18 miles NE. ¾ E. of Thunder Bay Island.	2¾	80-100	---do----	-----do---------	5	29
	17	July 7, 1923	13 miles NE. ½ N. of Thunder Bay Island.	2¾	60	---do----	-----do---------	------	4
Georgian Bay:									
Lions Head, Ontario.	18	July 30, 1919	21 miles east of Surprise Shoal.	3	60	----------	-----do---------	------	2
	19	Oct. 6, 1919	Off White Bluff------------	3	70	Mud----	-----do---------	------	2
Wiarton, Ontario.	20	July 30, 1919	----------------------------	3	---------	----------	-----do---------	------	1

TABLE 51.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys kiyi from Lake Huron, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
27B	Alpena, Mich.	156	14+24	♀	83	3.7	4.9	11.1	8.2	3.2	8.2	5.3	11.1	2.0	1.9	2.6	2.8
382	-----do---------	180	14+23	♀	77	3.9	5.1	8.8	7.7	3.1	8.5	3.6	7.5	2.1	2.0	2.6	2.9
560	-----do---------	170	14+25	♀	80	3.8	5.1	10.3	8.5	3.1	8.0	4.3	8.9	2.0	1.9	2.6	2.9
581	-----do---------	155	14+23	♀	87	3.8	5.3	10.3	9.6	3.1	8.3	5.0	8.8	1.7	2.0	2.7	2.9
559	-----do---------	210	14+28	♀	83	3.9	5.0	9.2	8.1	2.6	7.5	3.5	7.5	2.1	1.9	2.4	2.9
775	-----do---------	194	14+24	♀	86	3.8	5.1	8.8	8.0	2.8	8.0	3.5	8.8	2.4	2.0	2.6	2.9
949	-----do---------	219	15+26	♀	89	3.9	4.9	8.7	8.7	2.7	7.8	3.9	8.7	2.2	1.8	2.5	3.0
958	-----do---------	208	13+23	♀	79	3.7	4.9	8.8	9.0	2.8	8.3	3.8	8.3	2.1	1.8	2.4	2.9
976	-----do---------	215	13+23	♀	81	3.8	5.2	8.9	8.9	2.9	8.2	3.7	8.6	2.3	1.9	2.6	3.0
54873	-----do---------	238	16+27	♀	80	3.9	5.1	8.2	8.8	2.6	7.2	3.9	8.8	2.2	1.9	2.5	2.9

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
27B	Alpena, Mich.----	3.7	4.0	2.6	3.4	1.9	4.0	6.4	3.0	1.9	2.5	1.9	1.0	10	12	11	15	2.0	1.0	9
382	-----do------------	3.9	3.8	2.5	3.5	1.8	3.6	9.0	2.9	1.9	2.6	1.7	1.3	10	12	11	16	1.4	.89	9
560	-----do------------	3.9	3.8	2.5	3.6	1.8	3.6	6.2	2.8	1.9	2.7	1.6	1.2	9	10	11	16	1.8	1.3	9
581	-----do------------	3.1	3.8	2.6	3.6	1.9	4.0	7.6	2.7	1.9	2.6	1.4	1.2	9	11	11	15	1.8	1.1	9
559	-----do------------	3.6	3.7	2.5	3.7	1.7	3.7	5.1	2.9	1.9	2.9	1.1	1.0	10	12	11	18	1.7	1.0	9
775	-----do------------	3.9	4.0	2.4	3.5	-----	3.3	6.9	3.0	1.8	2.7	1.6	1.1	10	12	12	18	1.7	1.1	9
949	-----do------------	4.2	4.0	2.6	3.6	1.9	3.4	5.0	2.9	1.9	2.6	1.7	1.1	10	11	11	16	1.7	1.0	8
958	-----do------------	3.8	4.0	2.7	3.3	1.8	3.6	8.8	3.1	2.0	2.5	1.4	1.0	10	11	12	17	1.7	1.2	9
976	-----do------------	4.1	4.1	2.4	3.4	1.9	3.9	6.7	3.0	1.7	2.5	1.5	1.2	10	10	11	16	1.7	1.1	9
54873	-----do------------	3.8	4.3	2.6	3.5	1.9	3.3	7.4	3.2	1.9	2.7	1.3	1.0	10	12	11	16	1.5	1.1	10

TABLE 52.—*Records of the occurrence of Leucichthys kiyi in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water and character of the bottom where made, the abundance of this species in the lift, and the number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Grand Marais, Mich.	1	Oct. 3, 1917	----------	4½	+65	----------	----------	------	6
Marquette, Mich	2	Aug. 5, 1921	31 miles N. ¾ E	4½	100	Reddish-brown clay.	Only specimens taken in lift.	------	11
	3	Aug. 8, 1921	6 miles NE. ¾ N	1½	42–65	Red clay	do	------	2
	4	Aug. 11, 1921	18 miles NE. by N	4½	100–80	----------	do	------	2
	5	Nov. 22, 1922	Off Granite Island	4½	------	----------	----------	1	12
	6	Dec. 5, 1922	do	4½	------	----------	----------	------	39
	7	1923	----------	------	------	----------	----------	------	1
	8	Nov. —, 1925	----------	------	------	----------	----------	------	1
Apostle Islands, Wis.	9	July 14, 1922	25 miles north of South Twin Island.	4½	50–90	Red and yellow clay.	Only specimens taken in lift.	------	4
	10	July 15, 1922	14–18 miles NW. by N. of South Twin Island.	4½	40–90	Clay	do	------	1
Coppermine Point, Ontario.	11	June 24, 1922	Agawa Bay	4½	40–50	Mud	do	1	------

TABLE 53.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys kiyi from Lake Superior, selected at random*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
1298	Grand Marais, Mich	174	♀	16+26	81	3.7	4.9	8.7	8.0	2.9	8.4	3.7	8.7	2.3	1.8	2.5	2.7
1357	do	171	♀	15+27	85	3.8	5.2	9.6	7.7	2.8	9.3	3.9	10.5	2.5	1.9	2.7	2.8
53548	Marquette, Mich	169	♀	15+25	84	3.7	4.8	8.4	8.1	2.8	9.3	4.0	8.8	2.2	1.9	2.5	2.8
54232	do	182	♀	14+26	80	3.7	5.1	9.4	8.0	2.9	8.2	4.0	8.0	2.0	1.9	2.7	2.8
54242	do	155	♀	14+26	77	3.6	5.1	10.1	8.6	2.9	7.7	3.8	8.6	2.2	1.9	2.7	2.7
59066	do	203	♀	14+24	84	3.8	5.2	9.2	8.5	2.9	8.7	3.9	8.1	2.0	1.9	2.6	2.8
59070	do	195	♂	16+29	80	4.0	5.5	8.4	8.2	2.7	7.5	4.8	9.7	2.2	1.9	2.7	2.9
59085	do	178	♀	15+24	72	3.7	5.0	8.4	7.1	2.9	8.0	4.2	8.9	2.1	1.9	2.5	2.8
59088	do	183	♀	16+26	75	3.7	5.1	9.5	7.8	2.9	9.5	4.1	8.3	2.0	1.8	2.6	2.8
59100	do	191	♀	15+22	81	4.0	5.4	10.9	9.1	3.0	7.9	3.8	7.6	2.0	2.0	2.7	3.0

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
1298	Grand Marais, Mich	3.7	3.6	2.6	3.8	1.8	3.5	5.5	2.7	1.9	2.8	1.2	1.0	10	12	11	17	1.7	1.0	9
1357	do	3.9	3.6	2.4	3.9	1.7	3.6	6.2	2.6	1.7	2.8	1.3	1.1	11	13	12	16	1.8	.94	8
53548	Marquette, Mich	3.7	3.6	2.5	3.4	1.8	4.0	6.2	2.8	1.9	2.6	1.4	1.1	10	12	12	16	1.6	1.0	8
54232	do	3.9	3.8	2.5	3.8	1.9	3.5	5.5	2.7	1.8	2.7	1.2	1.1	9	11	11	16	1.9	1.0	9
54242	do	3.8	3.7	2.6	4.1	2.0	3.7	6.0	2.6	1.8	2.9	1.4	1.0	10	12	11	16	1.9	1.0	8
59066	do	3.9	3.8	2.6	3.9	-----	3.8	6.4	2.8	1.9	2.8	1.4	1.0	11	11	11	17	1.8	1.0	8
59070	do	4.0	3.9	2.5	3.6	1.8	3.3	5.4	2.8	1.8	2.6	1.5	1.1	10	12	12	16	1.5	.93	8
59085	do	3.8	3.6	2.3	3.6	1.8	3.4	6.0	2.6	1.7	2.6	1.2	1.0	10	12	11	16	1.6	.91	9
59088	do	3.9	3.5	2.3	3.7	1.8	3.5	5.5	2.5	1.6	2.7	1.4	1.1	9	12	11	17	1.8	1.0	9
59100	do	4.0	3.7	2.4	3.6	1.8	3.0	5.9	2.8	1.8	2.6	1.5	1.1	9	11	11	16	1.8	1.0	9

TABLE 54.—*Records of the occurrence of Leucichthys kiyi in Lake Ontario*

For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the abundance of this species in the lift, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Percentage	Preserved specimens examined	
								+200 mm.	−200 mm.
Bronte, Ontario	1	June 29, 1921	13 miles E. ½ S.	2½, 2¾	40–50	Mud	(1)	7	------
Brighton, Ontario	2	June 10, 1921	20 miles S. by W. of Presque Isle Light.	2½	40–50	do	(1)	1	------
Sandy Pond, N. Y.	3	Aug. 30, 1923	14 miles west	1½, 2½, 3, 3¼, 3½	60	Clay and mud	(1)	1	------
Selkirk, N. Y.	4	July 11, 1921	5 miles NNW. of Nine-Mile Point.	3	25–35	Blue clay	(1)	2	------
Oswego, N. Y.	5	Sept. 1, 1923	Off Nine-Mile Point	3	30	Clay	(1)	1	------
	6	Sept. 4, 1923	8½ miles W. by N. ½ N.	1½, 2½, 3	70–75	Clay and mud	(1)	8	3
Sodus Point, N. Y.	7	July 12, 1921	8½ miles NNW.	2½, 2¾	60	Mud and clay	25	26	1
Charlotte, N. Y.	8	July 4, 1921	7 miles off Braddock Point Light.	2½, 2¾	65	Blue and brown clay.	33	31	------
Wilson, N. Y.	9	June 23, 1921	3 miles north	2½, 2¾	30	Brown clay	(1)	2	------
	10	June 25, 1921	5 miles north	2½, 2¾	50	Clay and mud	40	15	1
	11	July 16, 1921	do	2½, 2¾	50	do	10	------	------
	12	July 19, 1921	6½ miles N. by W. ½ by W.	2½, 2¾	65	Blue and brown clay.	75	31	2
	13	July 21, 1921	2 miles north	2½	20	------	(1)	3	------

[1] Rare.

TABLE 55.—*Numerical expressions of certain systematic characters for the type of the orientalis form of Leucichthys kiyi and for nine cotypes from Lake Ontario, selected according to size and locality*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
53221	Wilson, N. Y.	227	♀	17+28	82	4.2	5.6	9.9	10.8	2.6	8.3	3.1	7.8	2.4	2.1	2.9	3.2
53340	Charlotte, N. Y.	223	♂	16+29	81	4.1	5.7	9.6	10.2	2.6	7.8	4.0	7.9	1.9	2.1	2.9	3.1
54057	Wilson, N. Y.	224	♂	17+27	80	4.0	5.6	8.9	9.5	2.6	8.0	3.7	8.0	2.1	2.0	2.7	3.1
54064[1]	do	224	♂	15+28	79	4.0	5.4	9.0	9.2	2.8	8.8	3.6	7.4	2.0	2.0	2.7	3.2
54070	do	243	♀	17+29	78	4.2	5.8	8.3	8.9	2.8	9.0	3.6	7.8	2.1	2.1	2.9	3.3
54143	Sodus Point, N. Y.	202	♂	16+28	83	4.3	5.7	8.7	8.7	2.8	8.6	3.8	7.7	2.0	2.1	2.8	3.4
59815	Oswego, N. Y.	203	♂	16+28	81	3.9	5.2	9.7	10.0	2.9	7.8	3.7	9.2	2.4	2.0	2.8	3.0
54066	Wilson, N. Y.	199	♂	16+27	80	4.2	5.8	9.5	9.9	2.7	8.6	3.9	8.2	2.1	2.1	2.9	3.3
54206	Sodus Point, N. Y.	196	♂	16+29	81	4.0	5.6	9.0	9.8	2.8	7.8	3.9	7.8	2.0	2.1	2.9	3.1
59818	Oswego, N. Y.	199	♂	16+29	80	4.0	5.6	10.2	9.8	3.1	7.8	3.9	8.2	2.1	2.0	2.8	3.1

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
53221	Wilson, N. Y.	4.3	4.1	2.5	3.6	2.0	3.0	5.6	3.0	1.9	2.7	2.0	1.3	9	9	10	15	1.6	1.1	8
53340	Charlotte, N. Y.	4.3	4.1	2.4	3.5	1.9	3.5	5.0	3.0	1.8	2.6	1.9	1.3	10	11	11	16	1.5	1.1	9
54057	Wilson, N. Y.	4.3	4.2	2.5	3.7	2.0	3.4	5.5	3.0	1.7	2.7	1.8	1.2	10	12	12	15	1.5	1.0	8
54064[1]	do	4.3	3.9	2.5	3.6	1.8	3.1	5.4	2.9	1.8	2.6	1.8	1.3	10	11	11	17	1.5	1.1	8
54070	do	4.6	4.1	2.6	3.7	1.9	3.4	4.7	2.9	1.9	2.7	2.0	1.5	10	11	11	15	1.3	1.0	9
54143	Sodus Point, N. Y.	4.5	4.0	2.5	3.4	1.9	3.7	5.1	3.0	1.9	2.6	2.1	1.3	10	10	11	16	1.6	1.0	9
59815	Oswego, N. Y.	4.1	4.2	2.7	3.7	1.8	3.1	4.8	3.1	2.0	2.7	1.6	1.2	9	10	12	17	1.7	1.1	8
54066	Wilson, N. Y.	4.6	3.9	2.5	3.5	1.9	3.0	4.6	2.8	1.8	2.5	1.9	1.3	9	12	11	16	1.6	1.1	9
54206	Sodus Point, N. Y.	4.2	3.8	2.5	3.7	1.9	3.7	5.4	2.8	1.8	2.7	1.7	1.2	10	10	11	16	1.4	1.1	9
59818	Oswego, N. Y.	4.4	4.1	2.4	3.5	1.9	3.2	4.8	2.9	1.7	2.5	1.8	1.2	9	10	11	15	1.6	1.0	9

[1] Type, U. S. National Museum No. 88352.

TABLE 56.—*Records of the occurrence of Leucichthys hoyi in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Weight of lift in pounds	Percentage of gilled fish	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Washington Harbor, Wis.	1	Aug. 18, 1920	4 miles west of Boyer Bluff	2⅜	18-24	------	50	2	20
	2	do	5 miles west of Boyer Bluff	4	20	------	(1)	1	9
	3	do	14 miles E. ¾ N. of Rock Island	2½	30-50	------	(2)	1	64
	4	Aug. 19, 1920	3 miles WNW. of Boyer Bluff	4	20-40	------	(1)	------	1
	5	do	20 miles E. ½ N. of Rock Island	2½, 2⅝	71-90	900	(3)	------	5
Sturgeon Bay, Wis	6	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60-70	50	(3)	------	19
Algoma, Wis	7	Aug. 24, 1920	10 miles E. by N	2½	35-50	310	68	5	19
Sheboygan, Wis	8	Sept. 28, 1920	40 miles SE. by E	3½	35-40	------	------	2	28
	9	do	5 miles SE. by E	1½	30-32	------	75	4	81
	10	Oct. 1, 1920	11 miles southeast	2½	60	200	(2)	1	4
Port Washington, Wis	11	Sept. 25, 1920	18 miles E. ½ S	2½	65-48	285	53	4	34
	12	do	5 miles E. ½ S	1½	30	------	90	------	9
	13	Sept. 27, 1920	Off city	(4)	5	------	(5)	------	9
	14	May 26, 1922	8 miles northeast	2½	20-35	------	(2)	------	1
Milwaukee, Wis	15	Mar. 24, 1919	------	2½	50	------	(2)	15	54
	16	Sept. 23, 1920	27 miles ESE	2½	60	250	(5)	2	20
	17	Sept. 24, 1920	9 miles NNE	2½	22-25	------	(2)	3	20
	18	Nov. 15, 1920	20 miles ESE	2½	28-35	------	(6)	------	12
Racine, Wis	19	Oct. 8, 1920	------	1½	30	------	(2)	------	------
Michigan City, Ind	20	Sept. 3, 1920	22 miles NW. by N. ½ N	2½	30-40	------	42	2	22
	21	Oct. 11, 1920	20 miles N. by W. ¾ W	2½	30-40	535	34	------	13
	22	Nov. 8, 1920	18 miles NNW	2½	30-38	1,000	10	------	12
	23	Nov. 19, 1920	30 miles NNW	4½	48-50	------	(1)	2	23
	24	do	17 miles NNW	2½	28-32	700	50	3	23
	25	do	10 miles NNW	2½	18	------	(3)	------	------
	26	do	17½ miles NW. by N. ¾ N	2½	32	------	15	------	------
	27	Mar. 2, 1921	14 miles NNW	1½	26	------	96	------	12
	28	do	21 miles NNW	2½	30	1,000	81	------	------
	29	Mar. 4, 1921	15 miles NW. by N. ½ N	2½	28	1,000	96	10	2
	30	Apr. 1, 1921	------	2½	30	------	(2)	------	2
Grand Haven, Mich	31	Mar. 20, 1919	12 miles west	2¾	50-55	------	(2)	20	141
Ludington, Mich	32	Aug. 30, 1920	17 miles W. ½ S	2¾	60-70	------	(2)	------	1
	33	do	7 miles NW. by N	4½	14-26	------	------	1	49
	34	do	12 miles W. ½ S	2¾	45-50	------	(2)	------	5
Manistee, Mich	35	Aug. 27, 1920	4 miles west	1½	28-35	------	(2)	------	2
	36	Aug. 28, 1920	9 miles northwest	4½	28-32	------	(1)	3	7
Frankfort, Mich	37	Oct. 4, 1920	9 miles north of Point Betsie	2¾	60-70	1,400	22	4	33
Platte Bay, Mich. (field station).	38	July 21, 1923	1½ miles south of Otter Creek	1½	8-12	------	(1)	------	2
	39	July 23, 1923	do	1½	15-25	------	(1)	1	5
Northport, Mich	40	June 22, 1920	5 miles northwest of Cathead Light	2¾	40-60	------	(5)	------	2
	41	June 23, 1920	Off Northport Point	1½	28-40	------	60	1	67
	42	July 31, 1923	5 miles northwest of Cathead Light	2¾	40-60	------	(5)	33	10
Traverse City, Mich	43	July 18, 1923	West Bay	1½	30-40	------	50	------	------
	44	July 25, 1923	Off Lees Point	1½	6-16	------	(1)	------	3
	45	July 26, 1923	1¼ miles south of Barrow Harbor	(4)	5	------	------	------	10
Charlevoix, Mich	46	June 29, 1920	5 miles N. by E	2¾	40-55	------	9	10	36
	47	June 30, 1920	3 miles northwest	2¾	40-65	------	(2)	4	28
	48	Aug. 10, 1923	8 miles NNW. of Big Rock Point	2¾	45-50	480	(5)	------	------
	49	Aug. 11, 1923	3 miles NW. ½ W	2¾	35-60	------	(5)	1	------
	50	Aug. 21, 1923	------	2¾	------	100	(3)	1	------
Manistique, Mich	51	Aug. 11, 1920	13 miles SE. ½ E	4½	20	------	(1)	------	35
	52	Aug. 12, 1920	15 miles SE. by S. ½ S	2¾	60-70	200	(3)	------	15
Menominee, Mich	53	Aug. 16, 1920	8 miles south of Green Island	2⅜	16	------	(3)	1	33
Jackson Park Lagoon, Chicago, Ill.[7]	------	------	------	------	------	------	------	------	16
Pine, Ind.[7]	------	------	------	------	------	------	------	------	16
Ludington, Mich.[8]	------	------	------	------	------	------	------	------	13

[1] Only specimens taken.
[2] Lift not examined or percentage not ascertained.
[3] Rare.
[4] Pound net.
[5] Occasional.
[6] None.
[7] Field Museum collection, borrowed specimens.
[8] University of Michigan collection, borrowed specimens.

TABLE 57.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys hoyi from Lake Michigan selected at random*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
1665	Milwaukee, Wis.	201	16+28	♀	75	4.3	5.9	10.4	11.0	2.9	7.7	4.1	8.2	2.0	2.1	2.9	3.5
1671	do	220	16+27	♀	73	4.5	6.2	8.8	9.7	2.6	8.4	3.6	7.8	2.1	2.1	3.0	3.5
1704	do	209	15+27	♂	69	4.3	5.8	11.4	10.3	2.7	8.7	3.8	7.4	1.9	2.2	3.0	3.4
3020	Menominee, Mich	160	17+27	♀	69	4.1	5.7	8.8	9.6	2.7	7.4	4.0	8.4	2.1	2.0	2.8	3.2
3062	Washington Harbor, Wis.	208	15+28	♂	75	4.2	5.7	9.3	10.9	2.6	8.1	4.0	8.3	2.0	2.1	2.8	3.3
4027	Michigan City, Ind	148	15+30	♀	74	4.0	5.2	9.5	9.7	2.7	8.7	4.2	8.9	2.1	2.0	2.6	3.1
4256	Milwaukee, Wis.	141	17+28	♀	74	4.0	5.5	9.7	9.9	2.9	8.0	4.8	8.4	1.9	2.0	2.7	3.1
4259	do	171	15+26	♀	70	4.0	5.1	10.5	9.9	2.8	7.9	4.5	9.0	2.0	2.0	2.5	3.1
4344	Michigan City, Ind	171	16+26	♀	67	4.1	5.6	10.1	10.0	2.8	8.5	4.0	8.5	2.1	2.1	2.8	3.2
4357	do	201	17+29	♀	69	4.2	5.9	10.3	9.9	2.7	8.3	3.7	6.5	1.7	2.1	3.0	3.3

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
1665	Milwaukee, Wis.	4.7	4.1	2.7	3.8	2.0	3.0	5.4	3.0	2.0	2.8	2.2	1.6	9	10	11	15	1.6	1.2	9
1671	do	4.9	4.0	2.5	3.9	2.0	3.2	6.4	2.9	1.8	2.8	2.2	1.5	10	11	11	16	1.4	1.0	8
1704	do	4.6	3.9	2.5	3.6	1.7	3.7	5.3	2.9	1.8	2.6	2.0	1.6	7	11	11	15	1.8	1.1	8
3020	Menominee, Mich	4.5	3.9	2.6	3.9	1.9	3.3	5.5	2.8	1.9	2.8	1.8	1.3	10	13	11	15	1.7	1.2	8
3062	Washington Harbor, Wis.	4.5	4.0	2.6	3.7	2.0	3.4	5.1	3.0	1.9	2.7	1.8	1.5	9	10	11	16	1.8	1.3	8
4027	Michigan City, Ind	4.1	3.7	2.6	4.0	2.0	3.8	5.2	2.8	1.9	3.0	2.0	1.4	9	11	11	16	1.6	1.0	8
4256	Milwaukee, Wis.	4.3	3.5	2.6	3.9	2.0	3.8	5.0	2.5	1.9	2.8	1.9	1.2	10	13	10	15	1.7	1.1	8
4259	do	3.9	3.7	2.8	3.8	2.0	4.0	5.8	2.9	2.2	3.1	1.7	1.4	9	11	10	16	1.9	1.1	8
4344	Michigan City, Ind	4.3	3.7	2.4	3.7	1.9	3.7	4.8	2.7	1.8	2.7	1.9	1.3	9	10	11	16	1.7	1.2	8
4357	do	4.6	3.8	2.6	3.8	1.9	3.3	5.2	2.7	1.8	2.7	1.7	1.4	9	11	11	15	1.9	1.1	9

TABLE 58.—*Records of the occurrence of Leucichthys hoyi in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined	
								+200 mm.	−200 mm.
Lake Huron proper:									
Cheboygan, Mich.	1	July 21, 1917	5 miles north of Spectacle Reef.	2¾	35–50	Clay	Occasional		16
	2	Sept. 29, 1917	2 miles northeast of Spectacle Reef.	2¾	35–50	do	do		9
	3	Oct. 1, 1917		2¾	35–50		Only specimens taken in lift.		11
	4	Oct. 15, 1919		1½	35		Abundant		44
Rogers, Mich.	5	Oct. 14, 1917	12 miles E. by N. ½ N. of city.	2¾	35	Clay	Common		31
Alpena, Mich.	6	Aug. 13, 1917	38 miles east of can buoy	2¾	70–80		Only specimens taken in lift.		10
	7	Sept. 7, 1917	26 miles SE. by E. ¼ E. of can buoy.	4½	16–20		do		19
	8	Sept. 8, 1917	22 miles SE. by E. ½ E. of can buoy.	1½	30		Abundant		23
	9	Sept. 12, 1917	11 miles SE. ¾ E. of can buoy.	4½	15–17		Only specimens taken in lift.		4
	10	do	Center of lake east of can buoy.	2¾	65–80		do		14
	11	Sept. 14, 1917	Center of lake northeast of can buoy.	2¾	65–80		do		23
	12	do	24 miles SE. by E. ½ E. of can buoy.	4½	24		do	1	51
	13	Sept. 17, 1917	13½ miles SE. by S. of can buoy.	4½	15		do		2

TABLE 58.—*Records of the occurrence of Leucichthys hoyi in Lake Huron*—Continued

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Lake Huron proper—Continued.									
Alpena, Mich	14	Sept. 18, 1917	17½ miles N. by E. of Thunder Bay Island.	2¾	60		Only specimens taken in lift.		34
	15	Sept. 19, 1917	Center of lake northeast of can buoy.	2¾	65–80		do		6
	16	Sept. 20, 1917	14 miles NE. by E. of Thunder Bay Island.	2¾	65		do		33
	17	Sept. 21, 1917	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–75		do		11
	18	do	Center of lake east of can buoy.	2¾	65–70		do		9
	19	Sept. 22, 1917	15 miles SE. by S. ½ S. of can buoy.	4½	17		do	2	18
	20	Sept. 26, 1917	13 miles SE. by E. of can buoy.	4½	17		Occasional		3
	21	Sept. 13, 1919	Off Presque Isle light	1½, 2¾	60				52
	22	Sept., 16 1919		1½	30		Abundant		49
	23	do	40 miles ESE. of can buoy.	4½	20–30		Only specimens taken in lift.		4
	24	Sept. 18, 1919	14 miles N. by E. of Thunder Bay Island.	2¾	65		do		50
	25	June 30, 1923	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–70		do		15
	26	July 2, 1923	20 miles E. by N. of can buoy.	2¾	60–70		do		1
	27	July 5, 1923	18 miles NE. ¾ E. of Thunder Bay Island.	2¾	80–100		do		4
	28	July 7, 1923	13 miles NE. ½ N. of Thunder Bay Island.	2¾	60		do	1	4
	29	July 10, 1923	3 miles E. ½ S. of North Point.	4½	14–20		do	1	6
M. Couture[1] Capt. Pohlkotter	30	November		4½	24–30		Abundant		
Harbor Beach, Mich.	31	Oct. 27, 1917	35 miles NE. by N. ¾ N.	2¾	50	Clay	Occasional		26
	32	Dec. 9, 1917		1½	30		Abundant		25
	33	Mar. 15, 1919		1½	31		66 per cent		92
Tobermory, Ontario. W. Leslie, D. McInnis, W.W. Ransbury, W. J. Simpson, J. R. Simpson, K. McLeod, E. Darragh	34	June	10 miles southwest and west of Cape Hurd.	4½	30		Abundant		
North Channel: J. Merrylees, J. Young, A. Purvis	35	August	Off Gore Bay Light	4½	20–25		Common		
Georgian Bay:									
Lions Head, Ontario.	36	July 30, 1919	21 miles east of Surprise Shoal.	3	60		Only specimens taken in lift.		43
	37	Oct. 6, 1919	Off White Bluff	3	70		do		52
Wiarton, Ontario.	38	July 28, 1919	4 miles northeast of Cape Croker Light.	3	52		do	2	34
	39	July 30, 1919		3			do	2	38
	40	Nov. 28, 1919	Colpoy Bay	3	10–25		do		7
	41	Dec. 3, 1919	do	1½	15	Mud, rock.	do		25
Borrowed specimens:									
Port Huron, Mich.[2]									2

[1] See note, Table 20.

[2] University of Michigan collection.

TABLE 59.—*Numerical expressions of certain systematic characters for 15 specimens of Leucichthys hoyi from Lake Huron, 10 from depths of about 30 fathoms and 5 from depths of 60 fathoms or more, selected according to size and habitat*

Variety	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
30-fathom	234	Alpena, Mich.	177	♂	16+27	68	4.4	6.2	11.0	9.8	2.7	8.0	4.3	8.4	1.9	2.1	2.9
	238	do	147	♂	15+26	73	4.3	5.8	9.4	9.6	2.7	8.4	4.5	8.5	1.9	2.1	2.8
	247	do	173	♀	15+28	74	4.2	6.0	10.2	10.1	2.9	8.0	4.2	7.8	1.8	2.1	3.0
	252	do	182	♂	15+27	75	4.2	6.0	9.1	8.7	2.7	9.5	4.5	8.1	1.8	2.1	2.9
	268	do	189	♀	15+26	71	4.3	6.0	10.0	10.5	2.8	8.3	3.8	7.7	2.0	2.2	3.1
	36B	Harbor Beach, Mich.	184	♂	15+27	72	4.2	5.9	10.1	9.8	2.7	8.3	4.0	8.0	1.9	2.0	2.9
	38B	do	161	♂	15+27	74	4.1	5.7	10.0	10.3	2.9	7.3	4.0	8.2	2.0	2.0	2.8
	45B	do	152	♀	15+29	74	4.0	5.5	10.2	10.0	2.8	8.9	3.9	7.6	1.9	2.0	2.8
	58B	do	180	♀	15+27	69	4.1	5.6	9.2	9.4	2.8	8.5	3.7	7.3	1.9	2.0	2.7
	70B	do	163	♀	14+27	72	4.2	5.5	10.5	8.9	2.8	8.3	3.7	8.1	2.2	2.0	2.7
60-fathom	29B	Alpena, Mich.	161	♀	15+26	67	4.0	5.6	10.0	9.0	2.8	8.7	4.2	9.4	2.2	2.0	2.8
	30B	do	161	♂	16+28	79	3.9	5.2	9.7	9.5	3.0	9.4	4.2	8.9	2.1	2.0	2.8
	381	do	158	♀	14+27	79	3.9	5.2	9.7	8.6	3.0	8.4	4.6	10.0	2.1	2.0	2.8
	391	do	151	♀	15+26	78	3.9	5.4	10.7	9.5	3.0	7.7	3.9	10.0	2.5	2.0	2.8
	394	do	170	♀	15+26	73	4.0	5.7	10.6	9.5	3.1	8.4	4.4	9.4	2.1	2.0	2.9

Variety	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
30-fathom	234	3.3	4.4	3.6	2.3	3.7	2.0	3.0	5.4	2.6	1.7	2.7	1.9	1.3	9	11	11	15	1.9	1.1	8
	238	3.3	4.4	3.7	2.6	3.9	1.9	3.1	5.4	2.7	1.9	2.9	1.9	1.4	9	11	11	15	1.6	1.0	8
	247	3.2	4.6	3.9	2.5	3.7	1.9	3.5	5.0	2.8	1.7	2.6	2.0	1.4	9	11	11	17	1.6	1.0	9
	252	3.3	4.6	3.8	2.7	3.8	2.1	3.4	5.0	2.7	1.9	2.7	1.9	1.4	9	12	11	16	1.6	.97	8
	268	3.4	4.8	3.9	2.5	3.7	1.9	3.6	5.7	2.8	1.8	2.6	2.0	1.4	10	12	11	15	1.5	1.1	9
	36B	3.2	4.5	3.8	2.5	3.8	1.9	3.1	5.1	2.7	1.8	2.7	1.8	1.3	10	11	11	17	1.6	1.1	8
	38B	3.1	4.4	3.6	2.4	3.9	1.9	3.6	4.8	2.5	1.7	2.8	1.8	1.2	9	10	10	15	1.8	1.1	8
	45B	3.1	4.2	3.6	2.5	4.1	1.9	4.0	5.0	2.7	1.8	3.0	1.9	1.2	9	11	11	14	1.7	1.1	8
	58B	3.2	4.3	3.8	2.5	3.7	1.9	4.0	4.8	2.8	1.8	2.7	2.0	1.3	9	11	11	15	1.5	1.1	9
	70B	3.1	4.2	3.7	2.6	3.8	1.9	3.9	6.2	2.7	1.9	2.8	2.0	1.3	9	12	11	16	1.8	1.0	8
60-fathom	29B	3.1	4.1	3.8	2.5	3.8	1.9	4.8	5.0	2.7	1.7	2.7	1.8	1.3	9	11	12	16	1.7	1.1	8
	30B	3.1	4.4	3.6	2.3	3.7	1.9	4.0	5.1	2.6	1.7	2.6	1.8	1.3	10	12	11	16	1.8	1.1	9
	381	2.9	4.0	4.0	2.5	3.5	1.8	4.3	7.2	2.9	1.8	2.6	1.8	1.2	10	12	11	16	1.6	1.0	8
	391	3.0	4.2	3.8	2.6	3.8	1.9	3.4	5.5	2.7	1.7	2.7	2.0	1.1	9	11	11	17	1.8	1.0	8
	394	3.2	4.4	3.9	2.4	3.8	1.9	3.8	5.0	2.8	1.7	2.7	1.9	1.2	9	11	12	16	1.8	1.1	9

TABLE 60.—*Records of the occurrence of Leucichthys hoyi in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water and character of the bottom where made, the abundance of this species in the lift, and the number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Abundance	Bottom	Preserved specimens examined	
								+200 mm.	−200 mm.
Sault Ste. Marie, Mich.	1	June 14, 1922	In Whitefish Bay	1½	40–50	Common			
Marquette, Mich.	2	Aug. 8, 1921	6 miles NE. ¾ N.	1½	42–65	do	Red clay		28
Ontonagon, Mich.	3	Aug. 24, 1921	21 miles west	2½, 2¾, 4½	15–45	Occasional	do	5	16
	4	Aug. 25, 1921	6 miles NNW	2½, 2¾, 4½	20–38	do	Sand and clay	8	10
Apostle Islands, Wis.	5	July 11, 1922	Between Cat and South Twin Islands.	2½, 2¾	15–20	Only specimen taken in lift.	Sand	1	
	6	July 14, 1922	25 miles north of South Twin Island.	4½	50–90	Occasional	Red and yellow clay.		10
	7	July 15, 1922	14–18 miles NW. by N. of South Twin Island.	4½	40–90	Common	Clay		80
	8	do	20 miles northwest of Rocky Island.	4½	35–65	do	do	1	107
Duluth, Minn.	9	July 17, 1922	20 miles NE. by E.	2⅝	30–40	Lift not examined.	Sand	1	1
Grand Marais, Minn.	10	Sept. 14, 1921	Off Terrace Point	2½, 2¾, 4½	30–65	Occasional	Clay	20	10
	11	July 17, 1922	do	4½	30–65	do	do	3	9
Port Arthur, Ontario.	12	Sept. 15, 1923	Thunder Bay, off Thunder Cape.	2½	31	Only specimens taken in lift.	Brownish-gray clay.		3
	13	Sept. 17, 1923	Thunder Bay, south of Welcome Islands.	2½	23	do	do	3	4
	14	Sept. 19, 1923	Thunder Bay, off Sawyer Bay.	2½	49	do	do		10
Rossport, Ontario.	15	Oct. 4, 1921	Off Bread Rock	2½, 2¾	80–90	do	Grayish-brown clay.	1	1
	16	Sept. 20, 1923	Off Salter Island	2½	42	Occasional	Clay		2
Marquette, Mich.[1]								1	

[1] Field Museum collection, borrowed specimen.

TABLE 61.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys hoyi from Lake Superior, selected at random*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
53604	Ontonagon, Mich.	216	14+25	♀	69	4.3	5.8	9.7	10.8	2.8	9.0	3.9	6.9	1.7	2.2	3.0	3.4
53616	do.	222	16+26	♀	68	4.2	6.0	9.7	10.0	2.8	7.4	4.1	8.2	2.0	2.0	2.9	3.4
53630	do.	193	16+25	♀	74	3.7	5.1	9.6	9.1	3.0	8.0	3.7	7.8	2.1	2.0	2.8	2.9
53683	do.	203	16+28	♀	69	4.1	5.7	9.6	8.8	2.7	7.8	4.3	9.5	2.2	2.0	2.8	3.1
53774	Grand Marais, Minn.	200	14+24	♂	75	4.0	5.5	8.3	9.1	2.7	8.7	3.7	7.6	2.0	2.0	2.9	3.1
53817	do.	223	15+27	♀	79	4.2	6.0	10.1	10.2	2.9	9.6	4.2	7.9	1.8	2.0	3.0	3.3
53599	Ontonagon, Mich.	179	16+27	♀	73	3.8	5.2	9.4	10.4	2.7	7.3	4.0	8.5	2.0	2.0	2.7	3.0
53656	do.	159	15+25	♂	72	3.7	4.9	9.9	8.8	2.7	7.5	4.1	8.3	2.0	1.9	2.5	2.8
58293	Apostle Islands, Wis.	169	17+29	♂	78	3.9	5.2	8.8	9.3	2.6	8.0	4.0	8.8	2.2	1.9	2.6	3.0
58458	Grand Marais, Minn.	146	17+27	♀	70	3.7	5.0	9.9	9.9	2.9	7.8	3.8	8.1	2.1	1.9	2.6	2.9

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
53604	Ontonagon, Mich.	4.7	3.9	2.5	3.7	1.8	3.5	4.5	2.8	1.8	2.7	1.8	1.4	11	11	12	16	1.8	1.2	8
53616	do.	4.8	3.9	2.6	4.3	2.0	3.2	5.6	2.9	1.8	3.0	2.0	1.4	10	10	11	15	1.6	1.1	8
53630	do.	4.0	3.8	2.3	3.8	1.8	3.8	5.1	2.8	1.7	2.8	1.5	1.1	9	12	11	16	1.9	1.1	9
53683	do.	4.3	3.8	2.4	3.8	1.9	3.1	4.9	2.7	1.7	2.7	1.8	1.2	10	12	11	15	1.8	1.0	9
53774	Grand Marais, Minn.	4.3	3.9	2.3	3.7	1.9	3.8	4.5	2.8	1.7	2.6	1.6	1.1	11	11	11	17	1.5	1.1	8
53817	do.	4.8	4.3	2.4	3.9	1.9	3.5	5.7	3.0	1.6	2.7	1.8	1.4	10	11	11	17	1.8	1.1	9
53599	Ontonagon, Mich.	4.1	3.7	2.5	3.7	1.9	3.2	5.7	2.7	1.9	2.7	1.8	1.1	11	11	11	15	2.0	1.1	8
53656	do.	3.7	3.6	2.4	3.8	1.9	3.3	4.6	2.7	1.8	2.9	1.6	1.2	9	11	10	16	1.7	1.1	8
58293	Apostle Islands, Wis.	4.1	3.5	2.3	3.6	1.8	3.3	4.5	2.6	1.7	2.7	1.7	1.2	11	11	11	16	1.7	1.2	9
58458	Grand Marais, Minn.	3.9	3.5	2.5	3.8	1.9	3.5	4.8	2.6	1.9	2.9	1.7	1.4	9	10	11	16	1.8	1.2	8

TABLE 62.—*Records of the occurrence of Leucichthys hoyi in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.[1]	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined
1	July 26, 1922	Off Macdiarmid	2½, 2¾	30	[2] 50
2	Aug. 16, 1923	do.		18	1
3	Sept. 10, 1923	do.			6
4	July 29, 1924	do.		15	1
5	Sept. 1, 1923	Off Blackwater River		30	2
6	July 25, 1924	do.		54	2
7	Sept. 3, 1923	Humboldt Bay		6-35	[3] 13
8	Aug. 15, 1922	Off Murchison Island		25	2
9	Aug. 1, 1922	Ombabika Bay	4½	15-20	[4] 27
10	Aug. 17, 1922	Off Whitesand River		25	13
11	Aug. 30, 1923	Off Virgin Island		19	3
12	Aug. 3, 1922	Unknown		20-25	3
13	Aug. 5, 1922	do.		20-25	2
14	Aug. 15, 1922	do.		20-25	11
15	Oct. 26, 1922	do.			17
16		No data			18

[1] All but records 1, 9, and 15 from University of Toronto collections.
[2] Eight specimens over 200 millimeters.
[3] One specimen over 200 millimeters.
[4] Two specimens over 200 millimeters.

TABLE 63.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys hoyi from Lake Nipigon, selected according to size*

Field No.	Locality	Length, millimeters	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
57437	Macdiarmid, Ontario	212	16+28	♀	79	4.0	5.4	8.8	8.4	3.0	7.8	4.4	9.6	2.1	2.0	2.7	3.1
57460	do	218	15+27	♀	70	4.0	5.7	10.3	10.0	3.0	8.7	4.1	8.7	2.1	2.0	2.9	3.2
57590	do	215	17+28	♀	78	4.0	5.6	9.3	8.9	2.8	8.6	4.3	8.9	2.0	2.0	2.9	3.1
57615	do	202	16+29	♀	75	3.9	5.4	10.2	9.1	3.0	8.7	4.2	8.4	1.9	1.9	2.8	3.1
57639	do	200	16+28	♀	76	3.8	5.1	9.1	9.0	2.8	7.8	4.2	8.3	1.9	1.9	2.7	3.0
57696	do	153	16+29	♀	79	3.9	5.4	9.2	9.0	3.0	7.7	4.2	9.2	2.1	2.0	2.7	3.1
57704	Ombabika Bay	182	16+29	♂	81	3.8	5.5	9.0	8.2	2.9	9.5	4.0	8.2	2.0	1.9	2.7	2.9
57706	do	175	16+26	♀	77	3.8	5.1	9.7	9.7	2.9	7.9	4.6	9.7	2.1	2.0	2.7	3.0
57709	do	164	16+29	♀	75	3.9	5.0	9.0	9.1	3.0	7.9	4.0	8.2	2.0	2.0	2.6	3.0
57719	do	153	17+29	♂	74	3.9	5.2	9.6	9.5	2.9	8.0	4.6	10.2	2.2	2.0	2.6	3.0

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
57437	Macdiarmid, Ontario	4.1	3.8	2.3	3.5	1.8	3.0	5.3	2.8	1.6	2.6	1.4	1.2	10	12	11	15	1.7	1.2	9
57460	do	4.6	3.9	2.4	3.8	1.8	3.2	5.4	2.7	1.6	2.7	1.6	1.2	8	10	11	16	2.1	1.4	9
57590	do	4.3	3.7	2.4	3.7	1.8	3.3	5.7	2.7	1.7	2.7	1.7	1.3	10	11	11	15	1.7	1.1	9
57615	do	4.2	3.9	2.3	3.5	1.9	3.5	4.3	2.8	1.6	2.6	1.7	1.2	9	12	11	16	2.0	1.2	9
57639	do	4.1	4.0	2.3	3.6	1.8	3.0	4.9	3.0	1.7	2.7	1.6	1.2	10	11	12	15	1.8	1.2	9
57696	do	4.3	3.5	2.3	3.8	1.8	3.6	4.8	2.5	1.7	2.8	1.5	1.3	10	12	11	15	1.7	1.1	9
57704	Ombabika Bay	4.2	3.8	2.3	3.8	1.9	3.3	4.7	2.7	1.6	2.7	1.6	1.2	10	12	11	17	1.8	1.2	9
57706	do	4.0	4.0	2.4	3.5	1.8	3.4	5.6	3.0	1.7	2.6	1.8	1.1	10	11	11	15	1.7	1.3	9
57709	do	3.9	3.5	2.3	3.4	1.8	3.5	4.2	2.7	1.8	2.7	1.6	1.1	10	11	11	16	1.8	1.3	9
57719	do	4.0	3.5	2.2	3.8	1.8	3.9	4.8	2.6	1.7	2.8	1.4	1.1	9	11	11	16	1.8	1.3	9

TABLE 64.—*Records of the occurrence of Leucichthys hoyi in Lake Ontario*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the abundance of this species in the lift, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Percentage	Preserved specimens examined	
								+200 mm.	−200 mm.
Winona, Ontario	1	Nov. 23, 1917		2½			(1)	1	
Bronte, Ontario	2	June 29, 1921	13 miles E. ½ S	2½, 2¾	40–50	Mud	(1)	7	1
	3	June 30, 1921	Off Oakville	4¾	16			1	1
Brighton, Ontario	4	June 10, 1921	20 miles S. by W. of Presque Isle Light.	2½	40–50	Mud	(2)	13	3
	5	June 16, 1921	do	2½	40–50	do	(3)	12	
Sandy Pond, N. Y.	6	Aug. 24, 1923	9 miles west	3	25–28	Sand and mud	(1)	5	
	7	Aug. 30, 1923	14 miles west	1½, 2½ 3, 3¼, 3½	60	Clay and mud	(1)	14	1
Selkirk, N. Y.	8	July 11, 1921	5 miles NNW. of Nine-Mile Point.	3	25–35	Blue clay	(1)	8	2
Oswego, N. Y.	9	Sept. 1, 1923	Off Nine-Mile Point	3	30	Clay	(1)	7	2
	10	Sept. 4, 1923	8½ miles W. by N. ½ N	1½, 2½, 3	70–75	Clay and mud	(1)		4
Sodus Point, N. Y.	11	July 12, 1921	8½ miles NNW	2½, 2¾	60	Mud and clay	75	70	4
	12	July 13, 1921	NNW	3	40	Mud	(1)		
Charlotte, N. Y.	13	July 4, 1921	7 miles off Braddock Point Light.	2½, 2¾	65	Blue and brown clay.	66	58	
Wilson, N. Y.	14	June 23, 1921	3 miles north	2½, 2¾	30	Brown clay	(1)	4	
	15	June 25, 1921	5 miles north	2½, 2¾	50	Clay and mud	60	23	1
	16	July 16, 1921	do	2½, 2¾	50	Clay	90		
	17	July 19, 1921	6½ miles N. by W. ½ W	2½, 2¾	65	Blue and brown clay.	25	7	3
	18	July 21, 1921	2 miles north	2½	20		(1)	5	
Toronto, Ontario [4]								1	

[1] Rare.
[2] Occasional.
[3] Common.
[4] U. S. National Museum collection.

TABLE 65.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys hoyi from Lake Ontario, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
53194	Brighton, Ontario	128	14+28	♀	75	3.7	4.9	10.0	9.7	2.9	7.5	4.5	9.8	2.1	1.9	2.5	2.8
53277	Bronte, Ontario	167	16+30	♀	76	3.9	5.5	10.9	9.8	3.0	8.3	4.1	9.2	2.2	2.0	2.9	3.1
54079	Wilson, N. Y	164	17+29	♀	75	3.9	5.1	9.6	9.6	2.7	9.6	3.8	8.6	2.2	1.9	2.5	3.0
62468	Sandy Pond, N. Y	183	16+28	♀	73	3.8	5.3	9.8	8.7	3.0	8.3	4.3	10.1	2.3	2.0	2.7	3.0
54124	Sodus Point, N. Y	219	18+30	♀	71	4.0	5.6	8.7	8.7	2.6	8.5	3.9	7.5	1.9	1.9	2.7	3.0
54165	do	196	15+25	♂	67	4.0	5.4	9.7	9.2	2.7	8.1	3.7	7.2	1.9	2.0	2.8	3.1
54139	do	214	15+27	♀	69	4.1	5.7	8.9	9.2	2.7	8.9	3.6	7.9	2.1	2.2	3.0	3.3
54159	do	208	16+30	♀	76	4.1	5.9	10.0	9.0	2.8	9.0	4.1	8.6	2.0	2.0	2.9	3.3
54200	do	253	16+28	♀	74	4.4	6.1	10.2	11.9	2.8	8.8	4.0	8.1	2.0	2.2	3.1	3.4
54205	do	253	15+28	♀	71	4.2	6.0	10.5	10.2	2.7	8.7	3.9	7.9	2.0	2.1	2.9	3.4

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
53194	Brighton, Ontario.	3.7	3.7	2.6	3.6	1.8	4.1	4.2	2.8	2.0	2.8	1.5	1.3	9	10	11	15	1.8	1.1	8
53277	Bronte, Ontario	4.3	3.8	2.8	4.1	1.9	4.2	4.7	2.7	2.0	2.9	1.9	1.4	9	10	10	15	1.9	1.0	9
54079	Wilson, N. Y	4.0	3.8	2.4	3.5	1.8	3.8	4.6	2.9	1.8	2.7	1.7	1.2	9	----	11	16	1.7	------	9
62468	Sandy Pond, N. Y.	4.1	3.9	2.6	3.6	1.8	4.7	5.7	2.8	1.8	2.6	2.0	1.1	9	11	10	14	1.6	1.0	8
54124	Sodus Point, N. Y.	4.2	4.2	2.7	3.6	1.9	4.1	4.6	3.0	1.9	2.6	1.6	1.3	9	11	11	16	1.4	1.0	8
54165	do	4.2	4.3	2.6	3.7	1.9	3.7	5.4	3.2	1.9	2.7	1.7	1.2	9	11	10	14	1.6	1.0	9
54139	do	4.5	4.1	2.4	3.7	1.8	4.2	4.6	3.0	1.7	2.7	1.7	1.3	9	12	11	14	1.4	1.0	8
54159	do	4.7	4.1	2.5	3.7	1.9	4.0	4.9	2.9	1.7	2.6	2.2	1.4	9	11	10	15	1.5	.95	9
54200	do	4.8	4.2	2.6	3.9	2.0	4.3	5.1	3.0	1.9	2.8	2.0	1.5	9	10	11	15	1.5	1.2	8
54205	do	4.7	4.4	2.5	3.6	1.9	3.4	4.5	3.1	1.8	2.6	2.0	1.5	9	10	11	14	1.6	1.0	8

TABLE 66.—*Records of the occurrence of Leucichthys artedi in Lake Erie*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Port from which nets were set	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined	
					+225 mm.	−225 mm.
Monroe, Mich	1920				11	1
Sandusky, Ohio	Nov. 29, 1920		3		16	3
Ashtabula, Ohio	Oct. 20, 1920	S. by W. of breakwater	3	5–7	3	1
	Oct. 22, 1920	14 miles NE. by N	3	12	1	1
	Oct. 23, 1920	do	3	12	3	1
Erie, Pa	Oct. 24, 1920	12 miles N. by E	3		6	1
	do	19 miles NNE	3		1	23
	Oct. 25, 1920	17 miles NE. by N. ½ N	3	20–25	6	41
	Oct. 26, 1920	22 miles NE. ½ N	3		1	
Dunkirk, N. Y	Oct. 27, 1920	12 miles NW. by N	3	24	14	5
	Oct. 28, 1920	14 miles W. by N	3	25	5	35
Port Stanley, Ontario	Dec. —, 1922	West of the port	3		59	3
Erieau, Ontario	Dec. 3, 1924		3		25	
Borrowed specimens:						
Erie, Pa.[1]					22	
Do.[2]					3	
Cleveland, Ohio[2]					1	
Port Stanley, Ontario[3]					1	
Port Maitland, Ontario[3]					7	1
Port Dover, Ontario[3]					7	1
Merlin, Ontario[3]					1	

[1] Field Museum collection. [2] U. S. National Museum collection. [3] University of Toronto collection.

TABLE 67.—*Numerical expressions of certain systematic characters for 40 specimens of Leucichthys artedi from Lake Erie, 30 of them over 200 millimeters long and 10 under 200 millimeters long, selected according to size and locality*

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB
Albus form:										
East end, over 200 mm.	4049	Ashtabula, Ohio	225	Im. ♀	17+31	71	4.2	6.0	8.0	7.8
	4050	do	293	♀	18+30	77	4.5	6.5	8.3	8.9
	4051	do	277	♀	17+29	77	4.7	6.9	9.5	10.5
	4056	do	249	♀	18+30	74	4.4	6.3	9.5	9.6
	4060	Erie, Pa	247	♀	18+31	80	4.2	6.0	9.5	8.8
	4096	do	255	♀	17+30	75	4.5	6.7	10.0	10.5
	4114	do	234	♂	17+31	76	4.5	6.1	10.0	10.6
	4136	do	315	♀	17+28	76	4.6	6.7	9.0	9.0
	4145	Dunkirk, N. Y	231	♂	18+30	76	4.3	6.1	9.2	8.7
	4158	do	283	♂	18+30	72	4.6	6.5	8.8	8.5
West end	59330	Port Stanley, Ontario	276	♂	17+29	75	4.4	6.0	8.1	7.8
	59336	do	241	♀	16+30	69	4.4	6.2	8.0	9.3
	59351	do	305	♂	16+29	75	4.5	6.6	8.0	8.2
	59353	do	299	♀	16+28	77	4.7	6.6	8.3	9.9
	59364	do	282	♂	18+31	73	4.6	6.7	7.8	8.9
	59370	do	256	♀	18+30	75	4.4	6.5	7.7	8.8
	59372	do	250	♀	16+27	76	4.5	6.2	8.8	10.5
	59378	do	264	♀	16+30	81	4.7	6.6	8.0	7.8
	59380	do	231	♀	17+31	77	4.6	6.2	8.5	9.2
	59384	do	237	♂	17+27	72	4.4	6.3	8.7	8.4
Artedi form:										
Bluebacks	4600	Sandusky, Ohio	297	♂	16+29	77	4.6	6.3	9.5	9.9
	4602	do	305	♀	19+31	76	4.8	7.0	10.8	9.8
	52802	Monroe, Mich	302	♀	16+30	84	4.9	7.1	11.5	10.2
	52803	do	229	♂	18+32	89	4.5	6.5	10.1	11.9
	52806	do	234	♀	18+31	83	4.5	6.1	11.2	10.1
	52807	do	258	♂	16+30	82	4.6	6.4	10.0	10.2
	52808	do	254	♂	17+30	81	4.7	6.5	9.6	9.4
	52809	do	315	♂	19+30	78	5.0	7.1	10.1	9.9
	52812	do	260	♀	17+30	85	4.6	6.1	9.6	9.2
	52813	do	341	♀	16+30	84	5.2	7.4	12.1	11.3
Albus form:										
Under 200 mm	4057	Ashtabula, Ohio	181	♂	17+29	83	4.3	6.2	7.9	8.9
	4070	do	196	♂	16+29	73	4.4	5.9	9.2	8.9
	4102	Erie, Pa	168	Im. ♀	15+30	73	4.3	6.1	8.8	8.4
	4106	do	184	♂	16+28	77	4.2	5.7	9.2	9.4
	4130	do	194	♀	16+30	80	4.2	5.7	9.1	9.7
	4131	do	160	Im. ♀	18+29	74	4.1	5.9	8.9	8.9
	4137	do	193	♀	17+29	78	4.3	5.9	8.9	9.1
	4139	do	185	♀	16+28	71	4.3	6.1	9.7	8.4
	4147	Dunkirk, N. Y	128	Im. ♂	17+30	78	4.2	6.0	8.6	9.2
	4171	do	188	♀	17+28	75	4.2	5.8	9.6	9.4

Size	Field No.	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad
Albus form:															
East end, over 200 mm	4049	2.6	7.2	3.0	6.4	2.0	2.1	3.1	3.2	4.7	4.3	2.8	4.0	2.1	3.0
	4050	2.6	9.7	3.4	6.6	1.9	2.3	3.3	3.6	5.2	4.3	2.6	4.0	2.0	3.5
	4051	3.0	7.3	3.6	7.1	1.9	2.4	3.5	3.7	5.5	4.5	2.9	3.9	2.1	2.9
	4056	2.8	9.2	3.5	7.3	2.0	2.4	3.4	3.5	5.0	4.3	2.6	4.0	2.1	3.7
	4060	2.7	8.2	3.3	7.4	2.2	2.1	3.0	3.3	4.7	4.2	2.7	4.0	2.0	3.1
	4096	2.9	8.5	3.6	7.7	2.0	2.2	3.3	3.6	5.4	4.4	2.8	3.7	2.1	3.4
	4114	2.8	8.0	4.0	8.0	2.0	2.3	3.1	3.6	5.0	4.2	2.6	4.0	2.0	3.2
	4136	2.8	7.8	3.3	6.7	2.0	2.3	3.3	3.5	5.1	4.5	2.9	4.5	2.1	2.8
	4145	3.0	7.2	3.7	7.8	2.0	2.1	3.0	3.5	5.1	4.0	2.6	4.0	1.9	2.9
	4158	2.7	9.1	3.3	6.5	1.9	2.3	3.2	3.8	5.4	4.6	2.8	3.9	2.1	3.4
West end	59330	2.6	6.5	2.8	5.8	2.0	2.1	2.9	3.4	4.5	4.5	2.6	3.9	2.0	2.5
	59336	2.8	7.4	3.5	7.3	2.0	2.1	3.0	3.5	5.0	4.8	2.8	3.9	2.1	2.7
	59351	2.8	9.5	3.0	6.4	2.1	2.3	3.4	3.5	5.1	4.9	2.8	3.9	2.1	3.1
	59353	2.5	8.4	3.4	6.6	1.9	2.4	3.4	3.7	5.2	4.8	2.9	3.8	2.1	2.8
	59364	2.7	6.8	3.6	7.6	2.1	2.1	3.1	3.5	5.2	4.6	2.9	4.0	2.2	3.0
	59370	2.7	8.3	3.2	6.7	2.1	2.2	3.3	3.5	5.2	4.5	3.1	4.0	2.1	3.0
	59372	2.8	7.8	3.7	6.7	1.7	2.3	3.2	3.5	4.8	4.2	2.8	4.1	2.0	2.8
	59378	2.7	9.1	3.7	6.9	1.8	2.3	3.2	3.8	5.3	4.3	2.8	3.8	2.0	3.1
	59380	2.8	7.4	3.7	7.0	1.8	2.3	3.2	3.7	5.0	4.2	2.7	3.8	2.0	2.8
	59384	2.8	7.9	3.1	6.0	1.9	2.3	3.3	3.4	4.9	4.4	2.9	4.1	2.2	3.3
Artedi form:															
Bluebacks	4600	2.7	8.7	4.1	7.0	1.7	2.3	3.1	3.6	4.9	4.5	3.0	3.9	2.2	3.7
	4602	2.7	9.2	3.7	6.4	1.7	2.4	3.5	3.9	5.6	4.4	3.1	4.2	2.2	3.4
	52802	2.5	7.9	4.1	7.5	1.8	2.3	3.4	3.8	5.5	4.3	3.0	3.8	2.1	3.8
	52803	2.6	7.6	4.8	8.8	1.8	2.2	3.2	3.6	5.1	4.1	2.8	3.7	2.0	4.2
	52806	2.8	7.8	4.0	8.3	2.0	2.2	3.1	3.5	4.7	4.1	2.7	3.7	2.0	3.7
	52807	2.8	7.8	4.0	8.0	2.0	2.4	3.3	3.7	5.1	4.4	2.6	3.6	2.0	3.3
	52808	2.6	7.6	4.2	8.1	1.9	2.2	3.1	3.6	5.1	4.2	2.9	3.8	2.0	3.3
	52809	2.6	8.2	4.3	7.0	1.6	2.4	3.4	4.0	5.7	4.5	3.0	4.1	2.2	3.5
	52812	2.7	8.9	4.0	8.1	2.0	2.3	3.1	3.6	4.8	4.3	2.6	3.6	2.0	3.2
	52813	2.7	8.1	4.1	7.2	1.7	2.6	3.6	4.1	5.8	4.5	3.0	4.0	2.1	3.3

TABLE 67.—*Numerical expressions of certain systematic characters for 40 specimens of Leucichthys artedi from Lake Erie, 30 of them over 200 millimeters long and 10 under 200 millimeters long, selected according to size and locality*—Continued

Size	Field No	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad
Albus form:															
Under 200 mm	4057	2.7	8.6	3.6	7.8	2.1	2.1	3.1	3.4	4.9	4.2	2.8	4.0	2.1	3.7
	4070	2.7	8.5	3.8	8.5	2.2	2.2	3.0	3.5	4.6	3.7	2.7	4.0	2.0	3.3
	4102	2.9	8.4	3.8	8.8	2.3	2.1	3.0	3.4	4.8	4.2	2.8	4.2	2.0	4.2
	4106	2.7	9.4	3.9	8.7	2.1	2.1	2.9	3.3	4.5	3.8	2.7	3.9	2.0	3.5
	4130	2.8	8.4	3.9	8.0	2.0	2.1	2.8	3.4	4.5	4.0	2.8	3.9	2.0	3.7
	4131	2.8	8.0	3.8	8.0	2.1	2.1	3.0	3.3	4.7	4.1	2.8	3.8	2.1	3.5
	4137	2.7	7.4	3.7	8.0	2.1	2.2	3.0	3.4	4.6	3.8	2.7	3.9	2.0	2.9
	4139	3.0	9.2	4.2	8.0	1.9	2.3	3.3	3.4	4.9	3.9	2.8	3.9	2.0	3.9
	4147	2.8	8.5	4.2	9.1	2.1	2.1	3.0	3.2	4.6	4.0	2.9	4.1	2.1	3.3
	4171	2.9	8.1	3.8	7.5	1.9	2.2	3.0	3.4	4.7	4.0	2.5	3.7	1.9	3.0

Size	Field No.	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Scale rows		
Albus form:																	
East end, over 200 mm	4049	5.4	3.0	1.9	2.8	1.7	1.5	10	12	11	15	1.4	0.90	8	42	35	26
	4050	5.2	3.0	1.8	2.7	2.0	1.9	11	11	11	14	1.3	.92	8	40	32	25
	4051	5.8	3.0	2.0	2.6	2.1	1.9	9	10	11	16	1.4	1.0	8	41	32	25
	4056	5.0	3.0	1.8	2.7	2.0	1.7	10	12	11	16	1.5	1.0	8	42	33	24
	4060	4.9	2.9	1.9	2.8	1.9	1.4	9	11	11	16	1.6	1.0	8	40	32	24
	4096	5.0	3.0	1.9	2.5	2.0	1.7	9	10	11	14	1.5	1.1	7	41	32	24
	4114	5.2	3.1	1.9	2.9	1.8	1.6	9	10	11	16	1.5	1.1	9	42	32	25
	4136	4.8	3.1	2.0	3.1	1.9	1.6	10	11	11	16	1.4	1.0	9	45	32	24
	4145	5.3	2.8	1.8	2.8	1.9	1.6	9	11	11	16	1.5	.95	8	41	34	25
	4158	5.5	3.2	2.0	2.7	2.1	1.7	11	12	11	15	1.5	1.0	8	39	31	23
West end	59330	5.6	3.4	2.0	2.9	1.8	1.5	10	12	11	15	1.3	.92	7	40	31	24
	59336	5.4	3.4	2.0	2.7	1.9	1.6	10	10	11	15	1.4	1.1	8	40	32	24
	59351	4.7	3.4	1.9	2.7	2.0	1.5	10	12	12	14	1.3	.91	8	42	33	25
	59353	5.4	3.4	2.1	2.7	2.0	1.6	10	11	11	15	1.3	1.0	8	38	32	24
	59364	6.1	3.1	2.0	2.8	2.1	1.7	10	11	11	17	1.2	.95	8	40	32	24
	59370	5.7	3.1	2.1	2.7	1.7	1.8	11	11	11	16	1.3	1.0	8	42	33	25
	59372	5.9	3.0	2.0	3.0	2.0	1.5	11	10	11	15	1.3	1.0	8	41	35	25
	59378	5.8	3.1	2.0	2.7	2.0	1.9	11	13	11	15	1.3	.80	8	41	33	25
	59380	5.4	3.1	2.0	2.8	2.1	1.7	11	11	11	16	1.4	1.0	8	39	32	24
	59384	5.8	3.1	2.0	2.9	2.0	1.4	10	11	12	16	1.5	1.0	8	41	32	24
Artedi form:																	
Bluebacks	4600	5.7	3.3	2.2	2.9	2.4	1.9	9	11	11	16	1.3	.86	8	44	36	27
	4602	5.7	3.0	2.1	2.9	2.5	1.9	9	12	11	16	1.6	1.0	8	42	34	25
	52802	6.1	3.0	2.1	2.6	2.5	1.9	8	10	11	15	1.5	.88	8	43	33	25
	52803	5.0	2.9	1.9	2.6	2.2	1.7	10	10	12	16	1.4	1.0	9	44	34	25
	52806	5.0	3.0	2.0	2.7	2.2	1.7	9	11	11	17	1.6	1.0	8	44	36	27
	52807	5.0	3.2	1.9	2.6	2.2	1.7	10	11	11	18	1.4	1.0	7	45	34	26
	52808	5.6	3.0	2.0	2.7	2.2	1.7	10	11	11	16	1.3	.88	8	45	35	26
	52809	5.7	3.1	2.0	2.8	2.4	2.0	10	11	12	16	1.5	.94	8	43	34	25
	52812	4.6	3.2	2.0	2.7	2.1	1.8	11	12	11	17	1.4	.91	8	43	34	26
	52813	5.4	3.2	2.1	2.8	2.5	2.1	8	10	11	16	1.5	.93	8	46	36	26
Albus form:																	
Under 200 mm	4057	6.0	2.9	2.0	2.7	2.0	1.5	11	11	10	14	1.3	1.0	7	40	32	24
	4070	5.5	2.7	2.0	3.0	1.8	1.5	10	12	11	16	1.6	1.0	8	40	32	23
	4102	5.0	3.0	2.0	3.0	1.9	1.6	9	12	11	14	1.5	1.0	8	40	32	24
	4106	5.7	2.8	2.0	2.9	1.7	1.3	9	11	11	15	1.6	1.1	7	42	34	25
	4130	5.0	3.0	2.0	2.9	1.9	1.6	11	12	12	15	1.4	1.0	8	41	33	24
	4131	5.3	2.9	2.0	2.7	1.9	1.4	10	11	11	15	1.6	1.0	7	40	33	24
	4137	5.5	2.8	2.0	2.9	1.8	1.5	11	11	11	16	1.5	1.0	7	40	32	24
	4139	5.2	2.7	2.0	2.7	1.9	1.4	10	12	12	15	1.6	.94	8	41	33	24
	4147	5.7	2.8	2.0	2.9	1.8	1.4	10	10	11	14	1.5	1.0	7	42	33	24
	4171	5.0	2.9	1.8	2.7	1.7	1.4	9	11	10	15	1.8	1.2	8	41	31	23

TABLE 68.—*Records of the occurrence of Leucichthys artedi in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of bottom where made, percentage of this species in the lift, and total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Percentage of artedi	Preserved specimens examined: +225 mm.	Preserved specimens examined: −225 mm.
Menominee, Mich.	1	Aug. 16, 1920	Off Little Sturgeon	2⅜, 2½	11		100	4	1
	2	do	8 miles south of Green Island	2⅜	16		100	13	2
Oconto, Wis.	3	Nov. 17, 1920	4 miles northeast	2⅜	2		100	7	3
	4	do	3 miles southeast	(1)	5-6		100	14	10
Washington Harbor, Wis.	5	Aug. 18, 1920	4 miles west of Boyer Bluff	2⅜	18-24		45	10	2
	6	do	7 miles NNW	2⅝	11				2
	7	do	5 miles west of Boyer Bluff	4	20	Rock	(2)		2
	8	Aug. 19, 1920	3 miles WNW. of Boyer Bluff	4	20-24			3	
	9	do	20 miles E. ½ N. of Rock Island	2½, 2⅝	71-90	Clay, mud	(3)		1
	10	do	Off northwest end of St. Martin's Island.	4½	14	Rock	(2)		32
Sturgeon Bay, Wis.	11	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60-70	Mud	(3)		
Algoma, Wis.	12	Aug. 24, 1920	10 miles E. by N.	2½	35-50	Gravel, mud	(3)		
Port Washington, Wis.	13	Sept. 25, 1920	18 miles E. ½ S.	2½	65-48	Clay	(3)		
	14	Sept. 27, 1920	Off city	(1)	5		(4)	10	1
Milwaukee, Wis.	15	Mar. 24, 1919		2½	10-15		(4)	8	
	16	do		2½	50		(5)	1	
	17	Sept. 24, 1920	9 miles NNE	2½	22-25	Clay	(5)		
	18	Nov. 15, 1920	5 miles E. by S½ S.	2½	12		(6)	4	1
Michigan City, Ind.	19	Sept. 3, 1920	22 miles NWN. ½ N.	2½	30-40	Clay	(3)	1	
	20	Sept. 4, 1920	Off city	(1)	5	Sand	(4)	7	
	21	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30-40	Mud, clay	(3)		
	22	Mar. 2, 1921	14 miles NNW	1½	26	Clay	(6)		5
	23	Mar. 4, 1921	15 miles NW. by N. ½ N.	2½	28		(6)	4	
Muskegon, Mich.	24	Aug. 31, 1920		2¾				1	
Manistee, Mich.	25	Aug. 27, 1920	3 miles south	(1)	4	Sand	(3)	2	
Platte Bay, Mich. (field station).	26	July 21, 1923	1½ miles south of Otter Creek	1½	8-12	do	(2)		1
	27	July 23, 1923	do	1½	15-25	do	(2)		12
South Manitou Island, Mich.	28	July 30, 1923	Off the light	1, 7 1½	1-5		(3)	1	
Northport, Mich.	29	June 22, 1920	5 miles northwest of Cathead Light.	2¾	40-60		(2)		1
	30	June 23, 1920	Off Northport Point	1½	28-40		(2)		3
	31	July 31, 1923	5 miles northwest of Cathead Light.	2¾	40-60		(2)	4	
Traverse City, Mich.	32	June 22, 1920	4 miles north on east shore of West Bay.	(1)	4	Sand	(6)	3	
	33	June 25, 1920	do	(1)	4	do	(6)	6	4
	34	July 25, 1923	Off Lees Point	1½	4-6		(2)		2
	35	do	do	(7)	1		(2)	1	
	36	do	do	1½	6-16		(2)		1
	37	July 18, 1923	West Bay	1½	30-40	Clay	(3)		
	38	July 19, 1923	Barrow Harbor	(1)	5		(2)	11	3
	39	July 26, 1293	do	(1)	5		(2)	2	12
	40	do	1½ miles south of Barrow Harbor.	(1)	5		(6)		25
Manistique, Mich.	41	Aug. 11, 1920	13 miles SE. ½ E.	4½	20	Sand			11
Seul Choix, Mich.	42	Aug. 20, 1920	1½ miles west of Seul Choix Point.	(1)	5-8		(3)	7	
Borrowed specimens:									
Jackson Park Lagoon, Chicago, Ill.[8]								4	
Chicago, Ill.[8]								2	
Whiting, Ind.[8]									1
Green Bay[8]								14	2
Pine, Ind.[9]								1	

1 Pound net.
2 Only specimens taken in lift.
3 Rare.
4 Common.
5 Lift not examined or percentage not ascertained.
6 Occasional.
7 Seine.
8 Field Museum collection.
9 U. S. National Museum collection.

TABLE 69.—*Numerical expressions of certain systematic characters for 19 specimens of Leucichthys artedi from Lake Michigan over 200 millimeters in length and for 10 specimens under 200 millimeters long, selected according to size and locality*

[Ten of the larger fish are from Green Bay, half from deep water, and half from the shoals, and nine of them from Lake Michigan proper]

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA
		Green Bay:									
Over 200 millimeters.	3038	Menominee, Mich. (deep water)	242	16+30	♀	83	4.6	6.5	9.6	10.1	2.7
	3042	do	248	15+28	♂	76	4.5	6.2	9.2	9.1	2.8
	3046	do	253	17+32	♀	79	4.5	6.4	9.4	10.3	2.6
	3049	do	257	19+34	♀	84	4.5	6.4	8.8	9.9	2.7
	3057	do	285	18+30	♀	82	4.5	6.4	11.1	8.9	2.5
	4290	Oconto, Wis. (shallow water)	257	18+31	♀	82	4.3	6.2	10.3	9.3	2.6
	4294	do	258	17+30	♂	83	4.4	6.2	8.4	8.8	2.7
	4307	do	256	18+32	♀	83	4.7	6.4	10.5	9.8	2.6
	4310	do	252	17+32	♂	78	4.4	6.1	10.8	9.0	2.8
	4314	do	280	16+28	♂	89	4.6	6.6	9.6	10.5	2.6
		Lake Michigan proper:									
	1638	Milwaukee, Wis	255	19+31	♂	93	4.5	6.2	9.8	10.9	2.6
	1645	do	256	18+35	♂	77	4.4	6.0	10.2	10.6	2.7
	2792	Traverse City, Mich	248	18+29	Im. ♀	85	4.6	6.3	9.6	9.2	2.6
	3525	Michigan City, Ind	270	18+31	♀	81	4.5	6.1	10.7	10.3	2.7
	3556	do	258	19+32	♀	79	4.4	6.4	11.2	11.2	2.7
	3558	do	248	17+32	♀	81	4.2	6.0	9.7	10.6	2.6
	3607	Milwaukee, Wis	244	19+34	♀	79	4.2	5.9	10.9	11.0	2.7
	3724	Port Washington, Wis	255	18+31	♀	82	4.4	6.1	9.6	10.2	2.8
	4585	Seul Choix, Mich	289	17+30	♂	80	4.6	6.0	9.9	9.7	2.8
Under 200 millimeters.	3102	Washington Harbor, Wis	157	17+29	Im. ♀	83	4.4	6.5	11.2	9.3	2.9
	3228	do	188	16+29	♂	77	4.0	5.6	11.6	11.0	2.8
	3236	do	194	17+31	♀	71	4.3	5.8	8.8	8.0	2.6
	3252	do	163	17+31	♂	83	4.2	5.9	10.1	9.7	2.7
	59590	Traverse City, Mich	178	20+33	Im. ♂	86	4.5	6.3	9.3	9.8	2.7
	59592	do	165	18+34	Im. ♀	89	4.4	6.1	10.3	11.0	2.7
	59612	do	178	19+33	Im. ♂	83	4.5	6.2	11.8	10.9	2.7
	59614	do	177	16+29	♀	85	4.3	5.9	9.5	9.7	2.8
	59617	do	174	18+33	Im. ♂	85	4.5	6.2	11.2	10.2	2.8
	59690	do	198	15+28	♀	85	4.4	6.0	10.4	10.0	2.9

Size	Field No.	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad
Over 200 millimeters	3038	7.8	3.6	7.8	2.1	2.3	3.2	3.7	5.1	4.0	3.0	4.0	2.1	3.9
	3042	7.7	3.9	7.2	1.8	2.2	3.1	3.6	4.9	4.2	2.5	3.7	1.9	3.2
	3046	8.0	4.0	7.6	1.8	2.2	3.1	3.6	5.0	4.1	3.0	4.1	2.1	4.2
	3049	8.5	3.8	8.5	2.2	2.1	3.0	3.5	5.0	4.2	3.0	4.0	2.2	4.3
	3057	8.3	4.4	7.9	1.7	2.2	3.1	3.4	4.8	4.1	2.9	3.9	2.1	4.8
	4290	9.1	4.2	7.5	1.7	2.1	3.1	3.3	4.7	4.2	3.0	4.2	2.1	4.5
	4294	8.1	4.2	7.5	1.7	2.1	3.0	3.4	4.8	4.2	2.9	4.1	2.1	4.5
	4307	7.7	4.1	7.2	1.7	2.3	3.2	3.6	4.9	4.1	3.0	4.0	2.1	3.4
	4310	8.0	4.5	8.6	1.9	2.1	2.9	3.4	4.8	4.2	2.8	3.7	2.0	3.6
	4314	8.4	4.5	8.4	1.8	2.3	3.3	3.6	5.2	4.2	2.9	4.0	2.1	3.7
	1638	8.7	4.3	7.7	1.7	2.1	2.9	3.5	4.8	4.0	2.7	3.7	2.0	4.7
	1645	7.8	4.8	8.5	1.7	2.1	2.9	3.4	4.7	3.9	2.9	4.0	2.1	4.1
	2792	7.5	4.6	8.5	1.8	2.2	3.0	3.6	4.8	4.0	2.8	4.0	2.0	3.5
	3525	8.7	5.0	8.7	1.7	2.1	2.9	3.5	4.8	4.3	2.9	4.0	2.2	4.6
	3556	8.1	4.8	9.2	1.8	2.1	3.1	3.4	4.9	4.3	3.1	4.2	2.2	4.1
	3558	8.2	5.0	9.1	1.8	2.0	3.0	3.1	4.5	4.2	2.8	3.9	2.1	4.6
	3607	8.1	4.9	7.8	1.5	2.1	2.9	3.2	4.1	4.1	2.9	3.8	2.1	4.0
	3724	8.5	4.9	9.1	1.8	2.1	3.0	3.4	4.7	4.1	2.8	3.8	2.0	4.4
	4585	8.2	4.7	7.8	1.6	2.3	3.0	3.6	4.7	4.0	2.8	3.6	2.1	4.1
Under 200 millimeters	3102	7.4	5.4	9.8	1.8	2.1	3.1	3.2	4.7	4.1	2.8	3.8	2.0	3.5
	3228	7.5	4.9	9.4	1.9	2.0	2.7	3.0	4.2	3.8	2.7	3.6	2.0	4.1
	3236	7.7	4.4	8.4	1.9	1.9	2.6	3.1	4.2	3.9	2.7	3.8	2.0	3.6
	3252	8.8	5.0	9.0	1.7	2.0	2.8	3.2	4.5	3.8	2.7	3.7	2.0	4.2
	59590	7.4	4.9	9.3	1.8	2.2	3.1	3.4	4.7	4.2	2.8	3.7	1.9	4.2
	59592	7.5	5.0	9.2	1.7	2.1	3.0	3.4	4.7	4.1	2.8	3.7	2.0	4.0
	59612	7.1	5.0	8.9	1.7	2.2	3.0	3.4	4.7	4.1	3.0	3.9	2.0	3.9
	59614	8.4	4.6	8.4	1.8	2.1	3.0	3.3	4.6	3.9	2.9	3.7	2.0	4.5
	59617	7.9	4.7	8.7	1.8	2.2	3.1	3.4	4.7	4.2	2.9	3.8	2.0	3.8
	59690	7.9	4.5	8.8	1.9	2.2	3.0	3.3	4.5	3.8	2.6	3.6	1.9	3.9

TABLE 69.—*Numerical expressions of certain systematic characters for 19 specimens of Leucichthys artedi from Lake Michigan over 200 millimeters in length and for 10 specimens under 200 millimeters long, selected according to size and locality*—Continued

Size	Field No.	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters	3038	5.8	2.8	2.1	2.8	2.4	1.7	11	13	11	15	1.4	0.98	8
	3042	6.1	3.0	1.8	2.7	2.0	1.5	10	11	10	15	1.4	1.0	8
	3046	6.0	2.9	2.1	2.9	2.2	1.7	10	12	12	16	1.4	1.0	8
	3049	7.0	3.0	2.1	2.8	2.3	2.0	11	12	12	16	1.3	.96	8
	3057	6.2	2.9	2.1	2.7	2.1	1.6	10	12	12	15	1.3	.78	9
	4290	5.4	2.9	2.1	2.9	1.9	1.7	10	11	12	16	1.4	.94	9
	4294	5.8	3.0	2.0	2.9	1.9	1.6	11	12	12	16	1.2	.96	8
	4307	6.1	3.0	2.1	2.9	2.0	1.7	10	12	12	15	1.5	1.0	8
	4310	5.2	3.0	2.0	2.6	2.0	1.7	9	11	12	15	1.4	.97	8
	4314	5.3	2.9	2.0	2.8	2.3	1.8	11	12	12	16	1.4	.94	8
	1638	5.0	2.9	2.0	2.6	1.8	2.0	10	11	12	15	1.3	.91	9
	1645	5.2	2.8	2.1	2.9	2.1	1.8	11	12	12	16	1.4	.92	9
	2792	5.2	2.9	2.0	2.9	2.4	1.8	11	13	11	16	1.3	.85	9
	3525	5.0	3.1	2.1	2.9	2.3	2.0	10	11	11	15	1.3	.91	9
	3556	4.6	3.0	2.1	2.8	2.0	1.7	10	11	11	14	1.6	.92	9
	3558	5.2	2.9	2.1	2.7	1.9	1.8	11	12	12	15	1.2	.82	9
	3607	6.0	2.9	2.1	2.7	2.1	1.5	10	10	11	16	1.5	1.1	8
	3724	5.0	2.9	2.0	2.7	2.0	1.7	11	12	12	16	1.3	.96	8
	4585	6.2	3.0	2.1	2.7	2.0	1.8	10	12	12	16	1.3	.95	8
Under 200 millimeters	3102	5.1	2.8	1.9	2.6	2.0	1.6	9	10	11	16	1.6	.84	8
	3228	5.1	2.7	1.9	2.6	1.6	1.5	9	11	12	16	1.7	1.1	7
	3236	5.0	2.8	2.0	2.7	1.8	1.5	11	13	12	16	1.3	.70	8
	3252	5.0	2.7	1.9	2.6	1.8	1.6	10	11	10	15	1.5	.94	9
	59590	5.5	3.0	2.0	2.6	2.1	1.6	10	11	12	17	1.3	.93	8
	59592	5.2	3.0	2.0	2.7	2.0	1.7	10	11	12	15	1.6	1.0	8
	59612	5.4	3.0	2.1	2.8	2.0	1.7	9	11	11	16	1.7	1.0	9
	59614	5.1	2.8	2.1	2.7	2.0	1.6	10	11	11	16	1.4	.98	8
	59617	6.1	3.1	2.1	2.8	1.9	1.5	9	11	12	16	1.6	.97	8
	59690	4.5	2.7	1.9	2.7	2.0	1.5	10	12	12	16	1.5	1.0	8

TABLE 70.—*Records of the occurrence of Leucichthys artedi in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, the abundance of the species in the lift, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Abundance	Preserved specimens examined	
							+225 mm.	−225 mm.
Lake Huron proper:								
St. Ignace, Mich	1	July 17, 1917	Off the city	(1)	4	Occasional	8	3
Cheboygan, Mich	2	Sept. 29, 1917	Point Au Sable	(1)	3½	(2)	6	1
Rogers, Mich	3	Oct. 14, 1917	12 miles E. by N. ½ N. of city	2¾	35	Only specimens taken in lift.	2	......
Alpena, Mich	4	Aug. 13, 1917	Sulphur Island	(1)	4	Occasional	11	......
	5	Sept. 5, 1917	Misery Bay	2¾	3	Rare	1	......
	6	Sept. 8, 1917	22 miles SE. by E. ½ E. of can buoy.	1½	30	do	......	9
	7	Sept. 10, 1917	8 miles E. by N. of can buoy	4½	20	Only specimens taken in lift.	1	2
	8	do	13½ miles SE. by S. of can buoy	4½	15	do	3	9
	9	Sept. 12, 1917	11 miles SE. ¾ E. of can buoy	4½	15–17	do	......	1
	10	Sept. 14, 1917	24 miles SE. by E. ½ E. of can buoy.	4½	24	Rare	1	5
	11	Sept. 17, 1917	13½ miles SE. by S. of can buoy	4½	15	do	......	2
	12	Sept. 22, 1917	15 miles SE. by S. ½ S. of can buoy.	4½	17	do	......	3
	13	Sept. 26, 1917	13 miles SE. by S. of can buoy	4½	17	Only specimens taken in lift.	4	2
	14	Sept. 24, 1917	Can buoy to Sulphur Island	2¾	8–10	Common	1	3
	15	Sept. 27, 1917	do	2¾	8–10	do	......	......
	16	Nov. 2, 1917	7 miles ENE. of can buoy	2¾	15	Occasional	......	......
	17	Nov. 15, 1919	......	2¾	15	do	18	......
East Tawas, Mich	18	Oct. 22, 1917	Off the city	(1)	4–8	Common	21	6
Bay City, Mich	19	Oct. 25, 1917	Off Point Au Gres	(1)	4–8	do	25	1
	20	Nov. —, 1922	Saginaw Bay at Tobico	(1)	3	do	18	7
Harbor Beach, Mich	21	Dec. 9, 1917	......	......	......	(2)	2	9
	22	Mar. 15, 1919	......	1½	31	Rare	......	1
Duck Islands, Ontario.	23	Oct. 18, 1919	Off Islands	4½	5–10	Occasional	10	2
Tobermory, Ontario	24	Oct. 2, 1919	Off Plucky Island	4½	18–20	do	......	3

[1] Pound net. [2] Lift not examined or percentage not ascertained.

TABLE 70.—*Records of the occurrence of Leucichthys artedi in Lake Huron*—Continued

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Abundance	Preserved specimens examined	
							+225 mm.	−225 mm.
North Channel:								
Blind River, Ontario	25	Oct. 6, 1917	Off Grant Island	4½	3–5	Occasional		
	26	Nov. 8, 1917	Off the city	(1)	4	Common	6	
Cutler, Ontario	27	Nov. 11, 1917	Cutler Bay	3		do	20	
Gore Bay, Ontario	28	Nov. 10, 1917	Off Barrie Island	(1)	5	do	2	
Kagawong, Ontario	29	do	Off Clapperton Island	(1)	6	do	3	
	30	Oct. 16, 1919	do	(1)	6	do	1	
Georgian Bay:								
Wiarton, Ontario	31	Nov. 5, 1917	Colpoys Bay	(1)	4	do	2	13
	32	July 29, 1919	do	(1)	4	Occasional		6
	33	Dec. 3, 1919	do	1½	15	do	1	14
Killarney, Ontario	34	Oct. 12, 1919	Off the city	(1)	10–12	Common	26	15
Borrowed specimens:								
Georgian Bay [3]							16	9
Bayport, Mich.[4]							1	1
Port Huron, Mich.[4]							2	
Blind River, Ontario [4]							2	1
Collingwood, Ontario[4]							1	

[1] Pound net. [3] Donated by Dr. B. A. Bensley. [4] U. S. National Museum collection.

TABLE 71.—*Numerical expressions of certain systematic characters for 10 specimens of the manitoulinus form of Leucichthys artedi, 40 specimens of the artedi form of that species, 30 over 200 millimeters long and for 10 under 200 millimeters long, all from various parts of Lake Huron, selected according to size and locality*

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA
+200 millimeters:											
Manitoulinus form	1114	Cutler, Ontario	240	♂	17+29	69	4.3	6.3	8.5	10.0	2.4
	1118	do	248	♂	15+28	74	4.1	5.9	7.8	8.8	2.7
	1119	do	274	♀	15+29	76	4.2	5.9	9.2	9.4	2.7
	1120	do	257	♂	15+30	77	4.0	6.4	8.8	8.5	2.6
	1121	do	237	♂	17+30	72	4.0	5.7	8.7	9.0	2.8
	1123	do	286	♂	16+30	71	4.2	6.2	7.6	8.2	2.6
	1125	do	231	♂	16+30	70	4.0	6.0	7.4	8.5	2.5
	1127	do	268	♂	17+30	71	4.1	5.8	7.6	7.8	2.4
	1130	do	257	♂	18+29	73	4.0	5.6	8.3	8.1	2.6
	1131	do	268	♂	16+30	76	4.0	5.7	7.0	7.3	2.5
Artedi form—											
Open lake	13	St. Ignace, Mich	224	♀	18+31	80	4.2	6.0	10.1	9.7	2.7
	16	do	295	♀	18+31	90	4.7	6.8	10.4	10.5	2.7
	2515	Duck Islands, Ontario	250	♂	18+31	81	4.4	6.1	9.8	12.0	2.8
	2531	do	291	♀	19+31	78	4.4	6.2	9.7	9.3	2.6
	829	Cheboygan, Mich	305	♂	17+29	83	4.5	6.2	8.8	8.8	2.7
	834	do	281	♀	17+31	82	4.4	6.7	9.8	10.3	2.8
	196	Alpena, Mich	257	♀	18+32	83	4.7	6.8	9.9	10.5	2.7
	208	do	245	♂	16+29	82	4.4	6.3	10.2	9.4	2.8
	211	do	253	♂	17+31	80	4.4	6.2	11.5	10.4	3.0
	220	do	245	♀	17+31	84	4.3	6.0	9.6	9.9	2.7
Saginaw Bay	979	East Tawas, Mich	266	♀	16+28	87	4.5	6.6	11.5	10.6	2.7
	982	do	228	♀	18+33	79	4.5	6.5	8.0	9.3	2.5
	1024	Bay City, Mich	324	♂	18+30	81	4.8	6.9	9.9	10.9	2.6
	1035	do	283	♂	18+27	81	4.6	6.7	10.9	9.7	2.7
	1044	do	265	♂	18+32	82	4.5	6.4	10.3	8.9	2.6
	1045	do	296	♀	17+28	84	4.1	6.8	10.5	9.7	2.7
	1046	do	264	♂	16+31	81	4.7	6.9	9.7	10.2	2.5
	1050	do	348	♂	17+28	82	4.9	7.3	11.2	10.0	2.8
	1053	do	276	♂	18+29	75	4.7	6.5	10.6	10.3	2.6
	1054	do	270	♂	18+31	81	4.5	6.8	10.0	9.9	2.6
North Channel and Georgian Bay.	1083	Blind River, Ontario	258	♀	15+32	87	4.3	6.0	10.7	9.8	2.7
	1089	do	270	♀	18+32	83	4.5	6.3	9.9	9.6	2.8
	1109	Gore Bay, Ontario	291	♀	16+27	85	4.5	6.3	9.3	9.7	2.7
	1097	Kagawong, Ontario	290	♀	18+32	78	4.2	6.2	9.2	9.0	2.8
	1100	do	285	♀	16+29	81	4.3	6.3	8.8	8.6	2.8
	2436	Killarney, Ontario	262	♀	16+29	78	4.4	6.1	10.4	10.8	2.7
	2539	do	325	♂	15+30	83	4.4	6.3	9.5	9.3	2.8
	2547	do	272	♂	15+28	83	4.4	6.3	10.4	10.2	2.8
	1068	Wiarton, Ontario	242	♀	16+30	80	4.4	6.5	10.0	10.3	2.7
	1073	do	281	♂	17+27	89	4.4	6.3	9.8	10.2	2.6

TABLE 71.—*Numerical expressions of certain systematic characters for 10 specimens of the manitoulinus form of Leucichthys artedi, 40 specimens of the artedi form of that species, 30 over 200 millimeters long and for 10 under 200 millimeters long, all from various parts of Lake Huron, selected according to size and locality*—Continued

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA
—200 millimeters	210	Alpena, Mich	161	Im. ♂	18+32	79	4.6	6.1	11.5	10.3	2.7
	218	do	172	♀	16+33	83	4.5	6.1	9.5	9.5	2.7
	232	do	180	Im. ♀	16+28	79	4.3	5.8	9.5	10.0	2.7
	250	do	166	Im. ♀	16+30	87	4.6	6.3	11.4	11.0	2.7
	271	do	173	♂	18+31	83	4.4	5.9	10.8	9.7	2.8
	272	do	197	♀	17+29	80	4.5	6.3	9.8	9.7	2.7
	703	do	171	♀	17+31	78	4.1	5.7	10.1	10.0	2.9
	722	do	171	♀	16+30	83	4.2	5.8	9.9	9.2	2.9
	2582	Wiarton, Ontario	180	♂	18+29	81	4.1	5.6	10.5	9.0	2.7
	2616	do	178	♂	16+32	81	4.4	6.1	10.0	8.9	2.9

Size	Field No.	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad
+200 millimeters: Manitoulinus form	1114	7.9	3.8	7.5	1.9	2.1	3.0	3.3	4.9	3.7	2.7	3.9	2.0	3.4
	1118	8.2	3.6	6.7	1.8	2.1	3.0	3.2	4.7	3.7	2.7	4.2	2.1	4.2
	1119	9.0	3.4	7.2	2.1	2.1	3.0	3.3	4.7	3.7	2.8	4.0	1.9	4.3
	1120	9.0	4.0	7.4	1.8	2.1	3.3	3.4	4.9	3.4	2.7	4.0	1.9	3.9
	1121	8.2	3.4	7.7	2.2	2.0	2.9	3.2	4.6	3.7	2.6	4.0	2.1	3.4
	1123	9.2	3.7	7.1	1.9	2.0	3.0	3.2	4.8	3.7	2.8	3.8	2.0	4.1
	1125	8.0	3.6	7.2	1.9	2.0	2.9	3.1	4.7	3.8	2.6	4.0	2.0	3.8
	1127	11.1	3.5	7.0	1.9	2.1	2.9	3.0	4.2	3.8	2.6	3.8	2.0	3.2
	1130	9.1	3.6	7.1	1.9	2.0	2.9	3.2	4.4	3.6	2.8	3.7	1.9	4.5
	1131	8.1	3.7	7.8	1.8	1.9	2.8	3.0	4.4	3.7	2.5	3.7	1.9	3.6
Artedi form— Open lake	13	8.5	4.6	7.9	1.6	2.1	3.1	3.3	4.8	3.8	2.9	3.8	2.1	4.5
	16	8.5	4.7	7.9	1.6	2.2	3.2	3.6	5.3	4.0	2.8	3.9	2.0	3.6
	2515	8.3	4.6	8.5	1.8	2.1	3.0	3.4	4.9	3.8	3.0	4.1	2.1	3.6
	2531	9.0	4.1	7.1	1.7	2.1	3.0	3.4	4.9	3.9	3.1	3.8	2.1	3.8
	829	8.6	4.3	7.3	1.6	2.2	3.0	3.5	4.8	4.1	2.8	3.9	2.1	3.9
	834	7.9	5.1	8.3	1.6	2.2	3.3	3.5	5.1	4.3	3.0	4.0	2.2	3.7
	196	8.5	4.5	7.6	1.7	2.2	3.2	3.7	5.3	3.8	2.8	3.8	2.0	4.0
	208	9.4	4.1	8.1	1.9	2.2	3.1	3.4	4.9	3.9	2.8	3.9	2.0	4.2
	211	8.4	4.2	7.4	1.7	2.1	3.1	3.5	5.1	3.9	2.8	3.9	2.0	4.0
	220	8.5	4.2	8.1	1.9	2.1	3.0	3.2	4.5	4.0	2.8	3.9	2.1	3.8
Saginaw Bay	979	8.3	5.4	9.8	1.8	2.2	3.3	3.5	5.1	4.4	3.0	4.0	2.1	3.1
	982	8.7	3.8	6.9	1.7	2.2	3.2	3.6	5.1	4.3	2.8	4.1	2.1	3.3
	1024	8.7	4.2	7.1	1.6	2.3	3.4	3.7	5.3	4.4	3.2	4.3	2.2	3.2
	1035	7.5	4.7	7.8	1.6	2.2	3.2	3.6	5.2	4.3	3.2	4.2	2.3	3.8
	1044	9.4	4.4	8.2	1.8	2.2	3.2	3.4	4.9	4.4	3.2	3.8	2.0	4.6
	1045	8.5	3.9	6.5	1.6	2.3	3.3	3.7	5.3	4.7	2.9	4.0	2.2	4.4
	1046	8.1	4.5	9.0	1.9	2.2	3.3	3.6	5.3	4.2	3.0	4.1	2.1	3.5
	1050	6.9	4.5	8.4	1.8	2.3	3.5	3.7	5.6	4.4	3.0	4.0	2.3	3.3
	1053	7.7	4.1	8.0	1.9	2.2	3.1	3.6	5.0	4.4	2.9	4.0	2.2	3.2
	1054	8.5	4.3	7.4	1.6	2.2	3.3	3.5	5.2	4.4	2.9	3.9	2.1	4.1
North Channel and Georgian Bay.	1083	9.1	4.3	7.5	1.7	2.1	2.9	3.4	4.6	3.9	2.7	3.8	1.9	3.9
	1089	8.9	4.2	7.9	1.8	2.1	3.0	3.4	4.9	4.0	2.8	4.0	2.0	4.4
	1109	8.8	4.4	8.5	1.8	2.2	3.1	3.4	4.8	3.8	2.8	3.8	2.0	4.0
	1097	7.7	3.7	8.7	2.3	2.1	3.1	3.2	4.8	4.0	3.0	4.1	2.1	3.6
	1100	8.9	4.5	8.3	1.7	2.0	3.0	3.3	4.9	3.8	2.9	4.0	2.0	3.7
	2436	8.5	4.3	7.7	1.7	2.2	3.0	3.4	4.7	4.1	2.7	3.9	2.0	3.9
	2539	8.2	4.1	7.0	1.7	2.1	3.0	3.5	4.9	4.5	3.1	3.9	2.2	4.0
	2547	9.0	4.3	7.2	1.6	2.2	3.2	3.5	5.0	4.2	2.9	4.0	2.1	5.0
	1068	9.2	4.3	8.9	2.0	2.2	3.2	3.4	5.0	3.9	3.0	4.1	2.1	4.5
	1073	9.0	4.3	8.5	1.9	2.1	3.0	3.4	4.9	3.9	2.8	3.9	2.0	5.0
—200 millimeters	210	7.0	4.9	8.4	1.7	2.2	3.0	3.4	4.6	3.8	2.9	3.7	2.0	4.0
	218	7.8	4.7	7.2	1.6	2.2	3.0	3.3	4.6	4.0	2.7	3.5	2.0	3.5
	232	8.5	4.3	7.8	1.7	2.0	2.8	3.2	4.3	3.9	2.7	3.7	1.9	4.0
	250	7.5	4.4	8.7	1.8	2.1	3.0	3.1	4.8	3.9	3.0	3.6	2.1	3.9
	271	7.5	4.6	8.6	1.8	2.1	2.8	3.4	4.5	3.9	2.6	3.6	1.9	3.7
	272	8.3	5.3	9.3	1.7	2.2	3.1	3.4	4.8	4.3	2.6	3.9	2.0	4.0
	703	8.0	4.6	8.5	1.8	2.0	2.8	3.2	4.4	3.9	2.6	3.7	2.0	4.1
	722	8.1	4.5	7.7	1.7	2.1	2.9	3.3	4.5	3.7	2.8	4.0	2.0	3.7
	2582	9.4	4.2	8.7	2.0	2.1	2.9	3.2	4.4	3.9	2.7	3.6	2.0	3.7
	2616	7.1	4.8	8.9	1.8	2.1	2.8	3.2	4.3	4.0	2.6	3.7	2.0	3.3

TABLE 71.—*Numerical expressions of certain systematic characters for 10 specimens of the manitoulinus form of Leucichthys artedi, 40 specimens of the artedi form of that species, 30 over 200 millimeters long and for 10 under 200 millimeters long, all from various parts of Lake Huron, selected according to size and locality*—Continued

Size	Field No.	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
+200 millimeters:														
Manitoulinus form	1114	6.7	2.5	1.9	2.7	1.7	1.5	10	12	11	16	1.1	1.1	8
	1118	6.0	2.5	1.8	2.9	1.8	1.4	11	12	11	16	1.4	1.0	8
	1119	6.3	2.6	2.0	2.8	1.7	1.6	10	12	11	16	1.6	1.0	9
	1120	5.9	2.3	1.8	2.7	1.7	1.6	11	12	11	15	1.5	.98	8
	1121	5.8	2.6	1.8	2.8	1.7	1.4	10	11	12	16	1.6	1.0	9
	1123	6.0	2.5	1.8	2.6	1.6	1.5	11	12	11	16	1.3	.97	9
	1125	5.5	2.5	1.8	2.6	1.6	1.4	10	12	12	15	1.5	1.0	9
	1127	5.8	2.7	1.9	2.7	1.6	1.1	10	12	11	16	1.5	1.0	9
	1130	6.1	2.6	2.0	2.7	1.7	1.3	10	12	12	15	1.5	.98	8
	1131	5.3	2.6	1.8	2.6	1.6	1.3	11	13	12	14	1.3	.94	9
Artedi form—														
Open lake	13	6.3	2.7	2.0	2.7	2.0	1.6	11	12	11	16	1.5	1.0	9
	16	5.9	2.8	2.0	2.6	2.2	1.7	10	12	12	17	1.3	.99	9
	2515	5.6	2.7	2.1	2.9	2.0	1.8	10	11	12	17	1.3	1.3	8
	2531	5.3	2.8	2.2	2.7	2.4	1.7	11	12	13	17	1.2	.83	8
	829	6.1	3.0	2.0	2.8	2.0	1.7	11	12	11	17	1.2	.87	8
	834	7.1	3.0	2.0	2.7	2.5	2.0	11	11	11	16	1.1	.83	9
	196	5.8	2.6	1.9	2.6	2.2	1.7	11	11	11	16	1.4	.99	8
	208	5.2	2.7	1.9	2.7	1.9	1.6	9	11	11	16	1.5	1.0	8
	211	5.4	2.6	1.9	2.6	2.1	1.8	10	11	11	16	1.6	1.0	8
	220	5.0	2.8	2.0	2.6	1.7	1.4	10	11	12	15	1.5	1.0	8
Saginaw Bay	979	5.2	3.0	2.0	2.7	2.3	1.8	9	12	11	15	1.4	.88	8
	982	6.2	3.0	2.0	2.9	2.0	1.8	10	11	11	17	1.2	1.0	9
	1024	6.0	3.1	2.2	3.0	2.0	1.9	10	11	11	15	1.2	.96	8
	1035	5.3	3.0	2.2	2.8	2.2	1.9	10	11	11	15	1.3	.90	8
	1044	5.6	3.1	2.2	2.7	2.2	1.7	10	-------	12	15	1.3	.84	9
	1045	6.5	3.3	2.0	2.8	2.5	1.8	10	11	11	15	1.3	.85	9
	1046	5.4	2.9	2.1	2.8	2.2	1.8	11	11	11	14	1.2	.87	9
	1050	5.8	2.9	2.0	2.7	2.3	1.8	10	12	11	16	1.3	.89	8
	1053	5.8	3.2	2.1	2.8	-------	1.8	9	11	11	16	1.5	.94	8
	1054	6.5	3.0	1.9	2.6	2.3	1.8	10	11	11	15	1.4	.90	8
North Channel and Georgian Bay.	1083	5.9	2.8	2.0	2.7	2.2	1.4	10	12	12	16	1.4	.88	8
	1089	7.0	2.8	2.0	2.8	2.1	1.7	10	12	11	17	1.3	.91	9
	1109	5.9	2.7	2.0	2.7	2.2	1.8	11	12	12	16	1.2	.94	9
	1097	5.9	2.7	2.1	2.8	1.9	1.6	10	13	12	16	1.4	1.0	8
	1100	5.9	2.6	2.0	2.8	2.0	1.7	10	12	11	15	1.3	.84	9
	2436	5.1	3.0	1.9	2.8	2.3	1.7	9	11	12	16	1.3	.99	9
	2539	6.1	3.2	2.2	2.7	2.5	2.0	10	10	11	15	1.1	.91	8
	2547	6.6	2.9	2.0	2.8	2.3	1.8	10	11	11	15	1.2	1.1	8
	1068	5.4	2.6	2.0	2.8	2.1	1.8	10	11	11	16	1.4	.90	8
	1073	5.2	2.7	2.0	2.7	2.0	1.8	11	12	12	17	1.3	.92	8
−200 millimeters	210	5.7	2.8	2.1	2.8	2.0	1.8	10	11	12	16	1.6	.96	8
	218	4.8	2.9	2.0	2.5	2.0	1.7	10	12	11	16	1.5	.95	8
	232	5.2	2.9	2.0	2.8	1.9	1.6	10	11	11	16	1.4	.94	9
	250	6.0	2.8	2.1	2.6	2.1	1.9	10	11	11	16	1.5	.93	8
	271	4.9	2.9	2.0	2.6	2.2	1.7	9	12	11	16	1.4	.84	9
	272	5.3	3.0	1.8	2.7	2.0	1.6	10	12	11	16	1.4	.89	8
	703	5.1	2.8	1.9	2.7	1.8	1.7	9	11	11	17	1.5	.97	9
	722	5.0	2.6	2.0	2.9	2.1	1.7	10	12	11	17	1.4	.87	8
	2582	4.5	2.9	2.0	2.7	2.0	1.5	10	12	11	16	1.5	.93	9
	2616	5.5	2.9	1.9	2.6	2.1	1.6	11	13	11	16	1.4	.87	9

TABLE 72.—*Characteristics of certain herring that are intermediate between the artedi and manitoulinus forms*

Field No.	Locality	Scales	L/H	H/E	Pv/P	L/D	H/M	Color
1085	Blind River	74 (M)	4.5 (A)	3.9 (A)	1.8 (M)	3.6 (M)	3.0 (A)	Pale (A).
1086	----do	72 (M)	4.1 (M)	4.1 (A)	1.8 (M)	3.7 (M)	2.8 (A)	Do.
1090	----do	83 (A)	4.2 (M)	4.1 (A)	2.0 (A)	4.0 (A)	2.9 (A)	Do.
1091	----do	85 (A)	4.3 (A)	3.9 (A)	2.0 (A)	4.4 (A)	3.0 (A)	Dark (M).
1097	Kagawong	78 (A)	4.2 (M)	4.0 (A)	1.9 (A)	3.7 (M)	3.0 (A)	Pale (A).

TABLE 73.—*Records of the occurrence of Leucichthys artedi in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water and character of the bottom where made, the abundance of this species in the lift, and the number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined: +225 mm.	Preserved specimens examined: −225 mm.
Sault Ste. Marie, Mich.	1	June 14, 1922	10 miles NW. by W. ¼ W. of Point Iroquois Light.	2½, 2¾	38		Rare	2	
Grand Marais, Mich.	2	Oct. 3, 1917	In the harbor					4	
Marquette, Mich.	3	Feb. 8, 1921		1½	10–11			4	11
	4	Aug. 5, 1921	31 miles N. ¾ E.	2¾, 4½	100		Rare	4	
	5	Aug. 9, 1921	Marquette Bay	(1)	5	Sand	Occasional	3	11
	6	Aug. 11, 1921	18 miles NE. by N.	2½, 2¾	100–80		Rare	2	1
	7	Nov. —, 1925						5	
Ontonagon, Mich.	8	Aug. 16, 1921	54 miles W. by N.	4½	25–80			1	
	9	Aug. 24, 1921	21 miles west	2½, 2¾	15–45	Red clay	Rare	3	
	10	Aug. 25, 1921	6 miles NNW.	2½, 2¾	20–38	Sand-clay	do	8	
Apostle Islands, Wis.	11	July 11, 1922	Between Cat and South Twin Islands.	2½, 2¾	15–20	Sand	do	1	
Duluth, Minn.	12	July 17, 1922	20 miles NE. by E.	2⅝	30–40	do		2	
Grand Marais, Minn.	13	July 18, 1922	In Grand Marais Harbor.	(2)	1			300	
	14	July 17, 1922	At mouth of Devils Track River.	(2)	1			300	
Port Arthur, Ontario.	15	July 20, 1922	Off Demers Point	(1)	8	Mud	Occasional	8	4
	16	Nov. 25, 1922	Thunder Bay, between Pie and Welcome Islands.	2½			Abundant	12	
	17	Sept. 15, 1923	North of Silver Island	2½	14	Mud		5	
	18	do	Thunder Bay, off Thunder Cape.	2½	31	Grayish-brown clay.	Rare		1
	19	Sept. 17, 1923	Thunder Bay, inside Welcome Islands.	2½	11	do	do	2	
	20	Sept. 19, 1923	Thunder Bay, off Sawyer Bay.	2½	49	do	do	3	1
Rossport, Ontario	21	Oct. 1, 1921	Off the town	2¾	6		Occasional	6	
	22	Oct. 4, 1921	Off Bread Rock	2½, 2¾	80–90	Grayish-brown clay.	Rare	1	
	23	Mar. 10, 1922		2½			Common	44	18
	24	Aug. 10, 1922	Moffat Strait	(1)	4			11	8
	25	do	Off Armour Point	(1)	4			5	7
	26	Sept. 25, 1923	Moffat Strait	2½	13–14	Clay-sand		6	1
Michipicoten Island, Ontario.	27	June 19, 1922	6 miles northeast of East-End Light.	4½	15–35			4	
Coppermine Point, Ontario.	28	June 26, 1922	Off Alona Bay	2½, 2¾	60			7	
Batchawanna, Ontario.	29	June 17, 1922	Batchawanna Bay	(1)	3–13	Clay-sand		7	8
Borrowed specimens:									
Marquette, Mich.[3]								22	
Duluth, Minn.[4]								2	
Marquette, Mich.[5]								1	
Knife River, Minn.[5]									1
Duluth, Minn.[5]								4	
Port Arthur, Ontario.[5]								1	

1 Pound net.
2 Seine.
3 Field Museum collection.
4 University of Toronto collection.
5 U. S. National Museum collection.

TABLE 74.—*Numerical expression of certain systematic characters for 20 specimens of Leucichthys artedi from Lake Superior, 10 of them over 200 millimeters long and 10 under 200 millimeters, selected according to size and locality*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA
Albus form, over 200 millimeters.	015	Silver Island, Ontario	236	18+30	♀	80	4.1	5.9	9.6	9.7	2.5
	57379	Black Bay	262	18+30	♀	75	4.4	6.2	8.4	8.1	2.7
	0282	Moffat Strait	240	20+33	♀	83	4.4	6.1	9.6	10.3	2.7
	0287	do	232	18+32	♀	77	4.4	6.1	8.6	8.5	2.7
Artedi form: Over 200 millimeters	53852	Rossport, Ontario	314	18+29	♀	86	4.6	6.2	10.4	9.8	2.7
	57115	Alona Bay	270	17+28	♀	92	4.6	6.4	10.5	10.8	2.5
	57133	do	272	16+29	♂	94	4.6	6.4	11.3	9.3	2.7
	57846	Batchawanna, Ontario	258	16+31	♂	89	4.5	6.1	8.8	9.2	2.6
	57851	do	238	16+28	♂	82	4.3	5.9	9.3	9.5	2.7
	53739	Ontonagon, Mich	280	17+30	♀	90	4.5	6.2	11.2	11.5	2.8
Under 200 millimeters	53054	Marquette, Mich	190	18+30	Im. ♂	83	4.6	6.3	11.0	9.9	2.8
	53056	do	192	18+30	Im. ♀	90	4.6	6.6	12.6	10.1	2.7
	53060	do	176	17+29	Im. ♀	84	4.4	6.0	10.3	10.3	2.7
	53061	do	174	17+29	Im. ♂	89	4.5	6.2	10.1	8.7	2.6
	53508	do	195	17+30	Im. ♀	87	4.5	6.0	10.0	9.7	2.6
	53531	do	193	16+28	♂	84	4.4	6.2	9.2	9.4	2.7
	57199	Black Bay	140	18+32	Im. ♂	87	4.3	6.0	10.6	9.8	2.6
	57354	do	143	16+29	Im. ♂	78	4.2	5.7	9.5	9.3	2.6
	57355	do	173	18+30	Im. ♀	90	4.3	5.7	10.2	9.0	2.7
	57356	do	153	16+27	Im. ♂	72	4.2	5.7	9.6	10.2	2.7

Size	Field No.	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad
Albus form, over 200 millimeters	015	8.7	4.0	8.4	2.0	2.0	2.9	3.2	4.6	3.8	3.0	4.3	2.1	4.0
	57379	9.7	3.9	7.9	2.0	2.1	2.9	3.4	4.7	3.9	2.9	3.7	2.1	3.4
	0282	7.5	4.0	8.0	2.0	2.1	2.9	3.4	4.8	3.6	2.7	3.8	1.9	3.6
	0287	9.2	3.8	9.2	2.3	2.2	3.0	3.4	4.7	3.8	2.8	3.9	2.0	3.7
Artedi form: Over 200 millimeters	53852	7.8	4.6	8.0	1.7	2.2	3.1	3.6	4.9	4.5	2.9	3.7	2.0	4.2
	57115	7.9	4.9	10.0	2.0	2.2	3.0	3.5	4.8	4.4	2.9	3.6	1.8	3.8
	57133	8.5	4.7	8.2	1.7	2.2	3.2	3.4	4.8	4.5	2.9	3.8	2.1	4.4
	57846	8.1	4.6	9.5	2.0	2.1	2.9	3.4	4.6	4.3	3.0	3.5	2.0	3.5
	57851	8.6	4.7	9.5	2.0	2.1	2.9	3.2	4.5	4.2	2.8	3.6	2.0	4.2
	53739	7.5	4.9	9.6	1.9	2.2	3.0	3.5	4.9	4.4	2.8	3.4	2.1	4.4
Under 200 millimeters	53054	8.6	5.0	8.2	1.6	2.1	2.9	3.4	4.7	4.1	2.9	4.0	1.9	3.6
	53056	8.0	4.8	8.3	1.7	2.2	3.2	3.4	4.9	4.1	2.9	4.1	2.0	3.6
	53060	7.6	4.6	8.8	1.9	2.0	2.8	3.3	4.5	4.2	2.8	3.9	2.0	3.3
	53061	8.7	5.1	8.2	1.5	2.2	3.1	3.4	4.8	4.0	2.9	3.7	2.1	4.1
	53508	7.9	4.7	8.8	1.8	2.1	2.8	3.4	4.6	4.0	2.8	3.9	2.0	4.1
	53531	7.7	4.5	8.7	1.9	2.1	3.0	3.4	4.7	3.9	2.7	3.9	2.0	3.6
	57199	7.7	5.0	9.3	1.8	2.1	2.9	3.2	4.5	4.0	2.7	3.6	2.0	4.2
	57354	7.5	4.6	10.2	2.1	2.0	2.7	3.2	4.3	3.4	2.6	3.7	1.9	3.7
	57355	7.5	4.9	9.1	1.8	2.1	2.9	3.3	4.4	4.0	2.7	3.5	1.9	3.9
	57356	7.6	4.7	9.5	1.6	2.1	2.9	3.2	4.4	3.7	2.7	4.0	2.0	3.6

Size	Field No.	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Albus form, over 200 millimeters	015	5.4	2.7	2.0	3.0	1.8	1.6	11	11	12	16	1.5	1.0	8
	57379	5.2	2.8	2.1	2.8	2.0	1.6	11	12	12	15	1.3	.86	8
	0282	5.2	2.6	1.9	2.9	2.0	1.6	10	11	11	18	1.4	.95	8
	0287	5.2	2.4	2.0	2.8	1.9	1.6	11	13	11	15	1.2	.84	8
Artedi form: Over 200 millimeters	53852	5.5	3.3	2.1	2.7	2.2	1.8	10	12	12	17	1.4	.87	9
	57115	5.3	3.2	2.1	2.6	2.2	1.7	10	11	11	16	1.5	1.0	8
	57133	5.7	3.2	2.1	2.7	2.3	1.8	10	13	12	17	1.4	.83	8
	57846	5.5	3.3	2.2	2.6	2.1	1.7	11	13	11	17	1.3	.85	8
	57851	5.0	3.0	2.0	2.6	2.1	1.7	11	12	11	16	1.3	.92	8
	53739	5.6	3.1	2.0	2.4	2.2	1.9	10	10	11	17	1.5	.98	9
Under 200 millimeters	53054	5.1	3.0	2.1	2.9	2.0	1.7	11	11	12	18	1.5	.87	8
	53056	5.1	2.9	2.0	2.9	2.1	1.7	10	12	12	17	1.7	.84	8
	53060	5.0	3.0	2.0	2.8	1.9	1.7	10	12	11	18	1.5	.94	8
	53061	6.1	2.8	2.0	2.6	2.1	1.7	10	13	11	17	1.5	.87	8
	53508	5.3	3.0	2.1	2.9	2.0	1.8	11	12	12	18	1.4	.89	8
	53531	4.7	2.8	2.0	2.8	1.9	1.6	11	12	11	16	1.3	.93	8
	57199	5.3	2.8	1.9	2.6	1.8	1.5	10	12	12	18	1.5	.97	8
	57354	5.4	2.5	1.9	2.7	1.6	1.4	11	12	12	16	1.5	.88	9
	57355	4.7	3.0	2.0	2.6	1.9	1.6	10	13	12	17	1.5	------	9
	57356	5.0	2.7	2.0	2.9	1.8	1.6	10	11	11	17	1.5	1.0	8

TABLE 75.—*Records of the occurrence of Leucichthys artedi in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.[1]	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined	
					+225 mm.	−225 mm.
1	July 28, 1922	Off Macdiarmid	2½, 2¾	30	1	
2	Sept. 8, 1923	do		6		2
3	Sept. 11, 1925	do		5		5
4	July 30, 1922	Off Blackwater River		1		1
5	Sept. 6, 1923	Off Selwyn Island		7		3
6	Aug. 9, 1922	Humboldt Bay		5		5
7	Sept. 3, 1923	do		1-6		3
8	Sept. 5, 1923	Off McKellar Island				1
9	Aug. 10, 1922	Ombabika Bay		5		16
10	Aug. 21, 1923	do		1		15
11	July 26, 1923	Windigo Bay		3		3
12	Sept. 5, 1925	Off Shakespeare Island		1		2
13	Aug. 25, 1921	Off source of Nipigon River		10		1
14	July 26, 1922	do	2½, 2¾	10-15	8	7
15	Aug. 2, 1922	do		15		1
16	Aug. 28, 1923	Off Virgin Island		10-15		1
17	Aug. 30, 1923	do		18		1
18	Aug. 27, 1921	Sandy Bay		5		3
19	July 16, 1923	do		1		2
20	Sept. 6, 1923	do		7		2
21	Oct. 26, 1922	Unknown	4½		1	1

[1] All records except 1, 4, 14, and 21 are from University of Toronto collections.

TABLE 76.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys artedi from Lake Nipigon, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
57202	Off source of Nipigon River	220	19+32	♂	73	4.2	6.1	8.2	8.8	2.8	8.5	4.2	9.5	2.2	2.0	3.0	3.3
57205	do	237	18+29	♂	74	4.1	5.9	9.1	9.1	2.9	8.3	4.3	9.8	2.2	2.0	2.8	3.1
57207	do	222	16+31	♂	71	4.2	6.0	8.8	7.7	2.7	7.9	4.2	9.2	2.1	2.0	2.9	3.2
57209	do	224	18+31	♂	76	4.1	5.7	9.4	9.3	2.7	8.6	4.1	9.7	2.3	2.0	2.8	3.3
57218	do	224	18+32	♀	74	4.3	5.7	8.9	8.6	2.6	7.2	4.1	8.9	2.1	2.0	2.7	3.3
57220	do	225	18+34	♀	74	4.0	5.6	9.6	9.0	3.0	7.5	4.3	9.3	2.1	1.9	2.7	3.1
57221	do	242	16+31	♀	74	4.1	5.9	8.4	9.2	2.6	7.4	4.8	11.5	2.3	2.1	2.9	3.1
57225	do	222	17+29	♀	69	4.1	5.8	8.5	9.2	2.7	9.0	4.1	10.0	2.4	2.0	2.8	3.3
63173	Ombabika Bay	179	17+31	♂	69	4.3	5.5	9.4	8.9	2.7	7.7	4.0	8.5	2.0	2.0	2.7	3.2
63177	do	160	17+29	♂	78	4.3	5.7	10.6	8.4	2.6	8.2	4.0	8.4	2.1	2.0	2.7	3.2

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
57202	Off source of Nipigon River	4.8	3.9	2.8	4.2	2.0	3.6	4.6	2.7	2.0	2.9	1.8	1.5	11	13	12	16	1.3	0.98	8
57205	do	4.5	3.9	2.5	3.6	2.2	4.2	4.3	2.7	1.8	2.5	1.8	1.6	10	11	12	16	1.5	.95	8
57207	do	4.6	4.0	2.7	3.7	2.0	3.0	5.0	2.8	1.9	2.6	1.8	1.5	10	13	11	15	1.5	.91	8
57209	do	4.5	3.9	2.8	3.8	2.0	3.6	5.3	2.8	2.0	2.7	1.7	1.5	10	12	12	16	1.6	1.0	9
57218	do	4.4	3.7	2.8	3.7	1.9	3.4	4.7	2.7	2.1	2.7	1.9	1.5	10	12	11	17	1.5	1.0	9
57220	do	4.4	3.9	2.8	3.7	2.0	3.7	4.3	2.8	2.0	2.7	1.7	1.5	11	11	12	17	1.6	1.0	9
57221	do	4.4	4.0	2.9	3.8	2.0	3.3	5.3	2.8	2.1	2.7	1.7	1.4	10	12	12	16	1.4	1.0	8
57225	do	4.6	4.0	2.8	4.0	2.1	3.9	5.2	2.9	2.0	2.9	1.8	1.6	11	11	12	15	1.4	1.0	8
63173	Ombabika Bay	4.2	3.6	2.8	4.1	1.9	3.4	5.1	2.8	2.2	3.2	1.5	1.6	10	11	11	16	1.6	1.0	9
63177	do	4.3	3.6	2.6	3.7	2.0	3.7	5.1	2.7	2.0	2.8	1.7	1.7	10	12	12	17	1.7	.94	9

TABLE 77.—*Records of the occurrence of Leucichthys artedi in Lake Ontario*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Preserved specimens examined	
							+225 mm.	−225 mm.
Winona, Ontario	1	Nov. 23, 1917		2½			12	
Bronte, Ontario	2	do		2½			11	5
	3	June 29, 1921	13 miles E. ½ S.	2½, 2¾	40-50	Mud	1	
	4	June 30, 1921	Off Oakville	4¾	16		4	1
Brighton, Ontario	5	Nov. 22, 1917	Wellers Bay				12	
	6	June 10, 1921	20 miles S. by W. of Presque Isle Light.	2½	40-50	Mud	3	1
South Bay, Ontario	7	June 7, 1921	Off the shores	3			12	
Sandy Pond, N. Y.	8	Aug. 24, 1923	9 miles west	3	25-30	Sand and mud.	45	
	9	Aug. 30, 1923	14 miles west	1½, 2½, 3, 3¼, 3½.	60	Clay	14	1
Selkirk, N. Y.	10	July 11, 1921	5 miles NNW. of Nine-Mile Point.	3	25-35	do	27	1
Oswego, N. Y.	11	Sept. 1, 1923	Off Nine-Mile Point	3	30		1	2
	12	Sept. 4, 1923	8½ miles W. by N. ½ N.	2½, 3	70-75	Clay and mud.	2	
Charlotte, N. Y.	13	July 4, 1921	7 miles off Braddock Point Light	2½, 2¾	65	Clay	1	
Wilson, N. Y.	14	July 21, 1921	2 miles north	2½	20		25	14
Borrowed specimens:								
Toronto [1]							1	
Bay of Quinte [1]							6	
Winona, Ontario [2]							28	24

[1] U. S. National Museum collection. [2] University of Toronto collection.

TABLE 78.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys artedi from Lake Ontario, half of them of the albus form from the deep water at the west end of the lake, and the rest, which are nearest the artedi form, from other areas*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
Artedi form:																	
53138	Duck Island, Ontario.	260	♂	16+32	80	4.6	6.1	10.7	8.8	2.7	9.6	3.8	7.8	2.0	2.3	3.1	3.5
53139	do	291	♀	18+32	81	4.4	6.0	10.3	10.3	2.7	8.5	4.4	9.0	2.0	2.1	2.9	3.4
53962	Wilson, N. Y.	263	♀	20+33	74	4.7	6.7	9.0	9.0	2.6	8.4	4.2	8.2	1.9	2.3	3.2	3.6
53978	do	220	♀	16+30	71	4.5	5.9	8.7	10.0	2.3	6.7	3.7	7.2	1.9	2.4	3.2	3.8
53980	do	238	♀	17+29	80	4.2	6.4	9.5	10.7	2.5	7.4	4.0	7.6	1.9	2.1	3.2	3.3
53989	do	227	♂	16+29	75	4.2	5.8	8.7	8.3	3.0	8.3	3.7	7.8	2.1	2.1	2.9	3.3
53993	do	251	♀	15+28	76	4.5	6.4	9.6	9.8	2.8	8.3	4.0	8.6	2.1	2.2	3.1	3.6
54011	Pulaski, N. Y.	294	♂	17+32	78	4.4	5.9	9.8	9.8	2.8	8.1	3.8	7.7	2.0	2.2	3.0	3.5
54020	do	286	♀	19+32	80	4.6	6.2	9.4	9.0	2.7	9.5	3.8	8.4	2.1	2.1	2.9	3.6
54023	do	300	♂	18+30	77	4.4	6.3	10.0	10.6	2.9	7.6	3.8	7.8	2.2	2.2	3.2	3.4
Albus form:																	
1172	Bronte, Ontario.	265	♀	17+31	76	4.6	6.4	9.1	9.6	2.7	7.7	3.6	7.3	2.0	2.3	3.3	3.6
1174	do	232	♂	16+29	77	4.4	6.2	8.9	8.5	2.7	9.0	3.8	7.4	1.9	2.3	3.2	3.5
1176	do	283	♀	18+30	68	4.5	6.2	8.0	9.1	2.7	7.0	3.4	6.7	1.9	2.3	3.1	3.5
1180	do	231	♀	16+28	78	4.4	6.0	9.0	9.6	2.8	7.9	3.4	6.7	1.9	2.2	3.0	3.6
1183	do	284	♀	17+28	76	4.5	6.3	8.6	8.8	2.7	8.3	3.1	7.2	2.2	2.3	3.2	3.6
1189	do	263	♀	16+30	78	4.6	6.4	9.7	9.8	2.7	8.2	3.6	6.5	1.8	2.3	3.2	3.6
1196	do	235	♂	17+30	82	4.6	6.6	9.1	8.3	2.7	7.8	3.6	7.5	2.0	2.3	3.3	3.6
1230	Winona, Ontario.	277	♀	17+33	73	4.6	6.5	9.2	10.5	2.6	7.6	3.6	6.7	1.8	2.3	3.2	3.6
1231	do	291	♀	18+31	76	4.7	6.9	8.5	9.3	2.6	8.3	3.3	6.6	1.9	2.3	3.3	3.7
1238	do	295	♀	17+31	72	4.6	6.4	8.4	10.2	2.5	8.1	3.4	6.1	1.7	2.4	3.3	3.7

TABLE 78.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys artedi from Lake Ontario, half of them of the albus form from the deep water at the west end of the lake, and the rest, which are nearest the artedi form, from other areas*—Continued

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DO	AO	Br
Artedi form:																				
53138	Duck Island, Ontario.	4.8	4.1	2.8	4.0	1.9	3.7	4.2	3.1	2.1	3.0	1.9	1.5	10	11	11	16	1.6	0.91	8
53139	do	4.7	4.1	2.8	3.8	2.0	3.7	5.0	3.0	2.1	2.8	2.1	1.8	9	11	11	15	1.6	1.00	8
53962	Wilson, N. Y.	5.1	4.2	3.1	4.4	2.1	3.6	5.5	3.0	2.2	3.1	2.0	1.7	10	12	11	15	1.3	.86	8
53978	do	5.0	4.0	2.6	3.8	2.0	3.2	5.3	3.0	2.0	2.9	2.0	1.5	11	11	11	15	1.5	1.00	8
53980	do	5.0	4.6	3.0	4.5	-----	3.7	6.2	3.0	2.0	3.0	2.1	1.6	10	11	11	15	1.5	.98	8
53989	do	4.5	4.3	2.9	3.9	2.0	3.5	4.7	3.1	2.1	2.8	1.9	1.4	10	12	10	15	1.4	1.00	8
53993	do	5.1	4.2	2.7	3.7	2.1	3.7	4.8	3.0	1 9	2.6	1.9	1.8	10	11	12	15	1.5	1.00	7
54011	Pulaski, N. Y.	4.6	4.4	2.8	3.8	2.1	3.2	5.4	3.3	2.1	2.9	2.0	1.5	9	11	11	16	1.5	.90	9
54020	do	4.9	4.1	2.6	4.0	2.0	3.8	4.8	3.0	2.0	2.9	2.3	1.9	10	12	11	15	1.4	.91	9
54023	do	4.9	4.6	2.8	3.9	2.1	3.4	5.2	3.2	2.0	2.7	2.0	1.7	9	11	11	17	1.4	.95	8
Albus form:																				
1172	Bronte, Ontario.	5.0	4.3	2.8	4.0	2.1	3.3	5.2	3.1	2.0	2.9	2.4	1.8	10	11	11	15	1.3	.93	8
1174	do	5.0	4.3	2.6	3.7	2.0	3.7	6.3	3.0	1.8	2.6	2.0	1.5	10	12	12	16	1.4	.96	10
1176	do	4.9	4.3	2.9	3.9	2.1	4.0	5.9	3.1	2.1	2.8	1.9	1.7	12	11	11	16	1.2	.88	8
1180	do	4.9	4.3	2.7	3.9	2.0	3.3	5.8	3.3	2.0	2.8	2.3	1.8	10	10	11	14	1.4	.95	7
1183	do	5.0	4.4	2.7	3.9	2.0	2.9	5.5	3.2	2.0	2.8	2.0	1.6	10	11	11	15	1.4	.93	8
1189	do	4.9	4.6	2.7	3.9	2.0	3.2	5.4	3.4	2.0	2.8	2.1	1.7	10	11	11	16	1.4	.93	8
1196	do	5.2	4.5	2.7	3.8	2.1	3.1	5.5	3.1	1.9	2.6	1.9	1.5	9	12	11	16	1.4	.97	8
1230	Winona, Ontario.	5.0	4.4	2.8	4.1	2.1	3.2	5.2	3.2	2.0	3.0	2.1	1.8	10	12	11	15	1.3	.95	8
1231	do	5.4	4.6	2.8	4.3	2.1	3.2	5.0	3.1	2.0	3.0	2.2	1.7	10	12	11	14	1.1	.89	8
1238	do	5.2	4.5	2.9	4.2	2.1	3.2	5.7	3.2	2.0	3.0	2.0	2.0	11	10	11	17	1.3	1.00	8

TABLE 79.—*Records of the occurrence of Leucichthys nipigon in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.[1]	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined
1	July 28, 1922	Off Macdiarmid	2½, 2¾	30	3
2	Aug. 10, 1921	Off Murchison Island		15	3
3	Aug. 15, 1922	do		25	1
4	Aug. 23, 1923	Ombabika Bay		10	2
5	June 19, 1924	do		10	8
6	July 21, 1921	Off Britannia Island			1
7	June 21, 1924	Off Caribou Island		25	2
8	Aug. 1, 1922	Grand Bay			1
9	Sept. 3, 1923	Off Gros Cap		10	1
10	July 26, 1922	Off source of Nipigon River	2½, 2¾	10-15	11
11	Aug. 15, 1922	Unknown			3
12	Oct. 26, 1922	do	4½		1
13	Aug. 18, 1923	do			1
14	(2)				6

[1] All but records 1, 8, 10, and 12 from University of Toronto collections.

[2] No data.

TABLE 80.—*Numerical expressions of certain systematic characters for the type of Leucichthys nipigon and for nine cotypes from Lake Nipigon, selected at random*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
87092[1]	Orient Bay	282	19+37	Im. ♂	75	4.0	6.0	8.5	9.6	2.8	8.5	3.5	8.8	2.5	2.1	2.9	3.3
57564	do	255	21+36	Im. ♂	73	4.1	5.9	8.2	8.7	2.8	7.4	3.7	9.1	2.4	2.0	2.8	3.2
N1125[2]	Ombabika Bay	336	21+38	♀	79	4.2	5.7	8.1	8.0	2.8	8.8	3.3	6.8	2.0	2.1	2.8	3.3
N1128[2]	do	346	20+36	♀	69	3.9	5.5	7.8	7.8	2.7	9.6	3.3	7.5	2.2	1.9	2.7	3.1
57212	Off source of Nipigon River.	220	20+35	Im. ♂	72	3.9	5.3	8.4	8.4	2.7	8.0	3.9	9.1	2.3	1.9	2.6	3.0
57216	do	220	20+39	Im. ♂	74	3.9	5.5	8.5	8.8	2.8	8.4	3.8	9.1	2.3	1.8	2.6	3.0
57219	do	221	23+39	Im. ♀	82	3.9	5.5	8.1	8.9	2.8	8.5	4.1	9.6	2.3	1.8	2.6	3.0
57222	do	267	22+39	Im. ♂	75	4.1	5.7	8.2	8.3	2.7	8.6	3.8	9.8	2.5	1.9	2.7	3.1
57223	do	227	20+36	Im. ♀	78	4.0	5.5	8.7	8.6	2.8	7.8	4.0	8.7	2.1	1.8	2.5	3.0
57224	do	254	20+38	Im. ♀	75	4.0	5.5	7.9	7.8	2.7	8.0	3.7	9.4	2.4	2.0	2.7	3.0

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	Av/V	DR	AR	VR	PR	DC	AC	Br
87092[1]	Orient Bay	4.6	4.4	2.7	3.8	2.0	3.7	5.5	3.1	1.9	2.7	1.8	1.6	10	12	12	15			8
57564	do	4.5	4.3	2.5	3.9	2.0	2.9	5.4	3.0	1.7	2.7	1.7	1.4	11	11	12	17	1.5		9
N1125[2]	Ombabika Bay	4.6	4.4	2.7	3.6	1.9	3.5	5.5	3.2	2.0	2.6	1.7	1.6	11	13	12	18	1.3	0.94	9
N1128[2]	do	4.4	4.6	2.7	3.6	2.0	3.6	5.2	3.2	1.9	2.5	1.8	1.4	11	13	12	17	1.5	.98	10
57212	Off source of Nipigon River	4.0	4.0	2.6	3.7	2.0	3.0	5.6	3.0	1.9	2.8	1.5	1.4	11	13	12	15	1.6		9
57216	do	4.2	4.2	2.6	3.7	1.9	4.0	5.6	3.0	1.8	2.7	1.7	1.5	10	12	12	16	1.5	1.0	9
57219	do	4.3	4.2	2.6	3.7	1.9	4.5	5.0	3.0	1.8	2.6	1.4	1.5	11	11	12	16	1.6	1.1	10
57222	do	4.3	4.4	2.7	3.6	2.0	3.0	6.0	3.2	1.9	2.6	1.6	1.5	10	12	12	17	1.4	.96	9
57223	do	4.1	4.2	2.5	3.7	2.0	3.2	5.0	3.1	1.8	2.7	1.6	1.6	11	11	12	17	1.6	.95	9
57224	do	4.2	4.2	2.5	4.0	2.0	3.1	6.1	3.0	1.8	2.9	1.5	1.4	11	11	13	16	1.5	.96	8

[1] Type, U. S. National Museum number. [2] University of Toronto collection.

TABLE 81.—*Records of the occurrence of Coregonus clupeaformis in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, and the total number of preserved specimens examined]

Ports from which nets were set	Date	Location	Kind of net	Depth, in fathoms	Preserved specimens examined
Port Washington, Wis	Sept. 27, 1920	Off the city	Pound	5	4
Milwaukee, Wis	Nov. 15, 1920	20 miles ESE	2½-inch gill	28-35	1
	do	5 miles E. by S. ½ S	do	12	10
Michigan City, Ind	Mar. 4, 1921	15 miles NW. by N. ½ N	do	28	4
South Manitou Island, Mich	July 30, 1923	Off the lighthouse	Pound	3-5	22
Northport, Mich	June 23, 1920	2 miles south	do	4	4
Traverse City, Mich	June 22, 1920	4 miles north on east shore of West Bay	do	4	13
	July 18, 1923	Lower end of West Bay	do	5	15
	July 19, 1923	Bowers Harbor	do	5	6
	July 26, 1923	1½ miles south of Bowers Harbor	do	5	1
St. James, Mich	July 14, 1917	Sandy Bay	do	8	2
	June 28, 1920	do	do	8	18
Charlevoix, Mich	Aug. 11, 1923	3 miles NW. ½W	2¾ inch gill	35-60	1
St. Ignace, Mich	July 17, 1917	Off Gros Cap	Pound	6-10	2
Seul Choix Point, Mich	Aug. 20, 1920	1½ miles west of Seul Choix Point	do	5-8	15
Borrowed specimens:					
Pine, Ind.[1]					1
Edgmoor, Ind.[1]					1
Manitowoc, Wis.[2]					3
Sturgeon Bay, Wis.[2]					1
Algoma, Wis.[2]					2

[1] Field Museum collection. [2] Wisconsin Geological Survey collection.

TABLE 82.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Michigan, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
1	St. James, Mich.	483	10+17	♀	88	5.3	6.7	8.9	9.5	2.9	6.0	3.6	7.9	2.1	2.4	3.1	4.1
10	Gros Cap, Mich.	427	10+16	Im.♂	87	5.2	6.7	9.0	9.8	2.8	6.5	3.9	8.3	2.1	2.4	3.1	4.2
2	St. James, Mich.	406	11+16	Im.♀	89	5.1	6.9	9.2	10.4	2.6	6.8	4.0	7.6	1.8	2.4	3.3	4.1
2806	do	309	10+16	Im.♀	80	4.6	6.1	8.5	9.6	2.7	7.1	3.8	7.7	2.0	2.3	3.0	3.6
2810	do	296	10+16	Im.♂	88	5.0	6.5	9.2	9.4	2.6	7.2	3.7	8.4	2.2	2.4	3.1	3.8
2815	do	293	10+16	Im.♀	88	4.8	6.6	8.4	9.7	2.5	6.5	3.7	8.3	2.2	2.3	3.2	3.7
4566	Seul Choix, Mich.	299	10+16	Im.♂	83	4.7	6.3	9.6	9.4	2.8	6.7	4.0	7.6	1.8	2.2	3.0	3.6
3728	Port Washington, Wis.	193	10+17	Im.♀	83	4.5	6.4	8.4	9.4	2.7	7.1	4.2	9.1	2.1	2.1	2.9	3.5
3731	do	204	10+15	Im.♀	81	4.7	6.3	8.8	10.3	2.8	7.0	4.3	8.8	2.0	2.2	3.0	3.7
4270	Milwaukee, Wis.	224	11+15	Im.♀	80	4.8	6.6	8.1	10.2	2.6	7.3	4.0	8.2	2.0	2.2	3.1	3.7

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt. (*Lb. oz.*)
1	St. James, Mich.	5.2	5.0	3.5	3.6	2.8	1.9	10.1	4.0	2.7	2.8	2.2	1.9	11	12	11	16	1.3	1.0	10	3 11
10	Gros Cap, Mich.	5.4	4.9	3.4	3.7	2.7	2.1	11.2	3.8	2.6	2.8	2.3	2.0	11	11	11	17	1.4	1.0	8	2 4
2	St. James, Mich.	5.5	4.9	3.5	4.0	2.4	2.6	12.7	3.6	2.6	3.0	2.1	1.7	11	11	11	17	1.6	1.2	9	2 3
2806	do	4.8	4.6	3.3	3.2	2.5	2.9	11.3	3.5	2.5	2.4	1.8	1.7	11	11	11	17	1.4	1.2	9	15
2810	do	5.0	4.3	3.6	3.7	2.6	2.7	9.7	3.3	2.6	2.9	2.1	1.8	11	11	11	15	1.5	1.1	9	10.5
2815	do	5.2	4.8	3.5	3.9	2.6	2.5	10.1	3.5	2.5	2.8	2.0	1.7	12	12	11	16	1.4	1.1	9	12
4566	Seul Choix, Mich.	4.9	4.8	3.4	3.6	2.4	2.6	8.7	3.6	2.5	2.7	2.0	1.7	10	11	12	16	1.5	1.0	10	12.5
3728	Port Washington, Wis.	4.9	4.0	3.2	4.1	2.6	2.9	10.5	2.8	2.3	2.9	1.8	1.7	12	11	11	15	1.5	1.2	9	2.5
3731	do	5.0	3.9	3.4	4.0	2.6	2.7	10.2	2.9	2.5	3.0	2.0	1.7	12	12	11	15	1.5	1.1	9	3.5
4270	Milwaukee, Wis.	5.1	4.1	3.4	4.1	2.5	3.0	9.2	2.9	2.5	3.0	1.9	1.6	12	11	12	16	1.5	1.1	9	4.5

TABLE 83.—*Movements of the whitefish in the pound nets of Lake Michigan, according to data gathered from the operators of these nets*

Locality	Nets set	Depth, in feet	Appearance	Maximum abundance	Disappearance	Return in autumn
Port Washington, Wis.	April	20–60	June, first week	June and July	August	October, first week.
Michigan City, Ind.	April, second week	18–30	May, first week	Late May and early June.	June 15	October.
Grand Haven, Mich.	do	16–20	May, second week	July	August, first week	Do.
South Manitou Island, Mich.	June, second week	20–30	July, first week	do	do	(Nets out.)
Northport, Mich.	May, fourth week	40	September, second week.	October	October, last week	
Fox Islands, Mich.	June, second week	25–40	July, first week	July	August, first week	September, first week.
Traverse City, Mich.	May, first week	22–50	May, first week	June–July	July, last week	September, second week.
Beaver Island, Mich.	May, third week	40–45	May, third week	Late June and early July.	August, first week	September, fourth week.
Gros Cap, Mich.	June, first week	40–65	June, second week	July	July, fourth week	September, last week.
Seul Choix Point, Mich.	do	30–45	June, first week	do	August, first week	September, second week.

TABLE 84.—*Records of the occurrence of Coregonus clupeaformis in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, and the total number of preserved specimens examined]

Port from which nets were set	Date	Location	Kind of net	Depth, in fathoms	Preserved specimens examined
Lake Huron proper:					
St. Ignace, Mich.	July 17, 1917	Off the city	Pound	5	1
Cheboygan, Mich.	July 21, 1917	8 miles south	4½-inch gill	10–12	2
	Sept. 28, 1919	Hammond Bay	Pound	6	8
Rogers, Mich.	July 24, 1917		4½-inch gill	15	3
Alpena, Mich.	Aug. 13, 1917	15 miles southeast	do	10	4
	Sept. 17, 1917	13½ miles SE. by S.	2¾-inch gill	15	1
	Sept. 21, 1917	Off Sulphur Island	Pound	5	3
	Sept. 22, 1917	do	do	5	10
	Sept. 24, 1917	Between can buoy and Sulphur Island	2¾-inch gill	8–10	37
	Sept. 26, 1917	13 miles SE. by S. of can buoy	do	17	4
East Tawas, Mich.	Oct. 22, 1917	Off the city	Pound	4	16
Bay City, Mich.	Oct. 25, 1917	Saginaw Bay	do	6	15
Providence Bay, Ontario	Sept. 29, 1919				2
Duck Islands, Ontario	Oct. 22, 1919	Off Cockburn Island	Pound	8	7
North Channel:					
Kagawong, Ontario	Nov. 10, 1917	Off Clapperton Island	do	6	4
	Oct. 16, 1919	do	do	6	7
Gore Bay, Ontario	Nov. 10, 1917	Off Barrie Island	do		4
	Nov. 12, 1917	do	do		3
	Sept. 27, 1919	do	do		10
Georgian Bay:					
Wiarton, Ontario	Nov. 5, 1917	7 miles above the city	do	4	1
	July 29, 1919	Colpoys Bay	do	4	6
	Nov. 29, 1919	do	do	4	2
Killarney, Ontario	Oct. 12, 1919		do	10	16
Borrowed specimens:					
Georgian Bay [1]					28
Bay Port, Mich.[2]					1

[1] Donated by Dr. B. A. Bensley.
[2] U. S. National Museum collection.

TABLE 85.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Huron, selected according to size and locality*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
71	Cheboygan, Mich.	470	♀	10+17	85	4.6	6.4	8.5	8.8	3.0	7.4	3.6	8.1	2.2	2.1	3.0	3.7
1078	Wiarton, Ontario.	445	Im. ♀	11+17	76	4.7	6.5	9.3	9.5	2.8	7.4	3.5	8.0	2.2	2.2	3.0	3.7
1027	Bay City, Mich.	426	♂	10+16	79	4.9	6.7	8.5	9.9	2.9	7.3	3.7	8.5	2.3	2.3	3.1	4.0
1031	do	307	Im. ♀	10+15	85	5.0	6.3	9.0	9.4	2.8	6.8	4.2	8.0	1.8	2.3	2.9	3.8
543	Alpena, Mich.	307	Im. ♀	11+17	89	4.8	6.8	8.1	9.2	2.5	6.7	4.0	9.0	2.2	2.2	3.2	3.7
1936	Wiarton, Ontario.	306	Im. ♂	11+17	82	4.7	6.1	8.1	9.8	2.7	7.3	4.3	8.6	1.9	2.2	2.9	3.7
2465	Killarney, Ontario	300	Im. ♀	11+17	84	4.7	6.1	9.0	9.6	2.7	6.9	4.2	8.2	1.9	2.3	3.0	3.7
1015	East Tawas, Mich.	250	Im. ♀	9+17	77	4.7	6.4	9.0	9.0	2.4	6.9	3.9	8.0	2.0	2.2	3.0	3.6
1013	do	194	Im. ♂	10+16	85	4.6	6.1	8.3	9.7	2.5	6.5	4.1	7.4	1.8	2.1	2.8	3.5
980	do	201	Im. ♂	10+16	80	4.7	5.9	8.3	8.9	2.6	6.8	4.2	8.3	1.9	2.1	2.6	3.5

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt.
																					Lb. oz.
71	Cheboygan, Mich.	5.1	5.3	3.4	3.8	2.6	2.8	10.2	3.8	2.5	2.5	2.0	1.8	11	12	11	17	1.4	1.0	9	
1078	Wiarton, Ontario	5.2	5.4	3.2	3.6	2.6	2.3	13.4	3.9	2.3	2.6	2.0	1.8	10	12	11	16	1.4	1.0	9	2 9
1027	Bay City, Mich.	5.5	5.0	3.4	3.9	2.5	2.3	11.4	3.6	2.5	2.8	2.1	1.8	11	10	11	15	1.3	1.1	9	2
1031	do	4.4	4.5	3.2	3.7	2.7	2.7	10.1	3.5	2.6	2.9	1.8	1.7	12	12	12	16	1.5	1.1	9	13.5
543	Alpena, Mich.	5.3	4.5	3.4	3.9	2.6	2.6	11.4	3.2	2.4	2.8	1.9	1.7	12	12	11	15	1.4	1.1	9	13.5
1936	Wiarton, Ontario	4.7	4.6	3.3	3.7	2.6	2.8	10.3	3.6	2.6	2.9	1.8	1.7	12	11	11	16	1.2	1.0	9	12
2465	Killarney, Ontario	4.9	4.3	3.5	3.9	2.5	2.3	9.7	3.3	2.8	3.0	1.7	1.6	11	11	11	16	1.5	1.1	9	12.5
1015	East Tawas, Mich.	4.8	4.3	3.2	3.7	2.5	3.4	10.5	3.1	2.4	2.8	1.8	1.7	12	12	11	15	1.6	1.0	9	8
1013	do	4.7	4.1	3.5	4.5	2.4	2.6	10.5	3.0	2.6	3.4	1.8	1.5	11	10	11	15	1.6	1.3	9	3
980	do	4.4	4.0	3.0	3.6	2.5	2.5	10.1	3.2	2.4	2.8	1.8	1.6	11	11	11	15	1.6	1.2	9	4

TABLE 86.—*Showing the movement of the whitefish in the pound nets of Lake Huron, according to data gathered from the operators of these nets*

Locality	Nets set	Depth, in feet	Appearance	Maximum abundance	Disappearance	Return in autumn
Lake Huron proper:						
Alpena, Mich	April, first week	26-40	May or June	June-July	August, first week	September, middle.
East Tawas, Mich.	do	25-50	June, first week	June	July, middle	September, first week.
Point Au Gres, Mich.	do	25-50	April, first week	April to May 15	June, first week	September, third week.
Port Huron Mich.	March, last week	20-30	March, last week	April	June, last week	October, third week.
Cockburn Island, Ontario.	June, last week	45	June, last week	August and September.	October, third week.	
Duck Islands, Ontario.	June, first week	30-40	do	July and August	do	
Providence Bay, Ontario.	May, first week	45-60	July, third week	August	September, first week.	October.
North Channel:						
Blind River, Ontario.	do	25	May, first week	May and June	July, third week	October, first week.
Thessalon, Ontario.	do	25	do	do	do	Do.
Gore Bay, Ontario.	June, first week	25-30	June, first week	June	July, last week	September, first week.
Kagawong, Ontario.	May, first week	35	do	June, last half	July, third week	October, third week.
Georgian Bay:						
Killarney, Ontario.	do	65-75	May, last week	June and July		
Wiarton, Ontario.	do	35-40	June, second week	June, last half	July, first week	(No fall run; mud bottom.)

TABLE 87.—*Records of the occurrence of Coregonus clupeaformis in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water and character of the bottom where made, and the number of preserved specimens examined]

Port from which nets were set	Date	Location	Kind of net	Depth, in fathoms	Bottom	Preserved specimens examined
Sault Ste. Marie, Mich	June 14, 1922	10 miles NW. by W. ¼ W. of Point Iroquois Light.	2½ and 2¾-inch gill.	38		[1] 1
Marquette, Mich	Feb. 8, 1921		1½-inch gill			1
	Aug. 10, 1921	Marquette Bay	Pound	5	Sand	16
Ontonagon, Mich	Aug. 25, 1921	6 miles NNW	2½ and 2¾-inch gill.	20-38	Sand-clay	[1] 16
Apostle Islands, Wis	July 11, 1922	Between Cat and South Twin Islands.	2¾-inch gill	15-20	Sand	1
Port Arthur, Ontario	July 20, 1922	Black Bay off Demers Point	Pound	8	Mud	34
Rossport, Ontario	Aug. 5, 1922	Moffat Strait	do	4		13
	Sept. 25, 1923	do	2½-inch gill	13-14	Clay-sand	8
Coppermine Point, Ontario.	June 24, 1922	Agawa Bay	4½-inch gill	40-50	Mud	3
Batchawanna, Ontario	June 17, 1922	Batchawanna Bay	Pound	3-13	Clay-sand	12
Borrowed specimens:						
Sault Ste. Marie, Mich.[2]						1
Port Arthur, Ontario.[3]						1
Apostle Islands, Wis.[4]						10

[1] Only specimens taken in lift.
[2] Field Museum collection.
[3] U. S. National Museum collection.
[4] Wisconsin Geological Survey collection.

TABLE 88.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Superior, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
53526	Marquette, Mich.	348	10+16	Im. ♀	84	4.9	6.3	8.9	9.4	3.0	6.6	4.0	7.5	1.8	2.3	2.9	3.9
53530	do	350	11+17	Im. ♂	86	4.9	6.2	8.3	8.9	2.5	6.1	4.2	7.7	1.7	2.3	2.9	3.8
57052	Agawa Bay	380	11+17	♂	79	4.6	5.8	8.0	10.5	2.7	6.9	4.0	8.0	2.0	2.3	2.9	3.6
57362	Black Bay	278	11+17	Im. ♀	82	4.5	6.0	7.6	8.1	2.6	6.6	3.5	7.9	2.2	2.1	2.8	3.5
57366	do	271	11+16	Im. ♀	84	4.6	6.0	7.6	8.4	2.6	6.3	3.5	8.2	2.3	2.2	2.9	3.6
57381	do	297	11+16	Im. ♀	77	4.7	6.0	8.2	9.5	2.5	6.6	3.5	8.0	2.2	2.2	2.8	3.5
57840	Batchawanna Bay.	273	11+17	Im. ♂	86	4.5	5.9	8.0	7.9	2.7	7.5	4.0	9.4	2.3	2.1	2.8	3.5
53053	Marquette, Mich.	180	10+17	Im. ♀	86	4.5	6.2	8.5	9.4	2.8	6.8	4.2	10.0	2.3	2.0	2.8	3.5
53521	do	226	9+18	Im. ♂	91	4.6	5.9	8.6	9.3	2.6	6.1	4.7	9.4	2.0	2.1	2.8	3.5
53716	Ontonagon, Mich.	223	11+16	Im. ♀	84	4.6	6.2	8.7	9.2	2.7	7.9	3.8	7.9	2.0	2.1	2.9	3.8

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt.
																					Lb. oz.
53526	Marquette, Mich.	5.0	4.6	3.1	3.7	2.6	2.6	10.0	3.6	2.4	2.9	2.0	1.9	11	12	11	16	1.4	1.0	9	1 6.5
53530	do	4.8	5.0	3.4	3.9	2.7	2.6	10.2	3.9	2.6	3.1	1.9	1.7	11	11	11	15	1.4	1.0	9	1 6
57052	Agawa Bay	4.5	4.7	2.9	3.0	2.5	2.4	10.5	3.7	2.3	2.4	1.6	1.6	12	11	12	16	1.3	1.2	9	1 10.5
57362	Black Bay	4.6	4.3	3.8	4.1	2.6	2.4	10.3	3.2	2.8	3.1	1.6	1.5	11	12	12	17	1.6	1.2	9	12
57366	do	4.7	4.3	3.3	3.8	2.4	2.4	10.5	3.3	2.5	2.9	2.0	1.7	11	12	12	14	1.5	1.1	9	11
57381	do	4.5	4.7	3.6	4.0	2.5	2.4	10.1	3.7	2.8	3.1	1.6	1.6	11	11	12	16	1.6	1.2	9	13.5
57840	Batchawanna Bay.	4.5	4.4	3.3	3.9	2.5	3.1	9.6	3.4	2.5	3.0	1.8	1.5	11	13	11	15	1.5	1.0	9	8
53053	Marquette, Mich.	4.8	3.8	3.3	4.0	2.5	3.2	10.0	2.7	2.4	2.9	2.1	1.7	12	12	11	17	1.5	1.0	9	2
53521	do	4.6	4.0	3.3	3.7	2.4	2.8	8.9	3.1	2.6	2.9	1.7	1.6	11	12	11	16	1.6	1.1	10	4.5
53716	Ontonagon, Mich.	5.1	4.3	3.4	3.7	2.5	3.1	12.0	3.2	2.5	2.7	2.1	1.8	11	11	11	16	1.5	1.0	8	5.5

TABLE 89.—*Movements of the whitefish in the pound nets of Lake Superior, according to data gathered from the operators of these nets*

Locality	Nets set	Depth, in feet	Appearance	Maximum abundance	Disappearance	Return in autumn
Whitefish Point, Mich.	May, third week	24-90	June, first week	June and July	A few in August and September.	
Marquette, Mich.	June, first week	25-30	do	June and early July.	August, first week.	September, second week.
Black Bay, Ontario	do	40-50	do	Late June and early July.	do	October, first week.
Nipigon Bay, Rossport, Ontario.	May, third week	25-35	May, third week	June	July, first week	(No fall run.)
Gargantua, Ontario.	May, fourth week.	20-60	June, first week	July	August, first week.	(Nets out.)
Batchawanna Bay, Ontario.	May, third week	15-80	do	do	August, third week.	October, last week

TABLE 90.—*Records of the occurrence of Coregonus clupeaformis in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined
1	July 28, 1922	Off Macdiarmid	2½, 2¾	30	6
2	July 26, 1922	Off Blackwater River	2½, 2¾	1-3	3
3	Aug. 1, 1922	Ombabika Bay	4½	15-20	1
4	July 26, 1922	Off source of Nipigon River	2½, 2¾	10-15	21
5	[1]				3

[1] No data.

TABLE 91.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Nipigon, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
57251	Source of Nipigon River	206	10+17	Im.♂	86	4.3	5.4	8.5	9.8	2.8	6.4	3.9	7.9	2.0	2.1	2.6	3.4
57253	do	203	11+17	Im.♂	79	4.3	5.5	8.8	10.1	2.9	6.3	4.0	8.8	2.1	2.0	2.6	3.3
57255	do	213	11+17	Im.♀	77	4.4	5.6	9.6	9.1	2.8	6.8	3.8	9.6	2.5	2.1	2.6	3.5
57289	do	216	11+16	Im.♂	78	4.4	5.6	8.0	8.5	2.7	6.5	4.0	9.3	2.3	2.1	2.7	3.4
57328	do	212	11+18	Im.♂	89	4.4	5.7	8.5	10.7	2.7	6.4	3.9	8.8	2.2	2.1	2.4	3.3
57323	do	373	11+16	♀	79	4.8	6.1	7.9	8.8	2.6	7.3	3.3	8.1	2.1	2.2	2.8	3.5
57345	Mouth of Blackwater River	321	10+17	Im.♀	87	4.7	6.4	7.4	8.2	2.7	7.1	3.5	8.6	2.4	2.2	3.0	3.5
57346	do	328	10+17	♂	87	4.5	5.7	8.4	8.8	2.8	6.9	3.5	8.2	2.2	2.2	2.8	3.6
57598	Macdiarmid, Ontario	325	11+17	Im.♂	81	4.6	5.8	7.5	7.9	2.6	7.0	3.3	7.3	2.2	2.3	2.8	3.5
57713	Grand Bay	410	12+17	♂	84	4.3	5.5	9.0	9.0	2.8	7.7	3.8	7.4	1.9	2.1	2.6	3.4

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt.	
																					Lb.	*oz.*
57251	Source of Nipigon River	4.2	3.9	2.8	3.2	2.3	2.6	10.4	3.1	2.2	2.6	1.8	1.5	11	11	12	15	1.6	1.2	9		3.5
57253	do	4.3	3.9	3.0	3.6	2.4	2.7	11.1	3.0	2.3	2.8	1.8	1.6	10	11	11	16	1.6	1.1	9		3
57255	do	4.4	3.9	3.0	3.7	2.4	2.8	10.0	3.1	2.4	2.9	1.7	1.7	10	11	12	15	1.7	1.1	9		4
57289	do	4.4	4.0	3.1	3.9	2.4	2.5	9.0	3.1	2.4	3.0	1.6	1.4	11	13	12	16	1.6	1.1	8		4.5
57328	do	4.3	3.9	3.0	3.6	2.4	2.6	10.0	3.0	2.3	2.8	2.0	1.5	10	11	11	16	1.5	1.2	10		3.5
57323	do	4.5	4.7	3.6	3.9	2.4	2.4	11.0	3.7	2.8	3.1	1.9	1.6	11	12	11	15	1.4	1.0	9	1	11.5
57345	Mouth of Blackwater River	4.8	4.5	3.3	4.1	2.5	2.4	10.8	3.3	2.4	3.0	1.7	1.6	12	11	11	16	1.3	1.0	9		15.5
57346	do	4.5	4.2	3.2	3.9	2.4	2.3	10.2	3.4	2.5	3.1	1.6	1.5	10	12	11	16	1.5	1.1	8	1	2
57598	Macdiarmid, Ontario	4.4	4.7	3.2	3.6	2.3	2.5	11.6	3.7	2.5	2.9	1.8	1.5	11	12	11	16	1.3	1.0	9	1	3.5
57713	Grand Bay	4.4	4.8	3.1	3.3	2.4	2.8	10.1	3.8	2.4	2.6	1.6	1.6	11	12	11	15	1.4	1.1	9	2	2

TABLE 92.—*Records of the occurrence of Coregonus clupeaformis in Lake Erie*

[For each record is given, if known, the date and locality, the kind of gear used to make it, and the total number of preserved specimens examined]

Port from which nets were set	Date	Location	Kind of net	Preserved specimens examined
Monroe, Mich.	1920			2
Toledo, Ohio	Nov. 27, 1920	12 miles east	Trap	3
Sandusky, Ohio	Nov. 29, 1920	Around Bass Islands	do	5
Ashtabula, Ohio	Oct. 23, 1920	14 miles NE. by N	4¾-inch gill	2
Erie, Pa.	Oct. 24, 1920	12 miles N. by E	do	4
Borrowed specimens:				
Erie, Pa.[1]				1
Cleveland, Ohio[1]				1

[1] U. S. National Museum collection.

TABLE 93.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Erie, selected according to size*

[There is added also a specimen, No. 4405, of the so-called "hybrid" between the whitefish and the herring]

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
4061	Erie, Pa	402	10+15	♂	77	4.7	6.1	7.7	7.9	2.5	6.5	3.3	7.7	2.2	2.2	2.9	3.6
4065	do	382	10+18	♀	81	5.0	6.5	7.4	9.1	2.3	7.7	3.6	7.6	2.1	2.5	3.2	4.0
4066	do	369	11+17	♂	78	4.8	6.5	8.0	8.2	2.7	7.2	3.5	8.5	2.4	2.3	3.0	3.8
4059	Ashtabula, Ohio	375	11+18	♀	75	4.9	6.2	8.5	8.4	2.5	6.8	3.2	7.0	2.1	2.3	3.0	3.7
4590	Sandusky, Ohio	396	11+17	♀	85	4.8	6.3	7.9	8.2	2.7	6.3	3.8	8.2	2.1	2.3	3.0	3.6
4401	Toledo, Ohio	378	10+16	♀	81	5.0	6.4	8.0	8.4	2.6	7.8	3.4	6.7	1.9	2.5	3.1	4.0
4402	do	340	11+17	♂	80	4.9	6.0	8.6	8.0	2.7	6.5	3.4	7.9	2.2	2.3	2.9	3.8
4404	do	361	11+16	♂	77	5.0	6.2	7.8	8.8	2.7	7.0	3.6	8.0	2.1	2.4	3.0	3.9
52804	Monroe, Mich	360	11+16	♂	87	4.8	6.2	9.0	8.7	2.7	7.8	3.6	8.1	2.2	2.2	2.9	3.9
52805	do	376	10+15	♀	80	5.0	6.1	7.0	8.5	2.5	7.5	3.1	6.8	2.1	2.5	3.0	3.9
4405	Toledo, Ohio	282	14+23	♂	81	4.4	6.5	8.8	9.4	2.9	8.1	3.3	7.2	2.1	2.2	3.2	3.6

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt. *Lb. oz.*
4061	Erie, Pa	4.7	5.1	3.4	3.8	2.5	2.5	9.4	3.9	2.6	2.9	1.6	1.7	11	11	11	14	1.3	1.0	9	2 9.5
4065	do	5.1	5.0	3.2	3.7	2.5	2.7	10.4	3.8	2.5	2.8	2.0	1.8	13	11	12	13	1.1	1.1	9	2 2.5
4066	do	5.1	4.9	3.3	3.6	2.6	2.6	10.1	3.6	2.4	2.6	1.8	1.5	11	12	11	13	1.5	1.1	9	1 10
4059	Ashtabula, Ohio	4.7	4.9	3.6	4.0	2.5	2.4	10.5	3.8	2.8	3.1	1.9	1.7	11	12	11	15	1.3	1.1	9	2 8.5
4590	Sandusky, Ohio	4.8	5.0	3.3	3.7	2.5	2.3	10.4	3.8	2.5	2.8	1.9	1.6	11	12	12	13	1.2	1.0	9	1 13.5
4401	Toledo, Ohio	5.0	4.8	3.3	3.5	2.6	2.4	10.4	3.8	2.6	2.7	1.9	1.6	11	11	12	14	1.3	1.0	8	2 6
4402	do	4.8	4.9	3.5	4.0	2.5	2.3	10.0	3.9	2.7	3.1	1.8	1.6	10	12	11	15	1.5	1.1	8	1 9
4404	do	4.9	4.3	3.1	3.8	2.6	2.5	10.5	3.5	2.5	3.1	1.9	1.6	11	11	12	14	1.2	1.0	9	1 11.5
52804	Monroe, Mich	5.0	4.8	3.2	3.6	2.5	3.1	10.4	3.7	2.5	2.7	1.7	1.6	11	11	11	14	1.5	1.2	8	1 9
52805	do	4.8	4.6	3.5	3.5	2.6	2.3	10.4	3.8	2.8	2.9	1.9	1.6	12	13	11	14	1.2	1.0	8	2 4.5
4405	Toledo, Ohio	5.4	4.5	3.1	4.5	2.5	2.4	6.3	3.1	2.1	3.1	1.9	1.6	10	10	11	14	1.6	1.2	9	14.5

TABLE 94.—*Records of the occurrence of Coregonus clupeaformis in Lake Ontario*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, and the total number of preserved specimens examined]

Port from which nets were set	Date	Locality	Kind of net	Depth, in fathoms	Preserved specimens examined
Winona, Ontario	Nov. 23, 1917				2
Bronte, Ontario	do				2
	June 28, 1921	Off Burlington	4¾-inch gill	12	2
Port Hope, Ontario	Nov. 21, 1917				4
Brighton, Ontario	June 18, 1921	1 mile northwest of Proctor Island	4½-inch gill	5	3
Duck Islands, Ontario	June 7, 1921	Off the islands	3-inch gill		15
Cape Vincent, N. Y.	do	Off Grenadier Island	Trap		1
Sandy Pond, N. Y.	Aug. 27, 1923	Southwest of Stony Point Light	4½-inch gill	24	8
Selkirk, N. Y.	July 11, 1921	5 miles NNW. off Nine-Mile Point	3-inch gill	25–35	1
Borrowed specimens: Toronto, Ontario [1]					1

[1] U. S. National Museum collection.

TABLE 95.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Ontario, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
1157	Port Hope, Ontario	444	11+16	♂	83	4.7	6.2	8.7	8.6	2.7	5.8	3.7	7.4	1.9	2.3	3.0	3.7
1158	do	423	11+16	♂	90	4.8	6.4	8.5	8.9	2.8	7.4	4.0	8.4	2.1	2.2	3.0	3.7
62435	Sandy Pond, N.Y.	415	11+17	♂	78	4.8	6.6	9.1	9.0	2.7	6.9	3.7	8.6	2.3	2.2	3.1	3.7
53258	Bronte, Ontario	407	11+17	♂	85	4.7	6.4	9.4	8.6	2.9	6.6	4.0	8.8	2.1	2.1	2.8	3.6
54049	Port Ontario, N. Y.	293	10+17	Im. ♂	86	4.6	5.7	8.1	8.6	2.7	6.5	3.8	8.3	2.1	2.2	2.7	3.6
53154	Duck Island, Ontario	302	10+16	Im. ♀	83	4.9	6.5	9.0	8.6	2.7	7.0	4.1	8.8	2.1	2.2	2.9	3.7
53156	do	308	11+18	Im. ♀	82	4.6	6.2	8.3	8.6	2.8	6.5	4.0	7.8	1.9	2.1	2.9	3.5
53150	do	279	11+16	Im. ♀	86	4.8	6.6	9.6	10.0	2.9	6.6	3.9	8.4	2.1	2.2	3.0	3.8
53155	do	253	11+18	Im. ♂	79	4.5	6.0	8.0	8.4	2.6	7.0	3.8	9.3	2.4	2.1	2.8	3.4
1220	Winona, Ontario	274	10+19	Im. ♂	88	4.9	6.6	9.1	9.1	2.5	6.6	3.6	7.4	2.0	2.3	3.1	3.7

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt. (*Lb. oz.*)
1157	Port Hope, Ontario	4.8	5.1	3.3	3.4	2.6	2.1	10.0	3.9	2.5	2.6	1.9	1.8	11	12	11	16	1.3	0.94	9	2 14.5
1158	do	4.9	4.9	3.4	3.6	2.4	2.5	10.7	3.7	2.5	2.7	1.8	1.6	11	11	11	15	1.5	1.1	8	2 5.0
62435	Sandy Pond, N. Y.	5.2	5.0	3.7	4.0	2.8	2.6	10.7	3.6	2.7	2.8	2.0	1.7	10	12	11	10	1.4	1.0	9	2 5.0
53258	Bronte, Ontario	4.9	5.0	3.4	3.9	2.6	2.6	9.3	3.6	2.5	2.9	1.7	1.7	10	13	11	16	1.5	1.0	8	1 11.5
54049	Port Ontario, N. Y.	4.4	4.4	3.2	3.6	2.6	2.6	9.1	3.6	2.6	2.9	1.9	1.6	11	12	11	15	1.6	1.1	9	12.5
53154	Duck Island, Ontario	4.9	4.2	3.3	3.6	2.5	2.7	10.1	3.2	2.5	2.7	1.9	1.6	11	12	11	14	1.5	1.1	9	11.5
53156	do	4.8	4.4	3.3	3.6	2.7	2.7	9.4	3.2	2.5	2.6	1.7	1.4	11	12	11	16	1.5	1.1	9	14
53150	do	5.3	4.6	3.4	4.0	2.6	2.6	9.6	3.3	2.4	2.8	2.1	1.8	11	11	12	15	1.5	1.2	9	9
53155	do	4.5	4.3	3.3	4.2	2.6	2.8	11.2	3.2	2.4	3.1	1.5	1.4	11	12	11	15	1.5	1.0	9	7.5
1220	Winona, Ontario	5.0	4.5	3.3	3.7	2.6	3.0	9.1	3.4	2.4	2.7	1.8	1.8	11	12	11	15	1.5	1.0	8	10

TABLE 96.—*Records of the occurrence of Prosopium quadrilaterale in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, and the total number of preserved specimens examined]

Ports from which nets were set	Date	Location	Kind of net	Depth, in fathoms	Preserved specimens examined
Washington Harbor, Wis.	Aug. 18, 1920	7 miles NNW	2⅝-inch gill	11	1
Milwaukee, Wis.	Nov. 15, 1920	5 miles E. by S. ½ S.	2½-inch gill	12	2
Michigan City, Ind.	Nov. 19, 1920	17 miles NNW	do	28-32	1
	do	17½ miles NW. by N. ¾ N.	do	32	2
	Mar. 4, 1921	15 miles NW. by N. ½ N.	do	28	1
Manistee, Mich.	Aug. 27, 1920	3 miles south	Pound	4	2
Platte Bay, Mich. (field station).	July 21, 1923	1½ miles south of Otter Creek	1½ gill-inch	8-12	22
	July 22, 1923	do	do	12-18	5
	do	do	do	15-25	1
	July 23, 1923	do	do	15-25	14
South Manitou Island, Mich.	July 30, 1923	Off the lighthouse	do	8-10	4
Traverse City, Mich.	June 25, 1920	4 miles north on east shore of West Bay	Pound	4	3
St. James, Mich.	June 28, 1920	Sandy Bay	do	8	3
Cheboygan, Mich.	July 23, 1917	Near Epoufette			3
Borrowed specimens:					
Algoma, Wis.[1]					3

[1] Wisconsin Geological Survey collection.

TABLE 97.—*Numerical expressions of certain systematic characters for 10 specimens of Prosopium quadrilaterale from Lake Michigan, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
2793	Traverse City, Mich.	249	6+ 9	Im. ♀	84	5.4	7.1	9.3	13.2	2.4	6.5	4.6	8.8	1.8	2.3	3.0	4.0
2797	Beaver Island, Mich.	324	7+11	♂	89	5.1	6.5	9.8	13.6	2.7	7.4	4.7	7.5	1.5	2.2	2.8	4.0
2800	do.	341	8+11	♂	92	5.4	7.1	8.7	11.9	2.3	6.9	4.3	7.2	1.6	2.2	2.9	4.0
3101	Washington Harbor, Wis.	232	6+11	Im. ♀	94	5.2	7.0	8.6	12.8	2.5	7.0	5.5	8.5	1.5	2.2	3.0	3.9
4280	Milwaukee, Wis.	254	7+10	Im. ♀	87	5.5	7.1	10.3	14.1	2.4	5.9	5.0	7.9	1.5	2.3	3.0	4.1
4284	do.	256	7+11	Im. ♀	92	5.3	6.9	10.4	15.2	2.6	5.9	5.4	8.0	1.4	2.3	3.0	4.0
4392	Michigan City, Ind.	295	7+10	♂	88	5.4	7.2	9.4	12.2	2.4	6.5	5.0	9.5	1.8	2.3	3.0	4.1
4396	do.	293	6+10	Im. ♀	95	5.4	6.9	9.7	13.4	2.3	6.1	4.8	8.1	1.6	2.4	3.0	4.1
3373	Manistee, Mich.	299	7+ 9	Evis.	90	5.2	6.8	9.5	13.0	2.5	6.6	5.3	8.3	1.5	2.2	2.9	4.0
4639	Michigan City, Ind.	270	7+10	Im. ♀	89	5.2	7.1	10.0	13.5	2.4	6.5	5.4	7.9	1.4	2.2	3.0	4.1

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
2793	Traverse City, Mich.	5.3	4.3	4.2	4.1	2.8	3.0	20.9	3.3	3.2	3.1	2.0	2.2	11	10	10	14	1.2	1.4	8
2797	Beaver Island, Mich.	5.0	4.3	4.1	3.7	2.8	3.1	28.4	3.4	3.3	2.9	2.1	2.2	11	9	11	16	1.3	1.3	7
2800	do.	5.3	4.5	3.8	4.1	2.9	2.8	21.0	3.4	2.9	3.1	2.1	2.2	12	11	11	16	1.2	1.2	8
3101	Washington Harbor, Wis.	5.3	4.1	4.6	4.4	2.9	2.9	22.0	3.1	3.4	3.3	2.0	2.3	12	11	11	15	1.1	1.4	8
4280	Milwaukee, Wis.	5.4	4.5	4.1	4.1	3.0	2.8	23.0	3.4	3.2	3.2	2.1	2.3	11	9	10	16	1.4	1.5	7
4284	do.	5.2	4.4	4.7	3.9	2.8	2.8	24.0	3.4	3.6	3.0	2.0	2.1	12	9	11	14	1.4	1.6	8
4392	Michigan City, Ind.	5.4	4.5	4.2	4.0	3.3	2.8	24.5	3.4	3.1	3.0	2.2	2.1	12	11	11	14	1.3	1.3	7
4396	do.	5.2	4.7	4.5	3.7	3.1	2.8	24.3	3.7	3.5	2.9	2.2	2.3	13	10	11	15	1.3	1.4	7
3373	Manistee, Mich.	5.3	4.4	4.6	3.7	3.1	2.9	26.1	3.3	3.4	2.8	2.0	2.3	12	10	11	16	1.3	1.3	7
4639	Michigan City, Ind.	5.5	4.5	4.3	4.0	2.9	2.8	23.1	3.3	3.2	3.0	2.2	2.2	11	10	11	15	1.4	1.4	8

TABLE 98.—*Records of the occurrence of Prosopium quadrilaterale in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, and the total number of specimens examined]

Port from which nets were set	Date	Location	Method of capture	Depth, in fathoms	Preserved specimens examined
Lake Huron proper:					
St. Ignace, Mich.	July 17, 1917	Off the city	Pound net	4	4
Cheboygan, Mich.	July 21, 1917	8 miles south	4½-inch gill net		1
Alpena, Mich.	Sept. 10, 1917	13½ miles SE. by S. of can buoy	do	15	2
	Sept. 14, 1917	24 miles SE. by E. ½ E. of can buoy	do	24	2
	Sept. 17, 1917	13½ miles SE. by S. of can buoy	2¾-inch gill net	15	5
	Sept. 20, 1917	On north grounds	4½-inch gill net	10-12	1
	Sept. 22, 1917	15 miles SE. by S. ½ S. of can buoy	do	17	1
	Sept. 26, 1917	13 miles SE. by S. of can buoy	2¾-inch gill net	17	1
	Nov. 2, 1917	7 miles ENE. of can buoy	do	15	41
	Nov. 15, 1919		do	15	40
Duck Islands, Ontario	Oct. 18, 1919	Off Greater Duck Island	Hand line	2	34
North Channel:					
Blind River, Ontario	Oct. 6, 1917	Off Grant Island	4½-inch gill net	3-5	6
Gore Bay, Ontario	Nov. 7, 1917	Off Barrie Island	Pound net	5	2
Kagawong, Ontario	Nov. 10, 1917	Off Clapperton Island	do	6	3
	Oct. 16, 1919	do	do	6	2
Georgian Bay:					
Wiarton, Ontario	Nov. 5, 1917	7 miles above the city, in Colpoys Bay	do	4	6
Killarney, Ontario	Oct. 10, 1919	Off the city	do	10	1

TABLE 99.—*Numerical expressions of certain systematic characters for 10 specimens of Prosopium quadrilaterale from Lake Huron, selected according to size and locality*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
19	St. Ignace, Mich.	276	♀	6+10	84	5.3	6.7	9.5	11.0	2.5	6.8	4.8	8.6	1.7	2.3	3.0	4.1
69	Cheboygan, Mich.	300	♂	8+10	87	5.0	6.7	9.0	13.1	2.5	7.3	4.7	7.5	1.5	2.1	2.9	3.9
222	Alpena, Mich.	245	Im. ♂	5+11	86	5.0	6.5	9.6	12.1	2.5	7.2	5.5	8.4	1.5	2.1	2.8	3.9
330	do.	241	Im. ♀	8+11	93	5.2	6.7	9.4	13.0	2.5	6.8	4.9	8.6	1.7	2.2	2.9	4.0
431	do.	288	♂	6+11	90	4.8	6.6	8.8	12.5	2.5	7.2	5.0	7.4	1.4	2.1	2.8	3.9
1070	Wiarton, Ontario.	295	♀	6+11	88	5.2	6.8	8.9	10.8	2.5	7.7	4.7	7.6	1.6	2.3	3.0	4.0
1104	Kagawong, Ontario.	316	♀	7+11	89	5.1	7.1	9.0	13.3	2.4	7.0	4.4	7.0	1.5	2.2	3.1	4.0
1096	Gore Bay, Ontario.	363	♀	6+10	88	5.2	7.2	9.1	11.0	2.4	6.0	4.1	6.8	1.6	2.2	3.1	4.1
2497	Duck Islands, Ontario.	276	♂	5+11	89	5.0	6.5	8.7	13.1	2.5	7.4	4.8	8.4	1.7	2.2	2.8	3.9
2519	do.	255	♂	5+10	90	5.0	6.6	9.1	12.7	2.5	7.9	5.2	8.6	1.6	2.2	2.9	3.9

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
19	St. Ignace, Mich.	5.3	4.3	4.4	3.5	2.9	2.9	26.0	3.4	3.4	2.8	1.9	2.4	11	10	11	16	1.3	1.2	7
69	Cheboygan, Mich.	5.3	4.6	4.2	3.7	2.8	3.3	-----	3.4	3.1	2.7	1.9	2.3	12	10	11	16	1.2	1.3	7
222	Alpena, Mich.	5.1	4.0	4.0	3.8	3.0	3.5	24.5	3.1	3.1	2.9	2.0	2.2	11	10	11	15	1.3	1.3	7
330	do.	5.2	4.1	4.6	3.5	3.0	3.2	22.7	3.2	3.6	2.7	2.0	1.9	12	10	11	15	1.2	1.4	7
431	do.	5.2	4.4	4.0	3.9	3.1	3.2	26.8	3.2	3.0	2.9	1.9	2.4	11	10	11	16	1.2	1.3	8
1070	Wiarton, Ontario.	5.3	4.5	4.1	3.6	3.0	3.1	25.6	3.4	3.1	2.7	2.0	2.0	12	11	11	18	1.2	1.2	7
1104	Kagawong, Ontario.	5.5	4.5	4.3	3.9	3.0	2.1	27.9	3.2	3.1	2.8	2.1	2.2	11	10	12	16	1.2	1.6	8
1096	Gore Bay, Ontario.	5.6	4.9	4.0	3.7	2.8	2.7	23.0	3.5	2.9	2.7	2.0	2.3	11	10	10	16	1.2	1.2	8
2497	Duck Islands, Ontario.	5.1	4.2	3.9	3.8	2.7	3.6	25.0	3.2	3.0	2.9	2.0	2.2	11	10	10	15	1.2	1.3	7
2519	do.	5.1	4.2	4.1	4.1	2.9	3.4	25.5	3.1	3.1	3.1	1.8	2.2	11	11	11	16	1.3	1.3	7

TABLE 100.—*Records of the occurrence of Prosopium quadrilaterale in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water, and the number of preserved specimens examined]

Port from which nets were set	Date	Location	Method of capture	Depth, in fathoms	Preserved specimens examined
Port Arthur, Ontario	July 20, 1922	Black Bay	Pound net	8	5
Porphyry Island, Ontario	Sept. 19, 1923	Off shore	Hand line	1	1
Rossport, Ontario	Oct. 1, 1921	Off the town	2¾-inch gill net	6	14
	Oct. 4, 1921	Les Petits Ecrits	Hand line	1	3
	Aug. 10, 1922	Moffat Strait	Pound net	4	1
	do.	Armour Point	do.	4	1
	do.	Morn Point	do.	4	1
	Sept. 25, 1923	Armour Harbor	4½-inch gill net	2	1
	do.	Moffat Strait	2½-inch gill net	13-14	7
Batchawanna, Ontario	June 17, 1922	Batchawanna Bay	Pound net	8	1
Stannard Rock Reef	Aug. —, 1923	On the reef			1
Apostle Islands, Wis.	July 12, 1922	South Twin Island	2¾-inch gill net	4	31
Grand Marais, Minn.	July 17, 1922	Devils Track River	Seine	1	11
	July 18, 1922	In the harbor	do.	1	6
Borrowed specimens: Lizard Islands, Ontario[1]					5

[1] Field Museum collection.

TABLE 101.—*Numerical expression of certain systematic characters for 10 specimens of Prosopium quadrilaterale from Lake Superior, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
53839	Rossport, Ontario	301	7+10	♀	84	5.1	6.7	8.3	14.1	2.4	7.0	4.1	7.7	1.8	2.2	2.8	4.2
53841	do	377	7+10	♀	87	5.2	6.7	9.3	11.6	2.5	8.1	4.6	7.8	1.6	2.3	3.0	4.1
53842	do	292	7+12	♂	90	5.1	6.4	8.6	12.5	2.5	7.1	4.3	7.3	1.6	2.2	2.8	4.0
53848	do	323	7+10	♂	91	5.0	6.3	7.9	11.0	2.5	6.8	4.8	8.0	1.6	2.2	2.7	3.8
53850	do	286	7+10	♀	74	5.0	6.5	8.1	11.6	2.5	7.7	4.4	7.5	1.6	2.2	2.9	3.8
58020	Apostle Islands, Wis	256	8+10	♀	86	5.0	6.0	9.0	12.8	2.6	7.3	5.6	8.5	1.5	2.2	2.7	3.9
58021	do	277	7+10	♀	90	5.0	6.5	8.7	11.5	2.6	8.1	5.2	7.1	1.5	2.1	2.8	3.9
58023	do	236	8+11	♀	97	4.9	7.1	8.1	11.1	2.5	7.1	4.8	7.1	1.4	2.1	2.8	3.8
58027	do	277	7+10	♂	93	5.0	6.2	7.7	11.6	2.4	6.7	5.0	8.1	1.6	2.1	2.7	3.9
58042	do	245	7+ 9	♂	86	4.9	6.5	9.6	11.5	2.6	6.9	5.4	8.4	1.5	2.1	2.9	3.8

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
53839	Rossport, Ontario	5.5	4.7	4.2	3.6	2.8	3.2	20.7	3.6	3.2	2.7	1.9	2.3	12	9	11	16	1.2	1.5	7
53841	do	5.4	5.1	4.2	3.8	3.1	3.1	25.8	3.9	3.2	2.9	1.8	2.2	12	11	11	16	1.3	1.3	7
53842	do	5.0	4.6	4.0	3.7	2.9	3.5	25.9	3.7	3.2	2.9	2.0	2.3	11	10	11	17	1.2	1.3	7
53848	do	4.8	4.6	4.0	3.7	3.0	2.9	22.8	3.6	3.2	2.9	1.6	2.0	13	10	11	17	1.2	1.3	8
53850	do	5.0	4.3	3.9	3.7	2.9	4.3	25.9	3.3	2.8	2.8	2.0	2.2	12	10	11	14	1.1	1.2	7
58020	Apostle Islands, Wis	4.8	4.2	4.2	3.6	2.8	3.2	23.1	3.5	3.5	3.0	1.8	2.2	12	10	11	16	1.2	1.4	7
58021	do	5.1	4.2	4.0	3.9	2.9	3.4	19.6	3.2	3.1	3.0	1.8	2.2	12	11	11	16	1.3	1.3	7
58023	do	4.9	4.2	4.0	3.7	2.7	2.9	21.8	3.3	3.1	2.8	1.8	2.0	12	10	11	16	1.1	1.2	7
58027	do	4.8	4.2	4.2	3.8	2.8	3.0	27.2	3.4	3.4	3.1	1.9	1.9	12	10	11	15	1.2	1.4	7
58042	do	5.0	4.1	4.8	4.0	2.9	3.0	22.7	3.1	3.6	3.0	1.7	2.0	12	11	11	16	1.4	1.3	7

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