AN ECOLOGICAL RECONNOISSANCE OF THE FISHES OF DOUGLAS LAKE, CHEBOYGAN COUNTY, MICHIGAN, IN MIDSUMMER

By Jacob Reighard

Professor of Zoology, University of Michigan

Blank page retained for pagination

CONTENTS.

Blank page retained for pagination

AN ECOLOGICAL RECONNOISSANCE OF THE FISHES OF DOUGLAS LAKE, CHEBOYGAN COUNTY, MICHIGAN, IN MIDSUMMER.[a]

By JACOB REIGHARD
Professor of Zoology, University of Michigan.

INTRODUCTION.

During the summers of 1909, 1911, and 1912 I was in charge of the biological station of the University of Michigan, situated on Douglas Lake. The little time that remained to me after my routine duties was given to collection of data bearing on the ecology of the fishes of the lake. It was my hope after a considerable number of years to reach general principles by the analysis of data thus collected. It is unlikely that I shall continue the work. It seems, then, worth while to put on record such facts as I have. They are few, and the inferences that may be drawn from them are tentative; yet they may furnish a starting point for some one else or suggest a method. The records of 1912 were made under my direction by an assistant, Mr. M. E. Houck.

Douglas Lake—Turtle Lake on many older maps—(fig. 1), lies at about latitude 46° 30′ N., in the Southern Peninsula of Michigan, at an altitude of 712 feet above sea level. Its northern shore is some 15 miles in a direct line from the Straits of Mackinac. Its greatest length from east to west is 3½ miles, its greatest width 2⅓ miles. The lake has somewhat the form of a fish, the flukes of whose tail form North and South Fishtail Bays at its eastern end. The total area of the lake, exclusive of Fairy Island, is about 5.1 square miles; its shore line, including that of Fairy Island, measures 14 miles. The shores are nearly everywhere a mixed sand of granitic origin. The water deepens gradually over a terrace or shoal until it is 3 to 6 feet deep. The terrace varies in width from a few yards to a hundred or more. The bottom then drops rapidly, in most places into deeper water, forming the "slope" or margin, which is as steep as loose sand can lie. The slope is that part of the bottom on which vegetation ordinarily grows. It extends to the lakeward limit of vegetation, usually at a depth of not more than 25 feet. The depth of water at the lakeward limit of vegetation in Douglas Lake is unknown. The deeper water beyond the slope has a depth of 82 feet over a limited area near the southern end of South Fishtail Bay, and a depth of 89 feet at another point. The deeper water does not reach 80 feet over most of the lake and is not continuous but is interrupted by bars and shoals. Pending the completion of a hydrographic map, details are not available.

A white disk lowered into the water on August 12, 1913, disappeared at a depth of 12.5 feet. This indicates that the lake is not rich in plankton, but no plankton

[a] Contributions from the Zoological Laboratory of the University of Michigan, no. 143.

measurements have been made. The bottom temperature at a depth of 70 feet on July 10, 1912, was 47° F. (8.3° C.). At a depth of 82 feet in South Fishtail Bay a temperature of 6° C. has been recorded in July. There is a well-defined thermocline at a depth of 40 to 45 feet. Its unusual distance from the surface is due to the heavy winds which cause the surface waters to be intermingled. Above the thermocline the temperature rises until in August it reaches 20° C. at the surface.

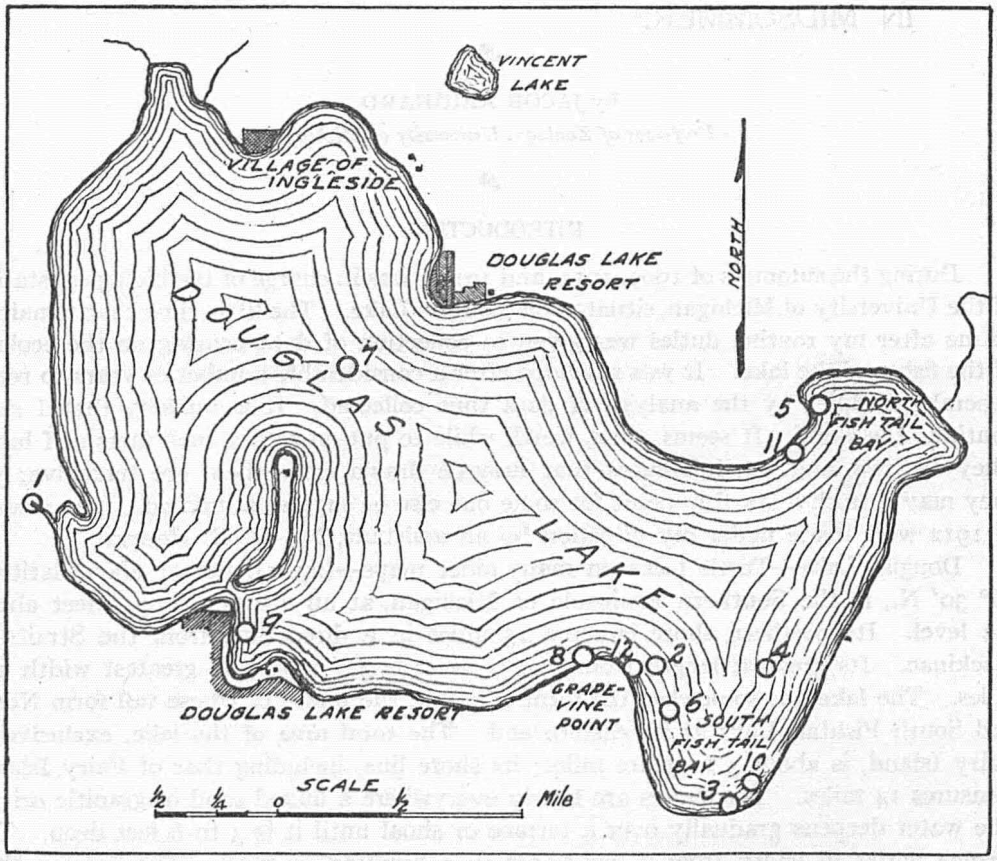

FIG. 1.—Map of Douglas Lake, Cheboygan County, Mich. The numbered circles show where collections were made. 1, Maple River; 2, two hundred yards east of Grapevine Point; 3, at the biological station; 4, sand bar; 5, protected cove on North Fishtail Bay; 6, deep channel east of Grapevine Point; 7, northeast of Fairy Island; 8, stony shoal on Grapevine Point; 9, protected bay at Bryant's landing; 10, east shore of South Fishtail Bay; 11, west side of entrance to North Fishtail Bay; 12, west side of South Fishtail Bay off Grapevine Point.

Above the thermocline in August there is abundance of dissolved oxygen, about 5.5 cc. per liter at the surface and 4.5 cc. at a depth of 33 feet. Below the thermocline the amount of dissolved oxygen is diminished. It varies in August from about 0.6 cc. per liter at a depth of 50 feet to nothing at a depth of 63 feet or more (Tucker, 1913). Below a depth of 45 feet the lake does not afford, in summer, enough oxygen to make it a suitable habitat for fish.

Little is known of the distribution of the vegetation in the lake. It is briefly discussed under fish habitats, but should be made the subject of special study.

Douglas Lake was at one time continuous with the Great Lakes and with Burts, Mullet, and Crooked Lakes to the south of it. The latter lakes continue to be broadly connected with Lake Huron by means of Crooked and Cheboygan Rivers. Douglas Lake, on the other hand, was long since separated from the other lakes. It has no direct connection with the Great Lakes, but is connected with Burts Lake by the Maple River. Thus its separation from the Great Lakes antedates that of Crooked, Mullet, and Burts Lakes and is more complete.

FISH HABITATS OF THE LAKE.

The following four fish habitats of the lake are provisionally recognized. A possible fifth habitat is suggested on page 246.

BARREN SAND-SHOAL HABITAT.

Wherever the terrace is without stones (pebbles may occur in the sand) it may be referred to as a barren sand shoal. The sand is loose and shifting in the more exposed of these shoals and practically always shows ripple marks. In less exposed places the sand particles are loosely united by a deposit of marl, probably of algal origin. This gives a certain firmness to the sand, as though it were mixed with clay and makes it resistant to wave motion. Such protected sand shoals are often free from ripple marks. The shore bordering all sand shoals is low, without an ice rampart of stones, and the first land terrace or bluff is at some distance from it. The shoal may be narrow (only a few yards or more) or wide (a hundred yards or more). The slope on its seaward edge is steep, as steep as loose sand can lie, and the water over the seaward edge is commonly about 4 feet deep. Near shore there may be a sparse growth of bulrushes but there is no other vegetation.

BARREN STONY-SHOAL HABITAT.

Wherever the shore is bordered by a bluff or terrace which is being eroded the shoreward margin of the shoal contains stones or small bowlders. Along such a shore there is commonly formed by the action of the ice a rampart of stones, which borders the shore like a low stone wall. The stony shoal is apt to be wide and the slope beyond it less steep than that of the sand shoal. The water over its outer edge is often 6 or 7 feet deep. Its bottom may be of shifting sand or of sand agglutinated with marl. Its shoreward border may support a growth of bulrushes or may be without them. Regarded as a fish habitat, its salient feature is the stones. Where the shore of the lake shows a series of headlands with intervening valleys, it is being eroded along the headlands and built up between them. The headlands are bordered by stony shoals and the intervening low shore by sand shoals. The two pass into one another without sharp demarcation.

THE VEGETATION HABITAT.

If we neglect the scant growth of bulrushes which may occur on the shoals, the vegetation of the lake is largely limited to the slope. In places the slope is continued into considerable areas of nearly level bottom covered by water less than 25 feet deep and overgrown with vegetation. Such an area, known as the "middle ground," extends

eastward and a little north from the northern end of Fairy Island to the mainland. There are similar areas south and west of Fairy Island. The slope, the middle ground, and similar areas lie in the open lake and are subjected to severe wave action. The water is usually in motion and the conditions are not in this respect unlike those found in a stream. Among the fish is at least one characteristic stream form, *Notropis cornutus*, the common shiner. This habitat may be called the unprotected vegetation habitat.

The vegetation is not emergent and is characterized by absence of water lilies. On the slope the plants are found on the less steep portions and there form a discontinuous fringe or zone. On a still, bright day one may see that the plant growth of the slope consists of little groups of *Potamogeton natans*, millfoil, and perhaps other plants which are 1 or 2 feet apart and in most places do not make dense masses. There are considerable stretches of the slope that are without vegetation. One of these lies opposite the laboratory on South Fishtail Bay. There are a few places in which the vegetation is more dense. On the whole, it occurs in patches or islands and within these it is sparse.

Where the shoals are protected from the wave action vegetation gets a foothold, muck accumulates, and the conditions approach those of a pond with relatively quiet waters. This is the case on the east and west sides of North Fishtail Bay, in the bay directly south of Fairy Island, and at the mouth of Bessie Creek. Water lilies occur in such situations and the large-mouthed black bass is the characteristic but not abundant fish. The common sunfish is more abundant here than elsewhere. This habitat of bays and estuaries may be referred to as the protected vegetation habitat. It contains most of the species of fish to be found in the lake. It merges into the unprotected vegetation habitat. For the present it seems best to treat the vegetation habitat as a unit, although in the future it may be advisable to subdivide it.

THE DEEP-WATER HABITAT.

Beyond the slope near the bottom is the abysmal or deep-water region, where the bottom is of a soft, black ooze and where there are no large water plants. It extends from a depth of 25 feet (probably somewhat less) to 89 feet, the extreme depth of the lake, and comprises the bottom and the layer of water 1 or 2 meters thick above it. Above the thermocline this layer of water is agitated by the wind, is relatively warm and well lighted, and contains in summer an abundance of oxygen. Passing downward along the bottom through the thermocline we encounter within a vertical distance of 7 feet a drop in temperature of some 10° F. As we descend the temperature near the bottom continues to drop from about 54° F. at the thermocline (July 10) to between 43° and 50°, depending on the depth reached. The water below the thermocline is not only cold but relatively quiet, unaffected by wave action, and relatively dark. In midsummer it contains little oxygen at any level and none at all at a depth of 63 feet or more. We have taken no fish below the thermocline in midsummer. They are then to be found only in those parts of the abysmal region that lie above the thermocline between the lakeward border of the vegetation zone and a depth of about 45 feet.

THE FISHES.

Our data concerning the fishes are given below under each species. The locality numbers in the tables refer to the map on page 220. The numbers in the column headed "Water depth" give the distances below the surface at which the fish were taken. They

are usually the depths at which gill and fyke nets were set on the bottom. Lengths of fishes do not include the caudal fin.

LEUCICHTHYS ARTEDI (Le Sueur), *lake herring*, or *cisco*.—This species has not been taken in nets, but adult specimens are frequently cast up on the beach of South Fishtail Bay. Three of them measured 5, 6½, and 7 inches, respectively, the latter a male with slender white testes ⅛ inch broad. A male 6⅞ inches long and with large testes was picked up, still living, over deep water in South Fishtail Bay, September 18, 1911. Our small-meshed gill net has taken suckers of 7 or 8 inches when set on the bottom in water of 26 and of 42 feet depth. It should have taken lake herring if they had been present there. In midsummer the same net has taken no fish when set on the bottom in water deeper than 45 feet, although in September a single sucker was taken at 72 feet. The absence of oxygen in the bottom water below 45 feet in midsummer makes it impossible for fish to live there. The lake herring must therefore live in deep water at some distance above the bottom. Perhaps its habitat will be found in the neighborhood of the thermocline. This species is characteristic of the Great Lakes, where its average length is 12 inches. Our largest specimens are only 7 inches long.

CATOSTOMUS COMMERSONII (Lacépède), *common sucker*.—The records in table 1 show the suckers taken in 1912.

TABLE I.—RECORDS OF CATOSTOMUS COMMERSONII TAKEN IN DOUGLAS LAKE IN 1912.

No.	Weight.	Length.	Sex.	Water depth.	Apparatus.	Stomach contents.	Locality in Fig. 1.	Date.
	Ounces.	*Inches.*		*Feet.*				
1	12	11.2	Male	4.5	Fyke	Empty	2	July 29
2	14	11.6	?	4.5	Gill	Not examined	2	July 31
3	10	10.8	?	4.5	Fyke	do	2	Aug. 3
4	9	11	Female	4.5	do	Empty	4	Aug. 5
5	5	8	do	5.5	do	do	4	Aug. 6
6	4.5	7.6	do	5.5	do	do	4	Aug. 7
7	4.5	8	Male	5.5	do	do	4	Aug. 10
8	6	8.8	do	5.5	do	do	4	Do.
9	14.5	12.4	do	5.5	do	do	4	Do.
10	10	11.8	do	5.5	do	do	4	Aug. 15
11	6	8.8	Female	26	Gill	do	6	Aug. 16
12	4	8	Male	26	do	do	6	Do.
13	3	7.2	Female	43	do	do	6	Aug. 19
14	5	8.4	do	6	do	do	3	Aug. 2

Common suckers have been seined in Maple River and have been seen at the mouth of Bessie Creek. There can be no doubt, then, that they occur over the whole lake and are amongst its commoner fishes. They are found in all the habitats. On September 23, 1911, one was taken in a gill net drawn from a depth of 72 feet. In July and August suckers have not been taken below the depth of 43 feet. They are sometimes seen feeding on the sand shoals in water a foot or two deep. They may therefore occur at any depth in the lake, but are not known below the thermocline in midsummer.

Food.—The young of this species are seen on the sand shoals in July and August in company with the young of the yellow perch and the spot-tailed minnow. In a school of 475 of these young fish taken on September 1, 1911, five were suckers between 1¾ and 2 inches long. The alimentary canal, from œsophagus to anus, of an individual 2 inches long was found to measure 3 inches. Its contents formed a brown mass inclosed in a mucus pellicle. The whole of it could be easily stripped from the canal. The contents

when forced out of the pellicle, proved to be wholly shells of a species of cladoceran, apparently *Chydorus*. A three-sixteenth-inch piece was cut from the middle of the alimentary canal where it is of average size, and the Crustacea in an estimated fifth of this counted. From this the entire number in the alimentary canal was estimated at about 2,400. Only 2 or 3 copepods were found in the sample, or 48 for the whole alimentary canal; the rest were Cladocera and all of one species. There was no sand, so that it may be safely said that the young sucker is not a bottom feeder, but lives wholly on the plankton.

The stomachs of 12 of the suckers included in the table were examined and found to be empty. In August, 1912, Prof. Frank Smith saw the adults feeding on the materials encrusting the vegetation at the mouth of Bessie Creek. They were sucking off whatever adhered to the floating stems and leaves of the plants. They went from plant to plant and mouthed over each branch from base to tip until the whole plant had been gone over.

The adult suckers may sometimes be seen at dusk or daybreak feeding on the bottom over the sand shoals. When approached they ordinarily make off at once for deep water. On July 3, 1912, I found several feeding on the sand shoals at midday, and each was surrounded by a group of a dozen or more log perch. The log perch were at that time laying their eggs in the sand and the suckers were feeding on the eggs. Each sucker was surrounded by a group of log perch which were trying to get such scraps as might be left from its feeding. It would be interesting to know whether this commensal relation between sucker and log perch obtains at other seasons and in deeper water.

While the suckers are thus engaged it is not difficult to approach them until they are at one's feet and to watch closely their method of feeding. The sucker moves slowly over the bottom. At intervals it stops, raises its tail until, if in very shallow water, the caudal fin breaks the surface. It buries its snout in the sand, often to the nostril, but sometimes only half so far. The fish then withdraws its snout from the sand and without moving from the place, works its jaws for several seconds as though chewing. At the same time a thin stream of sand is seen to come from its mouth. At intervals there is a sudden spurt of water and sand from its mouth so violent that it disturbs the bottom. When the fish has ejected all the sand it moves a short distance with its pectorals in close contact with the bottom and repeats its feeding movements. Wherever it has thrust its snout into the bottom there is left a deep pit which is usually a sharp mold of its snout and the lower part of its head. The pits are connected by broad sinuous trails made by the pectoral fins of the fish. These suggest the tracks of a huge snail and show oblique parallel lines where the edges of the pectorals have pressed against the sand at each stroke. These pits and trails are very characteristic impressions, and are abundant in shallow water throughout the summer. They are more numerous in protected places where the bottom is made somewhat coherent by the formation of marl, and where it possibly contains a larger percentage of nutritive matter. These "tracks" of the sucker enable one to tell each morning where they have been feeding during the night and in what abundance.

Great numbers of dead suckers are thrown up on the beach in South Fishtail Bay in July and August. Many of these have the characteristic form of starved fish. The

back is thin and sharp instead of round, and the head is disproportionately large compared to the body. This is because the head is made up largely of bone, and emaciation can not so greatly reduce its bulk as it does that of the more fleshy body and tail. The emaciated fish do not appear to be diseased and are not usually parasitized heavily enough to account for their emaciation. Death seems to be due to starvation.

Hankinson (1908) collected 41 suckers in Walnut Lake and gives their average weight as 2.5 pounds. Their average length, including the caudal fin, is, from Hankinson's tables, 16.2 inches. From Forbes's and Richardson's (1908) figure of the common sucker, the length from tip of the snout to the base of the caudal is found to be 0.88 of the total length from tip of snout to tip of caudal fin. Applying this correction to Hankinson's average length, we get an average length of his suckers of 14.3 inches, measured in the usual way from tip of snout to base of caudal. In contrast to this the 14 fish taken in Douglas Lake have an average length of 9.5 inches and an average weight of 0.48 pound.

From the fact that all stomachs of the common sucker were found empty, from their habit of feeding on the comparatively innutritious materials of the lake bottom and on those covering the stems and leaves of plants, from the large number of deaths among them in midsummer, and from their relatively small average size, it may be inferred that the fish get insufficient food.

In Walnut Lake Hankinson (1908) found, as the result of the examination of the alimentary canals of 13 common suckers, caddis-worms and cases, small bivalve mollusks, amphipods, insects, marl, midge larvæ, and *Daphnia*. Of these, the caddis-worms, amphipods, and midge larvæ are commonly associated with vegetation. It is not unlikely that the relatively slight development of vegetation in Douglas Lake makes it an unfavorable habitat for suckers.

The breeding grounds of the Douglas Lake suckers are unknown. According to the writer's unpublished observations, suckers breed in streams where there is swift water and gravel bottom. These conditions are found in Maple River and in Bessie Creek. Young suckers less than 2 inches long are found in June on the shoals of South Fishtail Bay, about 6 miles by the shore from either of these streams. They are doubtless fish of the season and, if the breeding habits of the suckers of Douglas Lake are the same as elsewhere, the young must have wandered to the shoals from the breeding grounds in Maple River and Bessie Creek. It is possible, however, that the essential requirement for breeding is suitable bottom, not running water. Bottom suitable for suckers is plentiful in Douglas Lake on the shoals, and the young suckers found there may be still on the breeding grounds.

In figure 2 the lengths and weights of the suckers included in table 1 have been plotted and a curve sketched to show their relation. It is clear that there is a definite relation of such a sort that, after a weight of 4 or 5 ounces has been reached, length increases less rapidly than weight. Thus between the weights of 4 and 5 ounces the increase in length is about 0.75 inch, while between 14 and 15 ounces it appears to be scarcely 0.1 inch. At the 15-inch length the line is nearly horizontal. Our data are not enough to make it advisable to draw the length-weight curve mathematically or to determine its formula. (See Hecht, 1913.)

PIMEPHALES NOTATUS (Rafinesque), *blunt-nosed minnow*.—Ten specimens, 2½ to 2⅞ inches long and evidently adult, were taken in the seine at Bryant's dock (location 9

on the map) on September 20, 1911. One hundred and ninety-three individuals about 1¾ inches long were taken on stony shoals on the west side of the entrance to North Fishtail Bay on September 18 of the same year. With them were three *Notropis cayuga* and four *N. hudsonius*. A few were taken in August in company with large numbers of *N. hudsonius* on the sand shoals of South Fishtail Bay. In life they are distinguishable from *N. hudsonius* by the following field characters: (*a*) Darker color; (*b*) a peculiar jerky movement in progression. The fish do not move directly ahead, but by a flick of the tail and of the pectorals the head is jerked to one side and then to the other or several times to one side and several times to the other, so that the course is zigzag; (*c*) the body is semitranslucent, so that the vertebral column and the viscera may be seen faintly from the back; (*d*) the scales in front of the dorsal on the back are crowded so as to appear much smaller than the scales behind them.

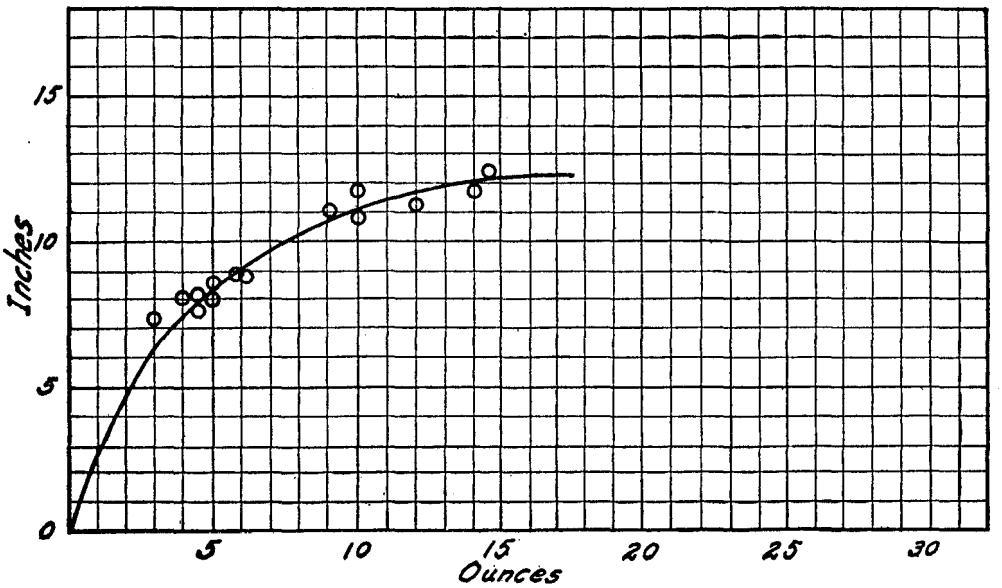

FIG. 2.—Graph showing the relation of length and weight for the 14 common suckers, *Catostomus commersonii*, included in table 1. Each space on the horizontal line represents 1 ounce; each space on the vertical line 1 inch. Curve drawn free-hand.

We have collected this species in numbers only on or very near stony shoals and in the neighborhood of protected bays. Stony shoals afford it breeding grounds, for it lays its eggs beneath flat stones and similar objects on the bottom, and the mucky bottom of protected bays affords it food, for it is a "mud eater." It has been taken but rarely and in small numbers on the sand shoals along the south and west shores of South Fishtail Bay, although frequent collections have been made there. These wave-swept shoals afford neither stones nor muck.

SEMOTILUS ATROMACULATUS (Mitchill), *horned dace*, or *creek chub*, has been taken only in the vicinity of Bryant's dock (locality 9). Here the adult was found in considerable numbers in company with *Pimephales notatus* and *N. hudsonius*. It is abundant in Maple River near the lake. Bryant's is a resort of fishermen. It is possible that the horned dace has been introduced here as a bait fish and has not extended its range to other

parts of the lake, but it is more likely that it has made its way thither from Maple River.

NOTROPIS CAYUGA Meek, *Cayuga minnow.*—Three specimens only have been taken in the lake at locality 11, on stony shoals at the west side of North Fishtail Bay at the entrance. The slopes bordering these shoals are sparsely grown with plants, and they are so much protected from wave action that there is a thin crust of algal marl uniting the superficial sand particles.

NOTROPIS HUDSONIUS (De Witt Clinton), *spot-tailed minnow,* and the common shiner are the most abundant of the Douglas Lake minnows and the most widely distributed. On July 29, 107 specimens of the spot-tailed minnow were taken with the seine on the sand shoals of South Fishtail Bay in about 2 feet of water. They were of nearly uniform length and averaged 2.8 inches; 64 were females and 24 males. These were immature fish and were in schools together with young of the yellow perch and common sucker. Two hundred and sixty-seven immature individuals were seined in the same place on September 1, 1911. On the 20th of July, 1912, 9 mature individuals $3\frac{1}{8}$ to $3\frac{7}{16}$ inches long were seined at Bryant's dock (locality 9), together with mature *Pimephales notatus* and *S. atromaculatus.* Mature individuals 4 to 6 inches long are found in many places in the lake where there is abundant vegetation on the slope. Here the fishermen seek them for bait and take them with the baited minnow hook by casting, as one casts for trout with the fly. They are taken in company with the common shiner and in about equal abundance. The fishermen locate these schools by the disturbance of the water's surface due to their rising, and often visit several patches of vegetation before they find them. Hence it appears that the fish may travel together in schools from one patch of vegetation to another.

The alimentary canal of one of the immature individuals taken on the sand shoal was found to be filled with Cladocera, apparently of the genus *Chydorus,* the form that makes up the bulk of the food of the young perch and suckers taken in the same habitat. The Cladocera were apparently as numerous as in the young perch, but there were no other Crustacea such as occur in the perch. The short, slender, close-set gill rakers with the narrow gill openings make an excellent apparatus for the capture of these small Crustacea. The roof and sides of the mouth and the tongue have many short papillæ set in curved longitudinal rows, and these may serve to hold the Crustacea while permitting water to pass backward. There are no records of the stomach contents of the adults of this species in Douglas Lake. Elsewhere (Forbes and Richardson, 1908) it is known to feed on insects, crustaceans, and vegetation.

NOTROPIS CORNUTUS (Mitchill), *common shiner,* is taken on the hook in the same manner as *N. hudsonius* and in company with it in patches of vegetation in nearly all parts of the lake. It is very abundant. Three taken in South Fishtail Bay in August, 1911, measured, respectively, 3.5, 3.75, and 4.06 inches in length. These were in fine condition, the mesentery heavily laden with fat. The contents of the alimentary canal were as follows for the three specimens:

1. About two-thirds Cladocera, apparently *Chydorus;* one-third insects, apparently larval.

2. Remains of insects and a small quantity of Cladocera.

3. Some fragments of broad, green leaves on which were bryozoan tubes; some *Gloitrichia;* a large number of detached bryozoan branches, some of them with stato-

blasts; an insect larva; a green gelatinous mass including Cladoceran shells and probably composed of partly digested algæ.

Forbes and Richardson (1908) say of the common shiner: "It is especially a minnow of creeks and the smaller rivers—our coefficients for which are 3 and 2.45, respectively—scarcely ever occurring in either lakes or the smaller streams. It shows also a marked preference for clear waters." Hankinson found this species in Walnut Lake, chiefly on shoals with "abundant luxuriant aquatic vegetation and black bottom soil." It was common on but one shoal. Its abundance and wide distribution in Douglas Lake are unusual. It occurs not only in the lake but is the commonest fish taken in the seine in Maple River. According to the writer's unpublished observations, the species breeds only in running water on gravel bottom. Maple River and Bessie Creek afford the conditions of its known breeding grounds. Moreover, the young fish have not been recognized with certainty in the lake, which adds to the probability that it does not breed there. It is more likely that the adults travel from the lake to the breeding grounds in Maple River and Bessie Creek and that when partly grown the young go from the breeding grounds as far as the eastern end of the lake, a distance along shore of about 6 miles. The breeding grounds of this most important bait fish of the lake should be located and preserved.

AMEIURUS NEBULOSUS (Le Sueur), *common bullhead*, does not appear to be abundant. In 1911 four were taken on the hook in the vegetation on the east shore of South Fishtail Bay. Three of them measured 9½ inches in length and the fourth 10¾ inches. The records for 1912 are given below:

TABLE II.—RECORDS OF AMEIURUS NEBULOSUS TAKEN IN DOUGLAS LAKE IN 1912.

No.	Weight.	Length.	Sex.	Water depth.	Apparatus.	Stomach contents.	Locality in fig. 1.	Date.
	Ounces.	*Inches.*		*Feet.*				
1	13	10.4	Female	5.5	Fyke	Bumblebee	4	Aug. 6
2	10	11	do	5.5	do	Small fish	4	Aug. 10
3	3	6	Male	12	Gill	Empty	7	Aug. 20

None were taken in gill nets set at greater depth than 12 feet, so that they are probably confined to the vegetation of the slope and to similar situations elsewhere. The largest specimen taken is 6 inches shorter than Hankinson's (1908) largest (Hankinson's measurements include the caudal fin), and 7 inches shorter than the Illinois maximum as recorded by Forbes and Richardson (1908). Examination of the contents of two stomachs shows nothing unusual except the inclusion of a bumblebee.

Young individuals of this species were taken in July at various points along the shore of North Fishtail Bay and in an adjacent beach pool. In 1909 swarms of young were seen in the same place together with the male. In August they had reached a length of an inch and a quarter.

UMBRA LIMI (Kirtland), *mud minnow*, has not been taken in the lake itself, but is abundant in the oxbow ponds that have been cut off from Maple River near the lake. It should occur in the mucky bays and estuaries of the lake itself.

ESOX LUCIUS (Linnæus), *common pike*, or *pickerel*, is the largest and one of the most abundant fish in the lake. The following table gives data concerning 22 individuals of this species.

TABLE III.—RECORDS OF ESOX LUCIUS TAKEN IN DOUGLAS LAKE.

No.	Weight.	Length.	Sex.	Water depth.	Apparatus.	Stomach contents.	Locality in fig. 1.	Date.
	Ounces.	*Inches.*		*Feet.*				
1	104	30.6	.....	15	Gill.....	2 4-inch perch.....	12	July 3, 1911
2	28	15	.....	25–30	.....do.....	2 perch, 4½ and 3¾ inches long.	3	July 11, 1911
3	12	13.2	Male.....	4	.....do.....	Fish, not determined.....	3	Aug. 3, 1912
4	15	15.4	Female.....	12	.....do.....	Empty.....	3	Aug. 8, 1912
5	15	14.8	Male.....	12	.....do.....	Fish remains.....	5	Aug. 11, 1912
6	16	15.2	.....do.....	12	.....do.....	Fish.....	5	Aug. 12, 1912
7	21	16.4	.....do.....	12	.....do.....	Empty.....	5	Aug. 13, 1912
8	30	18	Female.....	26	.....do.....	.....do.....	4	Aug. 15, 1912
9	29.5	16.8	Male.....	26	.....do.....	.....do.....	6	Do.
10	26	17	.....do.....	26	.....do.....	.....do.....	6	Do.
11	10	12.8	Female.....	26	.....do.....	.....do.....	6	Do.
12	10	12.8	.....do.....	26	.....do.....	.....do.....	6	Do.
13	18	15.6	.....do.....	26	.....do.....	.....do.....	6	Aug. 16, 1912
14	24	17.6	.....do.....	26	.....do.....	.....do.....	6	Do.
15	24	17.6	.....do.....	13	.....do.....	2 fish.....	7	Aug. 20, 1912
16	29.5	17.2	.....do.....	13	.....do.....	.....do.....	7	Do.
17	10	13.6	.....do.....	25	.....do.....	Empty.....	7	Do.
18	10.5	13.6	Male.....	25	.....do.....	.....do.....	7	Do.
19	25	17.8	Female.....	25	.....do.....	.....do.....	7	Do.
20	27	18.?	Male.....	12	.....do.....	.....do.....	5	Aug. 14, 1912
21	12	13.2	.....do.....	12	.....do.....	.....do.....	5	
22	59	19.6	.....do.....	45	.....do.....	.....do.....	6	Aug. 18, 1912

This fish has been taken in all parts of the lake and at all depths between 4 and 45 feet. It appears not to go below the thermocline in midsummer, but at other seasons it is possible that, like the sucker, it goes into deeper water.

Seven of the 22 stomachs examined contained the remains of fish, while the rest were empty. There is no evidence that in midsummer the Douglas Lake pike takes other food than fish. It is clear that the spiny fin rays of such fish as perch do not keep them from the maw of the pike, for in two cases the stomach contents were perch about 4 inches long.

The pike tabulated range in weight from 10 to 104 ounces. We have taken individuals whose weight we estimated at 10 to 12 pounds and those of 18 pounds have been reported by fishermen. Of the 20 whose sex was determined, half were males. The average weight of males is 22.8 ounces, of females 19.6 ounces, but the number of fish used is too small to make the figures significant and includes a single male of 59 ounces.

A curve showing the relation of length to weight in these 22 fish is sketched in figure 3. The data are insufficient to show more than the general fact indicated for the sucker that there is a definite relation between length and weight of such a sort that, above 8 ounces, the length increases much less rapidly than the weight. The data represented by the curve, although meager, would be of considerable value if there were similar data from other lakes for comparison. It is probable that each species in a lake shows a length-weight curve peculiar to it. It is also probable that curves for the same species from different lakes might be characteristically different. The form of the curve for a single species from one locality might show to what extent the conditions of that locality are favorable to the species. Unfortunately the literature appears to contain no records full enough for comparison with those of Douglas Lake. Forbes and Richardson (1908) mention for the pike an average length of 36 inches and an average weight of 5 pounds. A curve for the Illinois pike, if it were to pass through the point thus

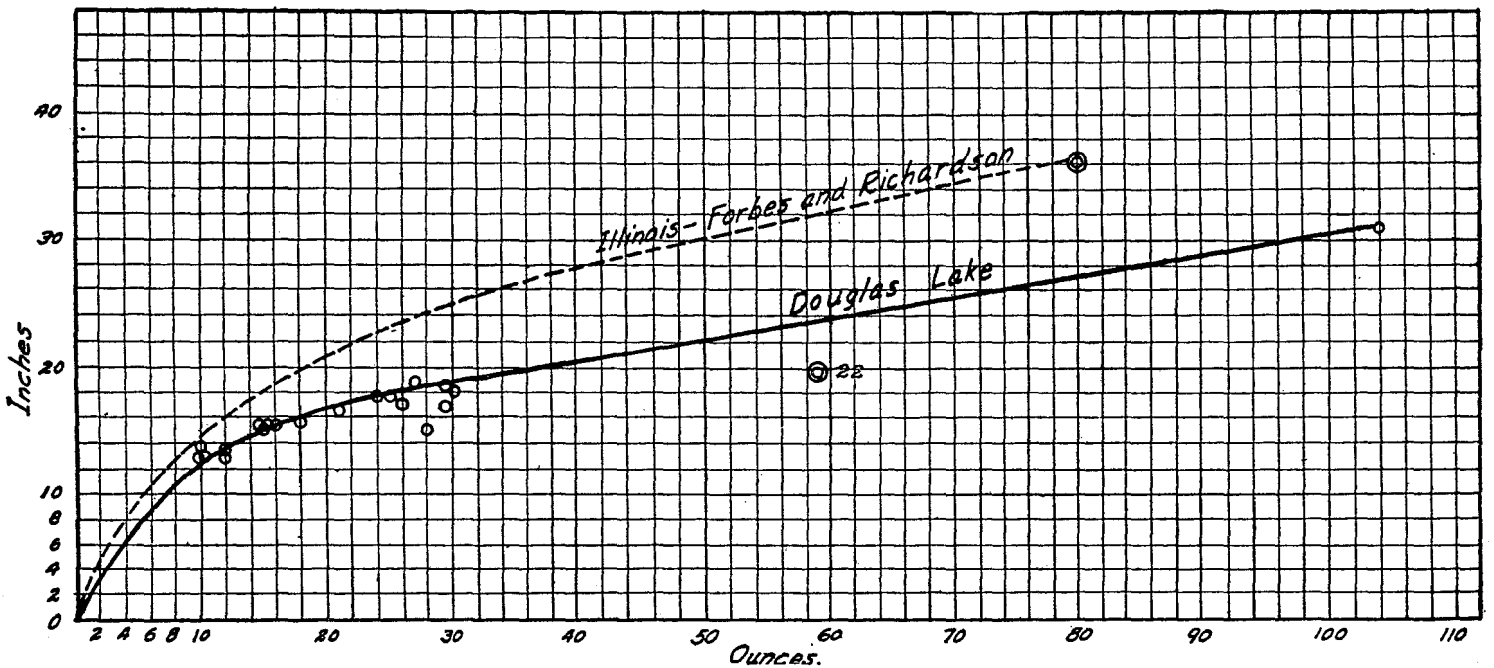

FIG. 3.—Graph showing the relation of length and weight for the 22 pike, *Esox lucius*, included in table III. Each space on the horizontal line represents 2 ounces; each space on the vertical line 2 inches. The individual numbered 22 had a spinal curvature, so that its length was less than the normal for a fish of its weight; the curve is therefore not drawn through it. Curve drawn free-hand. The broken line is a hypothetical curve for the pike of Illinois.

located for a single average fish, would be higher and of different form from that for the pike of Douglas Lake. Such a hypothetical curve is sketched in broken lines in figure 3 to show how curves for single species might be characteristic of localities. A comparison of our curve for the pike with that for the sucker shown in figure 2 shows that they differ. The sucker increases less rapidly in weight with increasing length than does the pike. A sucker of 12 inches weighs about 14 ounces; a pike of 12 inches, if our curve is correct, about 10 ounces. This is for Douglas Lake. With data enough for many species from many localities, one might be able to say, from a study of such curves, for what species of fish the conditions of each locality were most favorable. By defining or describing these conditions one might then possibly use them as a guide in the practical operations of fish culture.

It is interesting to note that pike 22 of our list had a large hump on the back due to curvature of the spine. If this was the result of an injury it had been inflicted so long before that no external scars remained. The deformity may even have been congenital. In spite of it the fish had thriven. The conditions of existence were not severe enough to eliminate it. Its position is shown at 22 on figure 3.

PERCOPSIS GUTTATUS Aggassiz, *trout perch*, is known only from the numerous specimens thrown up on the beach of South Fishtail Bay. It has not been taken in nets. In one specimen 2½ inches long the intestine contained the chitinous parts of an insect larva. This indicates that its habitat is the vegetation zone.

July 17, 1912, following a storm, many adults were picked up on the beach. Among these were females that gave up eggs freely on slight pressure. On the following day a search was made of the shoals in the hope of locating the breeding fish, but without result.

AMBLOPLITES RUPESTRIS (Rafinesque), *rock bass*.—The data collected concerning this fish are brought together in table IV.

TABLE IV.—RECORDS OF AMBLOPLITES RUPESTRIS TAKEN IN DOUGLAS LAKE IN 1912.

No.	Weight.	Length.	Sex.	Water depth.	Apparatus.	Stomach contents.	Locality in Fig. 1.	Date.
	Ounces.	*Inches.*		*Feet.*				
1	8	7.6	Female	5½	Fyke	1 small fish	4	Aug. 6
2	7	7.6	do	5½	do	do	4	Aug. 9
3	3¼	5.7	do	5½	do	do	4	Do.
4	9	8	Male	5½	do	Crayfish, fish	4	Aug. 12
5	6½	7.2	do	5½	do	Not determined	4	Do.
6	1	4	Female	4½	do	Empty	2	July 26
7	2	5.2	do	4½	do	do	2	Aug. 21
8	1	4		4½	do	Not examined		Aug. 1
9	1¾	4.2		4½	do	do		Aug. 3
10	1	3.7		4½	do	do		Do.
11	2	4.8	Male	5½	do	Empty	4	Aug. 15
12	12	8.8	do	5½	do	do	4	Do.
13	13	9.6		5½	do	do	4	Do.
14	9	8		5½	do	do	4	Do.
15	2	4.8	Female	5½	Gill	Cambarus virilis; dragon fly larva.		Aug. 16
16	2	4.8	do	5½	do			Do.
17	2	5	Male	5½	do			Do.

Although the records show it from but two localities, it is taken wherever there is vegetation in the lake. We have taken it at no greater depth than 5½ feet, a depth which is usually reached a little beyond the edge of the terrace. It may go deeper. I believe it is sometimes taken at greater depth on the hook, but not beyond the vegetation.

The table shows six specimens with food in the alimentary canal, and we have records of four others. Five of the 10 fish whose stomach contents were studied contained fish, in one case a sunfish, in the other cases the contents were not determinable. Three contained the remains of insects, in one case a dragon fly larva. Two contained each a crayfish; in one this was determined as *Cambarus virilis*, a species which is common in the deeper water of the lake and which occurs also under logs and the like in shallow water. In respect to food, the rock bass of Douglas Lake agree with those of Walnut Lake and of Illinois waters.

Systematic descriptions give the length for the species as 8 to 10 inches, which agrees very well with the 9 to 13 inches of our adult specimens. The weight-length

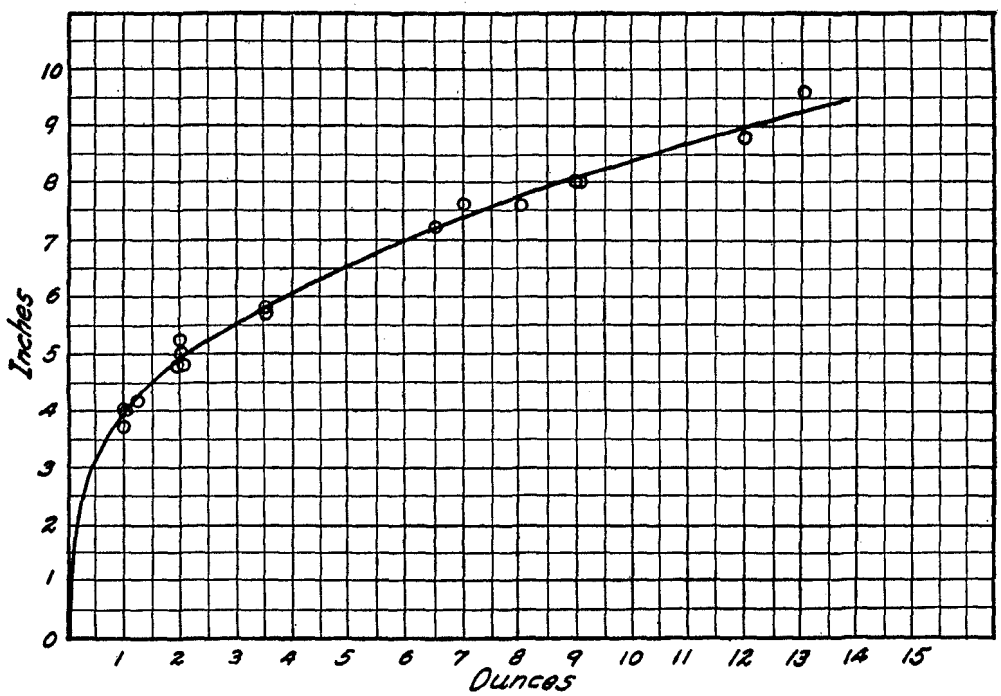

FIG. 4.—Graph showing the relation of length and weight in the 17 specimens of rock bass, *Ambloplites rupestris*, included in table IV. Each space on the horizontal line represents one-half ounce; each space on the vertical line one-half inch. Curve drawn free-hand.

curve is given in figure 4, but there are no similar data from other localities for comparison. There is nothing in our data to indicate that Douglas Lake is an unfavorable habitat for this species.

A rock bass 8½ inches long noted near the laboratory dock paid no attention to a baited hook until touched by it, but was then hooked. It proved to be blind, emaciated, with characteristically large head and without mesenterial fat. It was not too large for a good sized pike to swallow, and it is remarkable that it should have escaped death so long. The struggle for existence among the inhabitants of the lake had not been severe enough to eliminate either the blind rock bass or the crippled pike already referred to. Both were finally eliminated by man.

LEPOMIS PALLIDUS (Mitchill), *bluegill*.—Records for 8 specimens are given in table V.

TABLE V.—RECORDS OF LEPOMIS PALLIDUS TAKEN IN DOUGLAS LAKE.

No.	Weight.	Length.	Sex.	Water depth.	Apparatus.	Stomach contents.	Locality in Fig. 1.	Date.
	Ounces.	*Inches.*		*Feet.*				
1	11	8	Male	4·5	Fyke	Empty	2	July 26, 1912
2	6	6.8	do	4·5	do	do	2	Do.
3	1	3.6		4·5	do	do	4	Aug. 5, 1912
4	1·5	4·4		5·5	do	do	4	Aug. 6, 1912
5		5·9		3	Seine	Plant materials	5	Aug. 5, 1911
6		7·3		3	do	do	5	Sept. 5, 1911
7		4·5		3	do	Plants, mostly	5	Do.
8		3·8		3	do	Plants, insects	5	Do.

This species was taken only in shallow water and in vegetation. Although our records are from but three localities, the fish is taken on the hook wherever there is vegetation.

In size our specimens accord with the 5 to 8 inches of the systematic descriptions. The food of the 4 specimens examined is unusual and is therefore given in detail.

No. 5 had in its stomach 6 terminal buds and leaf whorls of *Elodea*, 2 terminal buds and leaf whorls of a *Chara*, numerous detached leaves of *Elodea*, and some brown, half-decayed fragments of vegetation, most of them long, like leaves of one of the Potamogetons. The intestine was crammed with partly digested plant fragments, on some of which were bryozoan statoblasts, and with numerous heads, wings, and legs of insects, apparently dipters, all imagoes. No. 6 contained in the stomach a mass of vegetation but no animal food. The vegetation was apparently water milfoil. The intestine held the same material in addition to one or two small insects. No. 7 had the stomach filled with unrecognizable plant fragments, on which were statoblasts. The intestine contained plant débris, together with two hydrachnids and two or three ostracods. In no. 8 the stomach was empty, but the intestine was filled with plant débris with numerous fragments of insects. Some of these appeared to be dipterous imagoes.

The fact that the plant fragments form so large a part of the food and that they consist in so many cases of succulent terminal buds and leaf whorls indicates that plant tissues form a normal part of the food and are not merely taken adventitiously with other food. Hankinson (1908) found only animal food in the stomachs of specimens examined by him, while Forbes and Richardson (1908) record the occurrence of 24 per cent of plant food in some of their specimens, a percentage much less than in our specimens.

EUPOMOTIS GIBBOSUS (Linnæus), *pumpkinseed*, is one of the commoner fishes in the vegetation of the lake. Our data concerning it are given in table VI.

TABLE VI.—RECORDS OF EUPOMOTIS GIBBOSUS TAKEN IN DOUGLAS LAKE.

No.	Weight.	Length.	Sex.	Water depth.	Apparatus.	Stomach contents.	Locality in Fig. 1.	Date.
	Ounces.	*Inches.*		*Feet.*				
1	4	6.6	Male	4·5	Fyke	Small shells	2	July 26, 1912
2	4	6.1	do	4·5	do	do	2	July 29, 1912
3	4	6.2		4·5	do	Not examined	4	Aug. 5, 1912
4	3	5·4	Female	5·5	do	Empty	6	Aug. 12, 1912
5	1½	7.8	Male	26	Gill	Minute shells, insects	6	Aug. 16, 1912
6								
7		6·5				Insect larvæ	5	Sept. 5, 1911
8		5·75				Chara, snails	5	Do.
9		5·5				Empty	5	Do.
10		5·25				do	5	Do.
11		5·6				Snails, insect larvæ	5	Do.
12		3·75				Crushed snails	5	Do.
13		3·5				Insect larva, ostracod shells, sand.		Do.

Like the bluegill, the pumpkinseed is found only in shallow water and among vegetation, but may occur wherever these are found in the lake.

The contents of the alimentary canal were examined in 9 individuals. In 6 small snails and their crushed shells were found. In 4 of the 6 the alimentary canal contained no other material than the snails; while in the fifth it contained in addition to the fragments of 3 small snails a quantity of *Chara* with orange fruits. The *Chara* may have been adventitious. One stomach contained insect larvæ exclusively; one contained insect larvæ in addition to snails; and a third insect larvæ, snails, and other material. Snails appear to be the most important element of the food and next to these insect larvæ, but exact percentages are not available. The snails found in no. 8, 11, and 12 were determined by Mr. H. B. Baker to belong to the species *Amnicola limosa* and *Planorbis bicarinata portagensis*. The former were adults from one-sixth to one-eighth inch long, while the latter were young individuals. Forbes and Richardson (1908) found that snails made up nearly half the food of 9 specimens examined by them, insects a fifth, and Crustacea a fifth. Hankinson (1908) examined 32 stomachs and found May-fly larvæ to be the favorite food, although Crustacea, snails, leeches, and other insects were included. The evidence on the whole indicates that snails are the most important element in the food. Fishes appear not to be taken.

Hankinson gives the length of 16 specimens and their average is 5.8 inches, including the caudal fin. The length without caudal fin as determined from figures forms 84 per cent of the total length, which makes the average of Hankinson's specimens 5.1 inches without caudal fin. Our Douglas Lake specimens average 5.2 inches. Judged by this standard, the conditions are about as favorable in the one lake as in the other.

The pumpkinseed appears to be more resistant to foul water than the bluegill. When numbers of each were placed together in a pail of water, all the bluegills were found dead after a time, while the pumpkinseeds were still active.

MICROPTERUS DOLOMIEU Lacépède, *small-mouthed black bass*.—The Douglas Lake data on this fish are given in table VII.

TABLE VII.—RECORDS OF MICROPTERUS DOLOMIEU TAKEN IN DOUGLAS LAKE.

No.	Weight.	Length.	Sex.	Water depth.	Apparatus.	Stomach contents.	Locality in Fig. 1.	Date.
	Ounces.	*Inches.*		*Feet.*				
1	5.5	.....	Female.....	4.5	Fyke.....	.....	2	July 26, 1912
2	1.5	5.1	Male.....	4.5	.....do.....	Empty.....	2	July 29, 1912
3	1.5	5.2	.....	4.5	.....do.....	.....do.....	2	July 21, 1912
4	6	8	Male.....	4.5	.....do.....	.....do.....	2	July 31, 1912
5	40.5	14	.....do.....	45	Gill.....	.....do.....	6	Aug. 15, 1912
6	56	15.6	.....do.....	45	.....do.....	2 fish, 1 crayfish.....	6	Aug. 19, 1912
7	34	12.8	.....do.....	35	.....do.....	Empty.....	7	Aug. 20, 1912
8	.....	12–14	.....	10–15?	Angle.....	.....do.....	10	Aug. 8, 1911
9	.....	12–14	.....	10–15?	.....do.....	Leopard frog.....	10	Do.
10	.....	12–14	.....	10–15?	.....do.....	Small crayfish.....	10	Do.
11	.....	12–14	.....	10–15?	.....do.....	Small crayfish, shiner, and frog.	10	Aug. 15, 1911
12	44	14.6	.....	10–15?	.....do.....	3¼ inch crayfish.....	10	Aug. 21, 1911
13	.....	.....	.....	.....	.....do.....	Good-sized crayfish.....	10	Aug. 25, 1911

The small-mouthed black bass is found over a large part of the lake, but anglers seek it along the lakeward margin of the patches of aquatic vegetation, where it is most abundant. Our data show that in midsummer it ranges to a depth of 45 feet, that is, to

the thermocline. In this it agrees with the pike, the perch, and the sucker. It may go deeper at other seasons of the year, as the sucker appears to do.

Six of the specimens in our table contained food, and we have records of two others. Of these eight, six had eaten crayfish with or without other food; four had eaten only crayfish; one had eaten crayfish in addition to a fish; one, crayfish in addition to fish and a leopard frog. The seventh had eaten a leopard frog only. The eighth contained numerous specimens of the large cladoceran, *Leptodora hyalina*. These last could not be examined with the lens, but the naked eye left practically no doubt as to their identity. With the exception of no. 6, the fish whose stomachs contained either frogs or fish (no. 9 and 11) had been taken on hooks baited with these but not with crayfish. If we exclude the frogs and fish in no. 9 and 11, there remain seven small-mouthed bass, six of which had eaten crayfish, accompanied in one case by fish, while one had eaten only *Leptodora*. The crayfish were not identified, but that found in the bass taken at 45 feet was probably *Cambarus virilis*, which has been several times brought up in the gill net from that depth, and is the only species known to occur there. There can be no doubt that in midsummer the crayfish is the chief constituent of the food of the small-mouthed bass in Douglas Lake. Forbes and Richardson (1908) call attention to the fact that little is known of the food of this species. They examined the stomachs of three individuals and found their contents to consist "wholly of fishes and crayfishes, approximately a third of the first and two-thirds of the second."

The size and the weight of the individuals taken in Douglas Lake indicate that conditions there are favorable to this species. The clear water and sand bottom are well-known characteristics of its preferred habitat; the pebble-strewn shallows, especially those about the north end of Fairy Island, afford it ideal breeding grounds (Lydell, 1903; Reighard, 1906).

The young of this species, together with those of the large-mouthed black bass, are often seen on the sand shoals in late summer in pursuit of the mixed schools of young suckers, perch, and spot-tailed minnows, which are common there. These they drive toward shore into shallow water. The bass, which are then 2 or 3 inches long, are two or three times as deep bodied as their intended victims, so that they are unable to follow them into very shallow water.

MICROPTERUS SALMOIDES (Lacépède), *large-mouthed black bass*, is not common in Douglas Lake. It occurs in North Fishtail Bay, where the bottom is mucky in places and the vegetation abundant, and is less common in other localities. We have records of two taken in South Fishtail Bay. One measured 12 inches and weighed 30 ounces; the other measured 14.4 inches and weighed 40 ounces. One contained a perch and the other two fish and a crayfish.

Fishermen tell of catching a peculiar bass on the "middle ground" to the east of the north end of Fairy Island. The writer has never seen it. It is probably the large-mouthed bass.

The conditions in Douglas Lake can not be regarded as favorable to this species. There is little mucky bottom in the shallow water, and few places afford the thick growth of aquatic plants that the small-mouthed bass prefer for its breeding ground (Lydell, 1903; Reighard, 1906).

PERCA FLAVESCENS (Mitchell), *yellow perch*, is one of the most abundant fishes in the lake. Our data concerning it are given in table VIII.

TABLE VIII.—RECORDS OF PERCA FLAVESCENS TAKEN IN DOUGLAS LAKE.

No.	Weight.	Length.	Sex.	Water depth.	Apparatus.	Stomach contents.	Locality in Fig. 1.	Date.
	Ounces.	*Inches.*		*Feet.*				
1–71	[a] 0.5	[a] 4.4	14 males, 57 females.	5.5	Fyke	2 insects, 1 copepod, in 6 fish examined.	4	Aug. 6, 1912
72–77	[a] .75	[a] 4.6	All females	5.5	do	Empty	4	Aug. 7, 1912
78	3	7.2	Female	5.5	do	Small perch	4	Aug. 8, 1912
79	1.5	6	do	5.5	do	Empty	4	Do.
80–221	[a] .5	[a] 4	22 males, 120 females.	5.5	do	Of 20, 14 empty, 6 with insects.	4	Do.
222	5.5	8.4	Female	26	Gill	Empty	6	Aug. 16, 1912
223	5	8	do	41	do	do	6	Aug. 17, 1912
224	5	8	do	41	do	do	6	Do.
225	5	7	do	41	do	do	6	Do.
226	4	7.6	do	41	do	do	6	Do.
227	3	7.6	do	41	do	do	6	Do.
228	5	8.4	do	43	do	do	6	Do.
229	4	8	do	43	do	do	6	Do.
230	4	8	do	43	do	do	6	Aug. 18, 1912
231	4	8	do	43	do	do	6	Do.
232	6	7.6	do	12	do	*Cambarus virilis*	7	Aug. 20, 1912
233	7	8.4	do	12	do	Empty	7	Do.
234	4.5	8	do	12	do	do	7	Do.
235	4.5	8	do	12	do	do	7	Do.
236	3	.....	.....	6	do	Not examined	6	Aug. 3, 1912
237	.....	5.8	.....	.....	Angle	Empty	5	Sept. 5, 1911
238	.....	5.8	.....	.....	do	do	5	Do.
239	.....	5.1	.....	.....	do	Small crayfish	5	Do.
240	.....	4.25	.....	.....	do	Empty	5	Do.
241	.....	4.25	.....	.....	do	1 crayfish, 1 dragon fly, nymph.	5	Do.
242	.....	4.25	.....	.....	do	Small fish	5	Do.
243	.....	4.25	.....	.....	do	Empty	5	Do.
244	.....	4.25	.....	.....	do	do	5	Do.
245	.....	4.6	.....	.....	do	Piece earthworm	5	Do.
246–66	.....	3.75–5.5	.....	.....	do	1 with fish, 2 with insects.	10	Sept. 9, 1911
267–8	.....	7.5	Female	.....	Gill	1 empty, 1 with insects	10	Do.
269	.....	7	do	35–40	do	Fish muscle	10	Sept. 14, 1911
270	.....	7.5	do	35–40	do	Not recognizable	10	Do.
271	.....	7.75	do	35–40	.....	do	10	Do.
272	.....	7	do	35–40	Gill	Empty	10	Sept. 15, 1911
272a	.....	7.25	.....	26–30	do	do	10	Sept. 13, 1911
272b	.....	7.75	.....	26–30	do	do	10	Do.
273	.....	8	Female	35–43	do	do	3	Sept. 16, 1911
274	.....	7.25	do	35–43	do	do	3	Do.
275	.....	7	do	35–43	do	1 2-inch crayfish	3	Do.
276	.....	7	do	35–43	do	Empty	3	Do.

[a] Average.

Perch range in midsummer from a depth of a few inches to about 45 feet. They have not been found below the thermocline even in September. They occur in all parts of the lake.

Perch of about 2 inches long are common on the shoals in misdummer, but have not been found elsewhere. In our collections made with the hook from the aquatic vegetation there are no perch more than 6 inches long (no. 237 to 266, table VIII). Larger perch do not appear to occur there, else we should have taken them among the 29 fish from the vegetation. For the 221 perch taken in the fyke net in shallow water we have recorded for most of them only the average length in each lot. There is one fish slightly in excess of 7 inches. On the other hand, in deep water where we have used a gill net of 1-inch square mesh we have taken no perch under 7 inches and many of 8 inches and more (no. 223 to 235 and no. 267 to 276). As perch of 4 or 5 inches have a depth of an inch or more, a net of inch mesh should have taken them if they were present. The average of the fish taken with the hook in vegetation is 4.6 inches (no. 237 to 245), while the average of the 25 taken in the gill net is 7.7 inches. It appears, then, that in

midsummer perch of less than 2.26 inches are found on the shoals, those between 4 and 6 inches in the vegetation, and those of 7 inches or more in deeper water.

Nineteen of the perch in our table showed recognizable stomach contents. Of these, 11 contained insects only, 1 contained insects together with a crayfish, 3 contained crayfish only, and 4 contained fish only. The relative importance of the three kinds of food is perhaps indicated by the frequency of the occurrence of each, which is the ratio: Insects 3, fish 1, crayfish 1.

The largest perch in our record is 8.4 inches. They appear to be exceptionally slender, for while in systematic descriptions the depth is given as contained 3.3 to 3.8 times in the length, the depth in Douglas Lake specimens is contained about 4.3 times in the length. Forbes and Richardson (1908) say "the species may reach the length of a foot and a weight of more than 2 pounds, but does not commonly weigh much more than a pound." The heaviest Douglas Lake specimen weighed but 7 ounces. There are no data from other lakes for comparison with those from Douglas Lake, but Douglas Lake specimens strike one as being slender, short, and under weight.

After storms perch are found dead on the beach in great numbers. Protruding from the mouth of such a one is often seen the head of another that has been swallowed tail first. When pulled out the swallowed perch is, in many cases, found to be almost as large as that from which it was drawn, and is without doubt the cause of its death. Cannibalism of this sort is common in the writer's experience among young wall-eyed pike kept in confinement and insufficiently fed. It indicates starvation. The small size of the Douglas Lake perch, the high midsummer mortality, and the occurrence of the sort of cannibalism described, indicate that the conditions in the lake are not the most favorable for perch.

In August and September schools of young perch are conspicuous on the sand shoals of South Fishtail Bay and doubtless on the other shoals. One of these was seined, and of the 475 individuals captured 203 were found to be young perch from 1.85 to 2.25 inches long. The remainder of the school was made up of 267 spot-tailed minnows and 5 suckers of about the same length as the perch. The young perch are readily distinguished in the water from the other species in the school by the seven bars on the sides, which are more pronounced than is usual with larger perch. They have also a well-defined black, basal spot at the caudal margin of the first dorsal, which has a more pronounced black border than in the adult.

Placed in an aquarium, the young fish may be seen to feed on plankton. When the fish are placed in formalin immediately after capture, twisted cords of brown fecal matter are soon found hanging from the vent. These have on the surface a smooth coherent pellicle consisting apparently of granular mucus. Under the needle the cord breaks readily into ovoid masses of equal size each of which is seen to consist, within the pellicle, of many tests of microcrustacea. The most numerous individuals were those of a *Chydorus*-like cladoceran, but *Simocephalus* and *Daphnia* were also present in numbers and there were a few copepods. These fecal cords varied in length from ⅛ inch to ⅝ inch. By counting the number of tests in one of the 40 ovoid masses into which a ⅝-inch piece broke, the number in the whole piece was estimated at 800. There were no remains of insect larvæ. The 203 young perch had thus consumed about 162,400 Crustacea, whose remains were found in the fecal cord. The stomach and intestine of one

individual opened was estimated to contain about four times as many Crustacea as the fecal cord, whose contents therefore represent one-fifth of the food contained in the alimentary canal at the time of capture. The total number of Crustacea in the alimentary canals of the 203 young perch at the time of capture was therefore in the neighborhood of 812,000. This is not the daily consumption, but represents rather the food taken within a comparatively short time. If one should collect the fecal cords passed by a known number of perch under normal conditions in unit time, there might be obtained a measure of the total daily consumption of microcrustacea per individual. The rate at which food consumption increases and the relation of this increase to the rate of growth might also be thus determined. The whole branchial apparatus of the young perch with its slender, close-set gill rakers forms an excellent instrument for the capture of microcrustacea.

By an examination of the gonads, the sex of 237 of the perch included in our table was determined. Thirty-six were males and 201 females, a ratio of about 1 to 6. In two instances our records (table viii, no. 1 to 71 and 80 to 221) show a considerable number of perch taken at one time and place. These two lots include 36 males and 177 females, a ratio of about 1 to 5. The remaining captures consist of from one to three fish, and in each case in which the sex is recorded the fish are females. The record shows that all the fish under consideration were taken with the gill and fyke nets. It does not show the relative size of males and females. If, as is possible, the males are smaller than the females, the smaller males may pass through the meshes of the nets and the sex ratio found in our collections may be due to the selective action of the nets used. One must be sure that the apparatus does not act selectively before a positive statement can be made as to the sex ratio.

The young perch found on the shoals secure an abundance of food, while the shallow water affords them a refuge from their enemies. When they have reached a length somewhere between 2¼ and 4 inches they seek larger food among the aquatic vegetation, which at the same time affords them a certain protection from their enemies. Here they remain until they are approaching 6 inches in length. They are then able to leave the aquatic vegetation and wander into deeper water, for their size affords them some protection from pike and bass. They now descend as far as the thermocline and make forays into shallow water beyond the vegetation.

PERCINA CAPRODES (Rafinesque), *log perch.*—Mr. H. V. Heimburger, a research worker at the biological station, reported that he had seen several individuals of this species in water about 3 feet deep at the edge of the vegetation in North Fishtail Bay. In August we have seined them in South Fishtail Bay on the sand bottom near vegetation in 3 feet of water, but they have not been taken in any of the other apparatus used by us.

We have no records of the stomach contents. Forbes and Richardson (1908) say: "A third of the food of 11 specimens was found by us to consist of crustaceans (mainly Entomostraca) and the remainder of insects, the latter chiefly *Chironomus* larvæ, larvæ of day flies and water bugs (*Corixa*)." Their habitat, as judged by the food, is probably the bottom in or near patches of vegetation.

Between June 28 and July 8, 1912, between 100 and 200 individuals were breeding on the sand shoals at the south end of South Fishtail Bay in water from a few inches to

2 feet deep. The eggs were laid in the sand and were fed upon by the log perch themselves as well as by suckers. A preliminary note on the breeding habits has been published (Reighard, 1913). A detailed account will be published later.

BOLEOSOMA NIGRUM (Rafinesque), *johnny darter*, is common in Douglas Lake. Its distribution in the lake and the factors controlling it are the subjects of a paper by Mr. H. V. Heimburger, now in manuscript (see also Heimburger, 1913), from which the following statements are extracted:

It occurs commonly in water of about 18 inches depth, on bottom which contains some muck and in the neighborhood of aquatic plants. The food of the adult consists, in midsummer, chiefly of larvæ of midges, but partly of Entomostraca. The midges lay their eggs on the floating leaves of aquatic plants and their larvæ are found in muck near by. It is well known that the eggs of this species are laid under stones, sticks, mussel shells, and the like in shallow water and are guarded by the male fish. Mr. Heimburger concludes that the localities in which the johnny darter occurs in Douglas Lake present "several features in common: (1) Mussel shells, sticks or stones are found on the bottom; (2) quiet water protected from prevailing winds so that the bottom is not subject to violent wave action; (3) a thin deposit of muck in the shallows, with patches of clear sand exposed; deeper muck deposit is found in the deeper water of the locality, but a deep muck deposit is not found in the shallow water; (4) masses of *Potamogeton*, etc., are found near the habitats where both adults and young are found. These factors are seen to be related very definitely to the food or breeding habits of *Boleosoma* and may therefore be regarded as factors determining the local distribution of this species."

ETHEOSTOMA IOWÆ Jordan and Meek is rare in Douglas Lake. Two specimens were taken in the minnow seine along with 75 johnny darters at the west side of the entrance to North Fishtail Bay in September, 1911. One was taken on sand bottom at the mouth of Bessie Creek. The species is recorded by Hankinson (1908) from Walnut Lake. The two Michigan records appear to mark the eastern limit of its range, which is the Mississippi Valley and northward.

COTTUS ICTALOPS (Rafinesque), *miller's thumb*.—This species is rare in Douglas Lake, and our records indicate that it is confined to the stony shoals. Its eggs are known to be laid under stones and other objects lying on the bottom and to be guarded by the male fish. We have found it in the lake only in localities which afford it nesting sites. These are Grapevine Point and the west side of North Fishtail Bay. In the latter locality it is recorded as abundant under stones. We have taken it also in Maple River.

LOTA MACULOSA (Le Sueur), *burbot*.—We have taken a young individual about 2½ inches long at the mouth of Carp Creek, where it enters Burts Lake. It was taken with *Umbra limi*, near dense masses of aquatic vegetation. Prof. N. H. Stewart is reported to have taken two very large specimens in a gill net in Douglas Lake in the summer of 1910.

FISH COMMUNITIES OF DOUGLAS LAKE.

In the second part of this paper there is suggested a classification of the fish habitats of the lake. The fish found within each of these habitats in midsummer might now be considered without reference to other habitats. But since fish may pass from one habitat to another with increase of size and change of food, it seems best to consider

communities of fish primarily with reference to their origin and interrelations. By community is here meant no more than a group of species or individuals whose members are regularly found together for a longer or shorter time. No precise use of the concept in its relation to habitat is attempted. Thus, the stony-shoal habitat harbors two communities, one of which, that of the young fishes, is more characteristic of sandy shoals. To attempt greater accuracy at the present time would be misleading. Although it seems best to treat communities of fish rather than the fish of a habitat, it is most convenient to use for most of these communities the names of the habitats in which they are best developed.

THE COMMUNITY OF YOUNG FISHES.

On the sand shoals are found mixed schools of young perch, spot-tailed minnows, and suckers, all about 2 inches long in late summer. These schools doubtless vary in the proportion of their constituents. Our only record gives perch 203, spot-tailed minnows 237, suckers 5; but the suckers are often seen to make up a larger percentage of the whole. On the stony shoals there are added to these schools many young blunt-nosed minnows, distinguishable from the other fish of the school by the jerky mode of swimming and by other field characters already described. What follows refers to the schools on the sand shoals, but would presumably answer as well for those on the stony shoals. Perch are known to spawn in the spring. In the hatchery ponds at Mill Creek, Mich., Mr. Dwight Lydell reports to me that they hang their purse-like masses of eggs on aquatic plants, brush, and the like. Abbott (1878) found them spawning on gravel amongst vegetation. H. M. Smith (1907) gives a similar account, and also finds the egg masses floating. I have found the floating egg masses in Saginaw Bay, Mich. Their spawning grounds in Douglas Lake are unknown, but from them the young perch must make their way to the shoals. Suckers (see under that species) are not known to spawn except in running water on gravel bottom. Presumably those of Douglas Lake spawn in such situations in Maple River and Bessie Creek, and the young fish make their way along shore to the shoals. The breeding habits of the spot-tailed minnow are unknown. From two or perhaps three different breeding grounds the young fish forming the communities under discussion reach the sand shoals and finally live together there in schools through the summer. The schools move about over the sand shoals, engaged now in feeding, now in fleeing from enemies. If the water is quiet, they approach the shore; as it becomes rougher they pass toward the lakeward edge of the shoal and are lost to sight. They may then enter the vegetation, but as this harbors many enemies it is more probable that they avoid it. All three species feed on the microcrustacea of the plankton, which at this season are extremely abundant. The total daily consumption of the whole school referred to above must reach many millions. Since the alimentary canals of the young fish are at all times crammed, there appears to be enough food for all, so that the fish are not in competition with each other.

While the schools of young fishes are on the sand shoals they are often pursued by young black bass about 3 inches long, small-mouthed and large-mouthed. The water on the shoals is not obstructed by vegetation, so that the stalking bass are plainly visible to their prey which attempt to escape the rushes of the bass by short rapid flights,

that may end in leaps into the air. Often the flight is toward shore into water so shallow that the deep-bodied bass are unable to follow.

Two influences seem to keep the young fish on the sand shoals. The first is abundance of plankton Crustacea, which at this time make up the whole food of the three species. Since these Crustacea no doubt have a uniform horizontal distribution, as in other lakes, their abundance merely *permits* the shoals to be used; it does not restrict the fish to them. The second influence, that which determines the use of the shoals, is the relative freedom that they afford from attacks of enemies. This freedom afforded by the mere presence of the fish on the shoals is increased by their habit of schooling. The coming together of three or four species to form a large school lessens the loss to each species and the risk to each individual. This follows in part from the fact that, if the toll taken by enemies remains constant, a large school loses a smaller percentage of its constituents than a small school. It follows also because in a large school there are more eyes on the watch for enemies, and therefore more chance that any individual will be warned by the flight movements of comrades, and thus be enabled to escape. Both the habit of schooling and that of frequenting the shoals are measures of protection, most effective when coincident, for the habit of schooling is most effective in open water, which affords no lurking place for the enemy, and in shallow water in which an enemy's approach is limited to the lakeward side. It would probably be ineffective or harmful in vegetation. That the occurrence of young fish on the shoals may be further influenced by temperature is indicated by the observations of Michael (Hankinson, 1908, p. 202–204).

By early September the young perch have reached a length of somewhat more than 2 inches. The suckers and spot-tailed minnows are of the same size. A year later the young perch have reached a length of about 4 inches, have changed their food habits, and are found in the vegetation. They have left the shoals and the community of young fishes and have now become for a time a part of the vegetation community. They do not return to the shoals, but their place there is taken by young fish of the year. The migration from the shoals probably takes place in late fall or early winter, so soon as low temperature or ice makes them uninhabitable, and when the perch are probably less than 3 inches long. The spot-tailed minnows also pass from the shoals into the vegetation and are thenceforth a part of its community. The young suckers, too, leave the shoals, and our next knowledge of them is when they are about 7 inches long. They are then ranging far beyond the vegetation into deeper water. Whether they are confined to the vegetation when between 2 or 3 and 7 inches in length we do not know. It is clear that the communities of young fishes are temporary.

The community of young fishes is found on the stony shoals as well as on the sand shoals, but on the stony shoals there is added to it the blunt-nosed minnow. The adult males of this species burrow beneath stones or other objects on the bottom, and thus form nests (Hankinson, 1908). The eggs are attached to the lower sides of the stones. The young fish are added to the community last described. Nothing is known of their food in Douglas Lake. It is presumably plankton Crustacea, the same as that of the other young fishes of the community, and they are doubtless held to the community by the same factors. The adults have been found only on or near stony shoals.

THE STONY-SHOAL COMMUNITY.

It has been pointed out that the presence of stones adds to the community of young fishes found on the stony shoals the blunt-nosed minnow. This form when breeding may be regarded as a member of the stony-shoal community. This community would then consist of three fishes which lay their eggs beneath stones—the blunt-nosed minnow, the miller's thumb, and the johnny darter. The miller's thumb makes excavations beneath stones and attaches its eggs in a mass to their lower sides (Hankinson, 1908). This has not been observed in Douglas Lake, but the fish themselves have been found beneath stones on the stony shoals and nowhere else. The johnny darter also lays its eggs on the lower sides of stones. It has rarely been found in Douglas Lake or elsewhere than on stony shoals or adjacent to them.

With the three fishes which form this community is found a small crayfish, *Cambarus propinquus* Girard. It forms burrows beneath stones, and these may be recognized by the little piles of fresh sand at their mouths.

The stony-shoal community, unlike that of young fishes, is composed of both young fish and adults and is probably permanent. What happens to its members when the shoals are ice covered we do not know.

The food of the young johnny darter is known to consist of Entomostraca, while that of the adult is chiefly midge larvæ with an admixture of Entomostraca. (Heimburger, 1913.) The blunt-nosed minnow takes a varied food, which, according to Hankinson (1908), consists chiefly of small organisms taken from the bottom, from water plants, and from the water. It appears that midges in various stages of development formed the chief food of this species in April and May. Besides midges, filamentous algæ, desmids, entomostracans, and in one case beetles, were found in the stomach. The food of the miller's thumb in Illinois was found to contain about 25 per cent of small fishes, 40 per cent aquatic larvæ, and the rest mostly Crustacea (*Asellus*). (Forbes and Richardson, 1908.) In Douglas Lake the blunt-nosed minnow and the johnny darter take similar food and find it in the same place, yet the blunt-nosed minnow has a somewhat larger choice, and the two forms are not altogether in competition. The miller's thumb presumably takes its supply of fish from among the blunt-nosed minnows and johnny darters, while the crayfish afford it Crustacea.

THE VEGETATION COMMUNITY.

The vegetation community includes the following forms:

Ameiurus nebulosus, bullhead.
Notropis hudsonius, spot-tailed minnow.
Notropis cornutus, common shiner.
Percopsis guttatus, trout perch.
Ambloplites rupestris, rock bass.
Lepomis pallidus, bluegill.
Eupomotis gibbosus, common sunfish.
Micropterus salmoides, large-mouthed black bass.
Perca flavescens, yellow perch, 4 to 6 inches long.
Percina caprodes, log perch.

Of these 10 species 8 have been found only in the vegetation, although, as pointed out elsewhere, some of them enter other habitats at the breeding season or when young. The

inclusion of *Percopsis guttatus* and *Percina caprodes* in the list is provisional. We have found insect remains in the stomach of the former, while Forbes and Richardson (1908) find the latter to feed on entomostracans and insects, and we found it always on the bottom near vegetation. What we know of the food of both forms, therefore, suggests the vegetation habitat. The small-mouthed bass, the sucker, and the pike are found in the vegetation habitat, but chiefly about its edges, while they are characteristic of the deep-water community in which we have placed them. The whereabouts of the young of these forms is unknown to us, but there is little doubt that they will be found in the vegetation. Here also we are likely to find the young of *Lota maculosa*.

With the possible exception of the log perch and the trout perch, the forms listed above are confined to the vegetation. We do not ordinarily find them elsewhere. They invade the shoals only, so far as known, when they afford them shelter similar to that to be had amongst vegetation. From the laboratory on South Fishtail Bay a dock consisting of planks supported on spiles extends from the shore to the seaward edge of the terrace, which is here an unprotected sand shoal. Beneath this numerous fishes found shelter—small black bass, both large and small mouthed; bluegills, rock bass, adult spot-tailed minnows, and small perch. To this retreat they had been able to make their way readily from the adjacent vegetation, and from it they were able to harry the schools of young fishes on the shoals. Such shelters were no doubt formerly afforded by the trunks and branches of fallen trees. With the destruction of the forests, fallen trees have become rare along the shore and are removed by those who use the shore as a roadway. When they were more abundant, fish must have been more plentiful on the shoals, for they were then able to find there the shelter conditions of the vegetation.

Short forays into deeper water in search of food are probably made by several of the fishes of the vegetation community. By the extension of these the 6-inch perch no doubt attain in time to a membership in the deep-water community. The breeding season finds certain of the vegetation fishes outside of the vegetation. The log perch then betakes itself to the sand shoals and is there closely associated with the adult suckers, which come to the shoals to feed on its eggs. The common shiner and the small-mouthed bass must also leave the vegetation to breed.

That the larger small-mouthed bass and the pike make raids from deeper water into the vegetation in pursuit of prey we can not doubt, for they are captured at its borders. Moreover, in the stomachs of the pike are found 4-inch perch, which are not known to occur outside the vegetation.

Three factors suggest themselves as determining the make-up of the vegetation community—food, shelter from enemies, and breeding habits. All 10 forms, of course, find their food within the vegetation. Three members of the community—the bullhead, the rock bass, and the large-mouthed bass—reach a considerable size, feed in part on fishes, and might obtain these outside the vegetation. But, of these, the bullhead is largely nocturnal or crepuscular and is slow of movement. It tends to lie in wait for its prey rather than to seek it actively. The conditions within the vegetation zone are favorable for this method of getting food. The rock bass and the large-mouthed bass include a considerable proportion of small fishes in their diet, and these are most abundant in the vegetation. The remaining forms feed on invertebrates, largely

insects, and find these most plentiful within the vegetation areas. Here the common sunfish finds snails and the bluegill plant tissues. The two species of *Notropis* might feed on plankton outside the vegetation, while the bullhead, rock bass, and large-mouthed bass might, like the pike and small-mouthed bass, obtain fish without restricting themselves to the vegetation. Food alone does not appear to limit these forms to the vegetation.

In addition to food, the seven smaller forms (excluding *Ameiurus*, *Ambloplites*, and *Micropterus*) find within the vegetation a refuge from certain enemies, chiefly pike and small-mouthed bass. Within its mazes rapid flight is much easier for a small form than rapid pursuit by a larger enemy.

The breeding habits of one of the forms in our list (the spot-tailed minnow) is unknown. The writer is familiar with the breeding habits of the remaining forms, and the papers of Hankinson (1908) and Shelford (1911) contain references to some of them. Two species (the log perch and the common shiner) breed on plant-free sand or gravel. A third, *Percopsis*, according to the unpublished observations of Doctors A. H. Wright and A. A. Allen, of Cornell University, to which reference is made by their permission, breeds "in swiftly running water and over a stony bottom." The common sunfish also may breed on gravel bottom. Four species (bullhead, rock bass, bluegill, and large-mouthed bass) lay their eggs, by preference, in nests made by exposing the fibrous roots of water plants. The bottom material removed in making the nests may be sand, marl, muck, or mud, but the essential of the nests is the rootlets which form its bottom. The eggs of the sunfish, rock bass, and bluegill adhere to the rootlets. Those of the bullhead lie free, united in masses. The bullhead, since its eggs are not adhesive, may make its nest in situations in which rootlets do not occur, but in the writer's experience these nests are always in vegetation. The common sunfish also makes a nest, the bottom of which is sometimes gravel but more often rootlets. The perch, too, commonly deposits its masses of eggs amongst vegetation, although when adult it wanders far beyond the vegetation. Thus there are 6 of the 10 forms that require vegetation as a part of their breeding environment (*Ameiurus*, usually; *Ambloplites; Lepomis*, usually; *Eupomotis*, usually; *M. salmoides; Perca*). In some of these forms the relation of the breeding habits to vegetation is not at first apparent. Thus *Lepomis pallidus* is often found breeding where there seems to be no vegetation, but in such cases closer inspection will show that its eggs are laid on the rootlets of bulrushes which are so near the denser vegetation as to afford the fish a ready retreat into it. The same is often true of the large-mouthed bass and the common sunfish.

Of the 10 forms included in our vegetation community we may repeat that all obtain food in the vegetation. Although some of them might obtain it elsewhere it is doubtful whether they could obtain it as well. At least four of these probably need the vegetation for protection (the two species of *Notropis*, *Percopsis guttatus*, and *Percina caprodes*). This need is scarcely less in the bluegill, the sunfish, and the perch, and in the young of the other forms. The two species of *Notropis* are not bottom forms. While they might obtain plankton food outside the vegetation, they would be very conspicuous there and could scarcely long escape their enemies. *Percopsis* and *Percina* are bottom forms and would more readily escape detection outside the vegetation. It is possible that they may wander to some distance from it. The relation of these 10 forms to the vegetation is summarized in table IX.

The cross in the table indicates that the species avails itself of the factor indicated; the zero indicates that it does not, or, in the case of the column headed "Protection," that it does not need to. Adult *Ameiurus*, *Ambloplites*, and *Micropterus* are larger than the perch which exist outside the vegetation. They must be held to it by some other factor than the need of protection. This may be food or some factor not included in our table. Since some of the species may obtain their food outside the vegetation, the data in our table indicate *that no one of the factors considered necessitates the occurrence together of the species which make up the vegetation community.*

TABLE IX.—SHOWING THE RELATION OF THE SPECIES OF FISHES INCLUDED IN THE VEGETATION COMMUNITY TO THE THREE FACTORS OF FOOD, PROTECTION, AND BREEDING AFFORDED BY THE VEGETATION.

Species.	Food.	Protection.	Breeding.	Species.	Food.	Protection.	Breeding.
Ameiurus nebulosus	×	o	×	Lepomis pallidus	×	×	×
Notropis hudsonius	×	×	(a)	Eupomotis gibbosus	×	×	×
Notropis cornutus	×	×	o	Micropterus salmoides	×	o	×
Percopsis guttatus	×	×	o	Perca flavescens, 4–6 inches	×	×	×
Ambloplites rupestris	×	o	×	Percina caprodes	×	×	o

[a] Unknown.

THE DEEP-WATER COMMUNITY.

In the deeper water near the bottom, down to about 45 feet, the following forms have been taken in midsummer:

Catostomus commersonii (common sucker), from 7 to 12 inches long, approximately.
Esox lucius (pike), between 12 and 30 inches long.
Micropterus dolomieu (small-mouthed black bass), between 12 and 16 inches long.
Perca flavescens (yellow perch), 8½ inches long.
Lota maculosa (burbot), large.

All these fishes wander far from the vegetation. The small-mouthed black bass feeds chiefly on crayfish. Presumably the larger pike prey on the other fishes of the community, but our records do not show that any pike had eaten fishes more than 4½ inches long. These were perch of a size found only among vegetation and were doubtless taken by the pike at its borders. It seems probable that the five fishes of this community are protected from one another in part by their size, for the individuals of each kind are usually too large to be eaten by the others except by the largest pike or burbot. The perch remain in the aquatic vegetation until they are about 6 inches long and large enough to enter the deep-water community.

The fishes of the deep-water community, except possibly the burbot, are much about the borders of the patches of vegetation and more or less within these patches. Here the pike (no. 1, 2, 3, 5, 6, 15, 16, table III) obtains the smaller perch and probably the other fishes of the plant zone. To a lesser degree, the small-mouthed black bass may obtain fish from the same source; at any rate it is commonly taken on the lakeward margin of the plant zone on hooks baited with shiners or spot-tailed minnows. The sucker is also known to enter the patches of aquatic plants. The characteristic feature of the deep-water community is then that its members occur near the bottom in deeper water outside the patches of aquatic plants, not that they may not also occur

within these patches. In this they differ from the rock bass, the small-mouthed bass, and the bullhead, which have been taken only in or near vegetation and in shallow water, although their size would apparently enable them to enter the deep-water community.

In addition to the five species listed, one other, the cisco, or lake herring, must occur at some level considerably above the bottom. This may be inferred from the fact that it has never been taken by us in fine-meshed gill nets set on the bottom in either shallow or deep water. It is probable that it should be regarded as a member of a nekton community characteristic of a mid-water habitat. No other fishes are known to be associated with it.

RELATION OF DOUGLAS LAKE SPECIES TO THOSE OF OTHER WATERS.

Douglas Lake has large areas of bare sand or gravel bottom, comparatively clear water, kept well agitated by the wind, and a relatively sparse growth of vegetation. It would be of interest to learn: (1) Whether its fishes give preference in other regions to the conditions that they find in Douglas Lake, and (2) whether their distribution over the continent is such as to afford these conditions. Forbes and Richardson (1908) give the only data known to me on the habitat preferences of American fresh-water fishes. For many species they indicate by coefficients or percentages the kind of water preferred (whether large rivers, small rivers, creeks, lakes, or ponds), the kind of bottom (mud, rock and sand, mud and sand), and the amount of current (swift to moderate, slow to stagnant, variable). I am unable to interpret these data in such a way as to make them available for a detailed comparison of the habitat preferences of the fishes of Douglas Lake with those of Illinois, and therefore restrict myself to noting two points:

There is no mud bottom in Douglas Lake, none at least in its shallower parts. The bottom is sand or gravel, with an overlying stratum of muck in the deeper water and in protected situations in shallow water. None of the species occurring in the lake are among those given by Forbes and Richardson as preferring mud bottom in other waters, and but two species (*Ameiurus nebulosus*, and *Umbra limi*) are commonly found on such bottom in other waters. The other Douglas Lake species, in so far as their preferences are indicated for Illinois, are found with greatest frequency on a bottom which includes rock or sand or both.

Among the fishes in our list the following are found by Forbes and Richardson to show a preference for small rivers or creeks: *Catostomus commersonii*, *Semotilus atromaculatus*, *Notropis cornutus*, *Ambloplites rupestris*, *Micropterus dolomieu*, *Percina caprodes*, *Boleosoma nigrum*. Suckers, rock bass, and small-mouthed bass occur often in lakes, but the horned dace and the common shiner are rare in lakes. Forbes and Richardson give the water preference of the horned dace as large rivers 1.67, creeks 3.77, lowland lakes 0.11. The species is of local occurrence in Douglas Lake and is possibly introduced. For the common shiner the Illinois preferences are large rivers 0.11, small rivers 2.45, creeks 3.00, lowland lakes 0.02, upland lakes 0.20. The species is one of the most widely distributed and abundant of the Douglas Lake fishes. Its abundance, together with the presence of the other species showing preference for small rivers and creeks, indicates that in the character of its bottom, the movement of its waters and the sparseness of its vegetation Douglas Lake affords the small-river-creek conditions preferred by these species.

For the purpose of discussing the general distribution of the fishes of Illinois, Forbes and Richardson have divided the region over which they occur into 12 districts and have tabulated the distribution of each species in these districts. The number of Douglas Lake species found within each of these districts is shown in table X, arranged in numerical order.

TABLE X.—SHOWING NUMBER OF DOUGLAS LAKE FISHES FOUND IN OTHER REGIONS.

Great Lakes basin	22
Upper Mississippi and Missouri Valleys	21
Lower Mississippi and Ohio Valleys	20
Quebec and New England	19
North Atlantic, New England to Chesapeake Bay	17
South Atlantic, Chesapeake Bay to Florida	13
Hudson River	12
Far north, north of Mississippi drainage, between Rocky Mountains and Lake Superior drainage	12
East Gulf district, to Mississippi drainage on west	10
West Gulf district, westward from Mississippi drainage, including Rio Grande	4
Florida Peninsula	3
Far northwest, west to Rocky Mountains	1

It is clear from the table that the Douglas Lake species are northern and northeastern rather than southern or southwestern in their range. A single species, the pike, crosses the Rocky Mountains into the far northwest, but the species is of common occurrence in the Northern Hemisphere. Three species, the large-mouthed bass, the bluegill, and the bullhead, occur in Florida, while four species are found in the west Gulf and Rio Grande region. All the Douglas Lake species, with the exception of the cisco, occur in the upper Mississippi and Missouri Valleys. In the lower Mississippi and Ohio Valleys all are found, with the exception of the cisco and *Etheostoma iowæ*. In Quebec and New England *Etheostoma iowæ*, *Notropis cayuga*, and the bluegill are lacking. These three, with the cisco and the miller's thumb, are lacking in the north Atlantic district, leaving 17 species. This number is reduced to 13 in the south Atlantic district, 10 in the east Gulf, and 4 in the west Gulf district.

In general, more Douglas Lake species are to be found in clear, rock and sand-bottomed, northern waters than in the more turbid southern and southwestern waters. Forbes and Richardson (1908) publish a list of 34 Illinois species that avoid the turbid waters of the lower Illinoisan glaciation. Ten of these are also Douglas Lake species. They give also a list of 37 species that tolerate the lower Illinoisan glaciation. In this list are but two Douglas Lake species.

The fishes of Douglas Lake appear, then, to give preference in Illinois, and presumably elsewhere, to those conditions of water and bottom that are available to them in Douglas Lake and to be distributed over the continent in districts in which such conditions are found.

SUMMARY.

1. Four fish habitats are provisionally recognized in Douglas Lake—the barren sand-shoal, the barren stony-shoal, the vegetation, and the deep-water. Each is defined (pp. 221, 222).

2. Twenty-two species of fish are listed from Douglas Lake, and detailed data on their occurrence, weight, length, food, and interrelations are tabulated and discussed (p. 229).

3. Four fish communities are provisionally recognized in Douglas Lake in midsummer—the community of young fishes, the stony-shoal community, the vegetation community, and the deep-water community (p. 239–246).

4. The community of young fishes is characteristic of the shoals. On the sand shoals it consists of perch (*Perca flavescens*), spot-tailed minnows (*Notropis hudsonius*), and suckers (*Catostomus commersonii*), all in schools together and all about 2 inches long in late August. On the stony shoals, young blunt-nosed minnows (*Pimephales notatus*) may be added to these schools (p. 241).

5. All the members of the young-fish community feed exclusively on plankton Crustacea (p. 241).

6. The occurrence of young fish of several species (*a*) in large schools and (*b*) on open shoals are conditions which, when they occur together, favor escape from predatory enemies. It is held to be the presence of such enemies that keeps the members of the young-fish community together and on the shoals (p. 241).

7. The community of young fishes is temporary. Before their second season its members forsake the shoals (p. 241).

8. The stony-shoal community consists of the young and adults of three species which lay their eggs beneath stones—the blunt-nosed minnow (*Pimephales notatus*), the johnny darter (*Boleosoma nigrum*), and the miller's thumb (*Cottus ictalops*). With these is associated a small crayfish (*Cambarus propinquus* Girard) (p. 242).

9. The factor which holds the members of the stony-shoal community together is the presence of stones or other similar objects which afford the conditions necessary for breeding (p. 242).

10. The stony-shoal community is permanent, except as it may be interfered with by winter conditions (p. 242).

11. The vegetation community consists of 10 species which, with one exception, are unknown except in or very near vegetation (p. 242).

12. The occurrence together of the members of the vegetation community is not attributed to a single factor, but to two or more factors, of which food, protection, and breeding conditions are specified (p. 243).

13. All members of the vegetation community find their food in the vegetation; in addition seven of them find there probably necessary protection, and six find in connection with vegetation their usual breeding conditions (p. 243).

14. The deep-water community consists of four or five species—the common sucker (*Catostomus commersonii*), the pike (*Esox lucius*),the small-mouthed black bass (*Micropterus salmoides*), the burbot (*Lota maculosa*). All of these occur near the bottom in deep water outside vegetation, although they may also penetrate vegetation and invade shallow water (p. 245).

15. The members of the deep-water community obtain their food in the deeper water and about vegetation. Their size is held to enable them to leave the vegetation, since by it each species is in some degree protected from enemies (p. 245).

16. The species of fishes found in Douglas Lake give preference in Illinois (Forbes and Richardson) to those conditions of water and bottom that are available to them in Douglas Lake (p. 246, 247).

17. The fishes of Douglas Lake are distributed over the continent in those districts in which the conditions available to them in Douglas Lake occur (p. 247).

LITERATURE CITED.

ABBOTT, C. C.
1878. Notes on some fishes of the Delaware River. Report of the Commissioner of Fish and Fisheries for 1875–76, Appendix B, p. 825–845. Washington.

FORBES, S. A., and RICHARDSON, R. E.
1908. The fishes of Illinois. Natural History Survey of Illinois, State Laboratory of Natural History, vol. III, CXXXI+357 p., with colored plates, 76 text fig., and atlas of 103 maps. Danville.

HANKINSON, T. L.
1908. A biological survey of Walnut Lake, Michigan. A Report of the Biological Survey of the State of Michigan, published by the State Board of Geological Survey as a part of the report for 1907, p. 157–288, pl. XIII–LXXV, 6 text fig. Lansing.

HECHT, S.
1913. The relation of weight to length in the smooth dogfish, *Mustelus canis*. Anatomical Record, vol. VII, p. 39–41. Philadelphia.

HEIMBURGER, H. V.
1913. The factors that determine the distribution of *Baleosoma nigrum* in Douglas Lake, Cheboygan County, Mich. Fifteenth Report Michigan Academy of Science, p. 120. Lansing.

LYDELL, D.
1903. The habits and culture of the black bass. Bulletin U. S. Fish Commission, vol. XXII, 1902, p. 39–44, 1 pl. Washington.

REIGHARD, J.
1906. The breeding habits, development, and propagation of the black bass. Sixteenth Biennial Report, Michigan State Board of Fish Commissioners, appendix, p. 1–73, 2 pl., 12 text fig.; also as Bulletin No. 7, Michigan Fish Commission. Lansing.
1913. The breeding habits of the log perch (*Percina caprodes*). Fifteenth Report Michigan Academy of Science, p. 104–5. Lansing.

SHELFORD, V. E.
1911. Ecological succession: III. A reconnaissance of its causes in ponds with particular reference to fish. Bulletin of the Marine Biological Laboratory at Woods Hole, Mass., vol. XXII, p. 1–38. Lancaster.

SMITH, H. M.
1907. The fishes of North Carolina. North Carolina Geological and Economic Survey, vol. II, 453 p., 21 pl., 188 text fig. Raleigh.

TUCKER, D. A.
1913. The oxygen content of the waters of Douglas Lake, Michigan. Fifteenth Report Michigan Academy of Science, p. 121–128. Lansing.